# Greater Worcester Comprehensive Climate Action Plan 2025 - 2050

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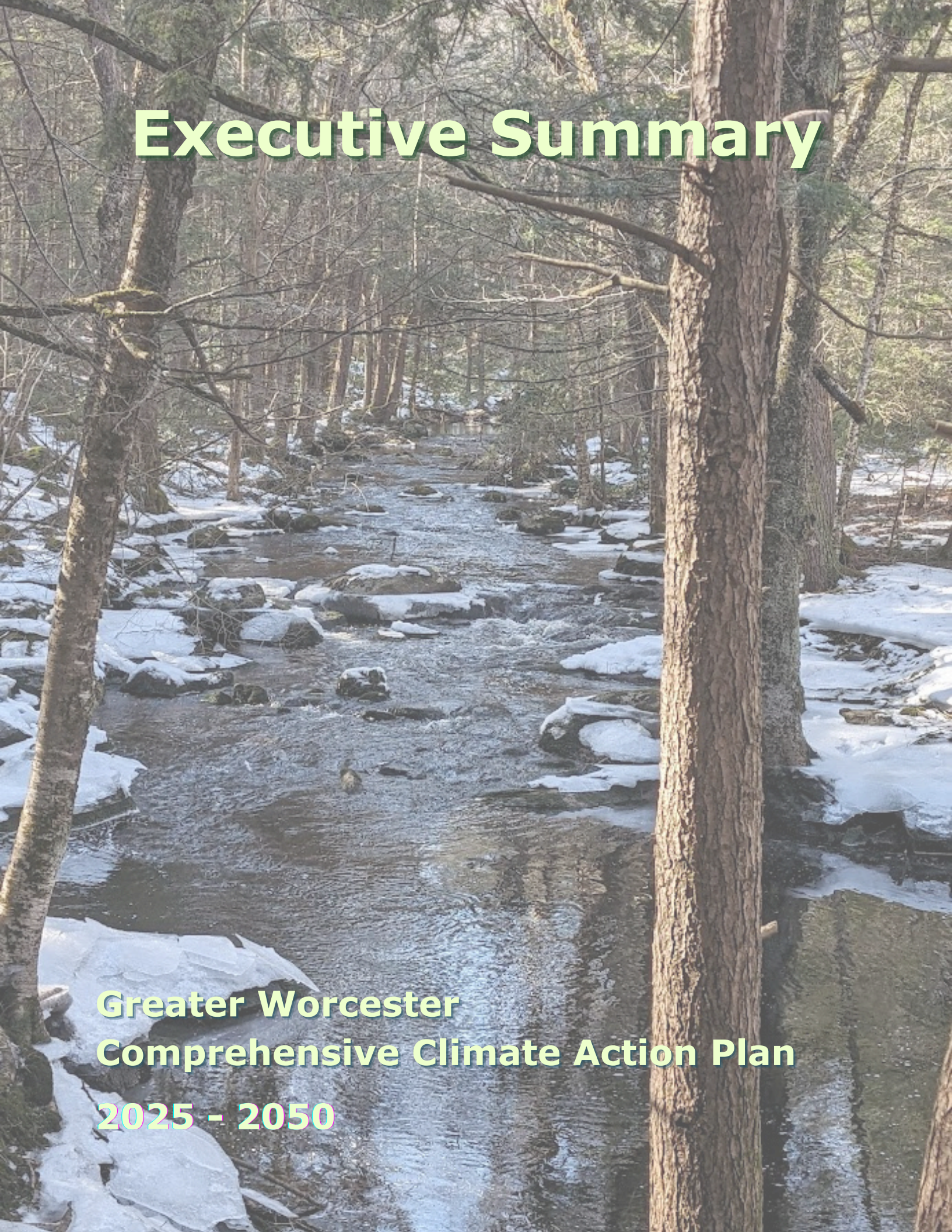
GREATER WORCESTER CLIMATE ACTION PLAN



# Executive Summary

## Greater Worcester Comprehensive Climate Action Plan

## 2025 - 2050

# EXECUTIVE SUMMARY

The Greater Worcester Comprehensive Climate Action Plan (GWCCAP) has been developed as part of a U.S. Environmental Protection Agency (EPA) Climate Pollution Reduction Grant (CPRG) Phase 1 Planning Grant. Created under the 2022 Inflation Reduction Act, the CPRG program provides an opportunity for states, metropolitan statistical areas (MSAs), and municipalities to design and implement long-term greenhouse gas (GHG) emissions reduction strategies. Through the CPRG program, the Greater Worcester Region, led by the Central Massachusetts Regional Planning Commission (CMRPC) and in partnership with the Montachusett Regional Planning Commission (MRPC) and the Northeast Connecticut Council of Governments (NECCOG) to represent the Worcester MA-CT Metropolitan Statistical Area, received a $1 million planning grant to develop both a short-term Priority Climate Action Plan (PCAP) and a long-term Comprehensive Climate Action Plan (CCAP), followed by an implementation status report due in 2027. The GWCCAP establishes a data-driven region-wide roadmap for reducing emissions across six major sectors: Waste and Materials Management; Electricity Generation and Use; Transportation; Agricultural, Natural, and Working Lands; Commercial and Residential Buildings; and Industry. Beyond emissions reductions, this plan also advances strategies that lend to building public health, resilience, equity, economic development, and regional collaboration. Its goals include reducing air pollution, mitigating extreme heat and flooding, expanding clean-energy jobs, improving access to external funding, and supporting long-term, climate-smart infrastructure investment.

Human-driven increases in atmospheric GHGs since the Industrial Revolution have intensified the natural greenhouse effect and destabilized climate systems, resulting in an urgency of action. For the Greater Worcester Region, climate projections show significantly hotter summers, more frequent heat waves, increased precipitation, heightened flooding risks, and growing dam-failure vulnerability, especially in river-basin communities. These projections threaten agriculture, infrastructure, and public safety, and validate the need for coordinated mitigation and resilience planning at the regional scale.

The development of the GWCCAP involved an inclusive, community-driven approach. Over 10 regional public workshops, 49 stakeholder and technical interviews, tabling events across two states, and multiple rounds of public surveys shaped priority actions and refined measures. This process built public buy-in, aligned local and regional efforts, and ensured that the plan reflects lived experience, not just technical modeling. In addition to community outreach, a 2022 GHG emissions inventory for the Greater Worcester Region was conducted to establish a baseline comprehensive accounting of carbon dioxide, methane, and nitrous oxide emissions across major economic and community activities. Total net emissions for 2022 were 6.65 million metric tons of $CO_2$ equivalent ($MMTCO_2e$), after factoring in an estimated 2.83 $MMTCO_2e$ of carbon sequestration from regional forests, which significantly offsets gross emissions of 9.48 $MMTCO_2e$. The inventory methodology relied on standardized emissions factors and publicly available activity data aligned with national best practices, creating a transparent baseline for tracking climate progress, prioritizing mitigation strategies, and informing policy decisions.

Emissions are concentrated within a small number of high-impact sectors, underscoring clear targets for future reduction efforts. Stationary energy (45%), transportation (39%), and electricity use (13%) account for the vast majority of total emissions, with the largest individual subsectors being passenger vehicles (32%), residential buildings (22%), and commercial and industrial

buildings (21%). These trends reflect the Region's reliance on fossil fuels for building heat, mobility, and power, mirroring statewide patterns, and suggest that decarbonizing buildings and transportation, while accelerating grid transition to clean energy, will yield the most substantial reductions.

To understand broader public-health implications, a co-pollutant inventory based on the 2020 National Emissions Inventory was also completed. This assessment quantified 64,498 metric tons of criteria air pollutants (CAPs) and 1,203 metric tons of hazardous air pollutants (HAPs) emitted within the Region, illustrating that fossil-fuel combustion harms both climate and community health, especially in vulnerable populations. Together, the GHG and co-pollutant findings emphasize that climate action can deliver dual benefits: reducing emissions while improving air quality and respiratory outcomes.

Business-As-Usual (BAU) projections reflect future emissions trajectories through 2050 assuming no additional regional climate action. BAU trends show modest emissions declines from efficiency improvements and a cleaner grid. However, they also reveal that the Greater Worcester Region will fall well short of state-mandated reduction targets without aggressive intervention. While emissions from the Electricity sector are expected to decrease under BAU conditions, transportation and building-heat emissions remain persistently high, reflecting continued dependence on gasoline, diesel, heating oil, and natural gas. BAU projections suggest that the Region will not meet the Commonwealth's mandated 2030 emissions threshold until approximately 2038 if it continues on the current path, highlighting an urgent need for coordinated policy, investment, and implementation across all major emitting sectors.

The Greater Worcester Region aligned its emissions goals with the Massachusetts Act of 2021 Chapter 8 and the Commonwealth's 2021 Clean Energy and Climate Plan, which require a 50% emissions reduction below 1990 levels by 2030, a 75% reduction by 2040, and net-zero emissions by 2050, with total emissions capped at no more than 85% below 1990 levels in 2050. Regional back-casting estimates indicate that the Region emitted approximately 14 MMTCO2e in 1990, meaning the region must reduce approximately 2.6 $MMTCO_2e$ from 2022 levels by 2030 and 7.5 $MMTCO_2e$ by 2050 to remain on track with these reduction goals. These targets set clear expectations for decarbonization outcomes and highlight the scale of change required in buildings, transportation, electricity, waste, and land-use systems. By grounding future measures in this analytical baseline, the Region can prioritize high-impact strategies, measure progress over time, and ensure an accountable path toward a net-zero, climate-resilient future.

The GWCCAP roadmap to net-zero emissions outlines 28 GHG emissions reduction measures across the six core sectors. Each measure contained within this roadmap includes the following implementation features:

- ⇨ **Key Objectives** – The overarching goals of the measure broken down into more tangible and measurable themes.
- ⇨ **Geographic Scope** – A short description of the expected geographic location or scope of the measure. Some measures may be proposed to be implemented across the entire Greater Worcester Region, while others may be targeted to specific communities or geographies.
- ⇨ **Implementation Authority and Responsibilities** – A listing of potential project partners with the authority to implement some or all the actions contained within the proposed measure and a brief description of their anticipated responsibilities.

- ⇨ **Implementation Timelines and Milestones** – A schedule with key milestones for implementing the measure over the Short (2025 – 2030), Medium (2030 – 2040), and Long (2040-2050) Terms.
- ⇨ **Metrics for Tracking Progress** – A listing of measurable indicators that will provide transparent ways to track progress and success of measure implementation.
- ⇨ **Quantified GHG Emissions Reduction** – The near-term (2030) and long-term (2050) projections of GHG emissions reductions compared to BAU projections if the measure is successfully implemented.
- ⇨ **Measure Costs** – The estimated total cost or range of costs to implement the proposed measure.
- ⇨ **Intersection with Other Funding Availability** – A listing of funding sources available from federal, state, local, and private sources that could be leveraged to implement the proposed measure.

Additionally, each sector closes with a Benefits Analysis detailing the anticipated co-pollutant reductions, direct or indirect benefits, and any potential disbenefits that may be achieved through the implementation of these measures. Quantified estimates of co-pollutant reductions include a combined total of particulate matter (PM 2.5), nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), volatile organic compounds (VOCs), and air toxins.

The Waste and Materials Management sector addresses both a growing environmental challenge and a major economic vulnerability for the Greater Worcester Region. Although waste only accounts for 2% of current regional GHG emissions, the issue is far larger than its emissions profile suggests. The Region's residents generate 0.75 tons of waste per person per year, nearly three times the global average, with most waste landfilled or incinerated. Landfill capacity is dwindling, particularly in Connecticut, which already ships 960,000 tons of waste out of state at a cost of $94 million annually, a figure projected to skyrocket to $4.8 billion per year by 2050 as disposal options shrink. Without intervention, the Region will face escalating financial burdens, increased emissions from long-haul waste transport, and the perpetuation of a linear "take-make-dispose" economy that accelerates resource depletion and pollution. A comprehensive shift to a circular materials economy, focused on waste prevention, reuse, recycling, and resource recovery, can address these combined climate and fiscal pressures. To achieve this system's transformation, the GWCCAP proposes five synergistic measures that together address every major point in the waste stream:

1. WMM1, Organics Waste Diversion: Expands bans on landfilling food waste and builds school-based separation and composting programs, with a goal of diverting 95% of all organics by 2050, avoiding methane emissions and reducing disposal costs.
2. WMM2, Net-Zero Wastewater Treatment and Anaerobic Digestion: Retrofits treatment plants and builds community digesters to capture methane and generate renewable energy, cutting emissions while producing up to 5% of regional electricity.
3. WMM3, Comprehensive Extended Producer Responsibility: Expands legislation to shift disposal costs from taxpayers to producers and incentivizes recyclable and compostable product design.
4. WMM4, Unit-Based Pricing (PAYT/UBP): Requires households to pay for waste per unit generated, reducing disposal volumes 40 - 60% wherever implemented.
5. WMM5, Regional Resource Recovery Network: Unifies currently disjointed municipal programs, enabling shared infrastructure, joint procurement, and circular-economy innovation hubs that turn waste into feedstock for new materials and fuels.

The Electricity Generation and Use sector is the third largest contributor to GHG emissions in the Region, accounting for approximately 1.24 $MMTCO_2e$, or about 13% of total regional emissions as of 2022. As the region transitions towards clean energy, electricity demand is expected to increase substantially due to widespread building electrification and electric vehicle adoption. Achieving the Greater Worcester Region's net-zero emissions goal will therefore require both a complete phaseout of fossil fuel-based electricity and a massive expansion of non-emitting generation and storage infrastructure. Diversifying the Region's energy sources with a resilient, reliable, and equitable energy mix capable of meeting rising demand while reducing carbon and co-pollutants is key. The GWCCAP identifies five measures designed to transform the Region's energy system:

1. EGU1, Solar Power Generation: Install distributed and utility-scale solar energy on rooftops, parking canopies, brownfields, and landfills to produce 25% of the Region's electricity usage.
2. EGU2, Wind Power Generation: Expand onshore and offshore wind capacity to provide 18% of the Region's electricity supply.
3. EGU3, Nuclear Power Generation: Introduce a Small Modular Reactor (SMR) to the Region producing 25% of regional electricity, supplemented by imported nuclear power.
4. EGU4, Energy Storage Systems: Install large-scale battery and pumped-hydro storage to store at least 5% of total electricity demand, stabilizing renewable intermittency.
5. EGU5, Hydro-Power Solutions: Expand in-region hydropower through non-powered dam conversions and import clean hydropower from outside the region, contributing 22% of the Region's electricity mix.

Transportation is the second-largest source of GHG emissions in the Greater Worcester Region, responsible for 39% of all emissions, with passenger vehicles alone contributing more than three-quarters of the sector's total. Emissions are driven primarily by internal combustion engine vehicles (ICEVs) running on gasoline and diesel, which also release methane and nitrous oxide, worsening local air quality and asthma rates. The Region's multimodal network, composed of personal vehicles, municipal and commercial fleets, rail, and public transit, does not currently provide equitable, reliable alternatives to driving, resulting in high vehicle miles traveled (VMT) and heavy dependence on fossil fuels. To achieve steep emissions reductions, the plan centers on two major themes: reducing car dependence by shifting trips to transit, biking, and walking; and accelerating the transition to zero-emission vehicles supported by a robust charging network:

1. T1, Bicycle and Pedestrian Infrastructure: Expand and improve bicycle and pedestrian infrastructure, including separated bike lanes, shared-use paths, e-bike programs, and wayfinding, to reduce VMT and enable safe, non-vehicular travel.
2. T2, Public Transit and Rail: Expand and electrify public transit and rail, support fare-free bus service, enhance Union Station, and advance projects like Compass Rail, MBTA extensions, and Bus Rapid Transit (BRT).
3. T3, Alternative Fuel Vehicle Charging Infrastructure: Build a comprehensive alternative fuels vehicle charging network, prioritizing municipal sites, multi-unit dwellings, and commercial centers to eliminate "range anxiety" and support regional electric vehicle (EV) adoption.
4. T4, Electrify Municipal Light-Duty Fleets: Accelerate the adoption of zero-emission light-duty municipal vehicles.
5. T5, Decarbonize Municipal Medium- and Heavy-Duty Fleets: Decarbonize medium- and heavy-duty municipal vehicles through battery electric and hydrogen technologies.

The Agricultural, Natural, and Working Lands sector of the Greater Worcester Region serves as the ecological foundation of the area's climate action framework. Encompassing over a million acres of farmland, forest, and green open space, this sector sequesters an estimated 2.83 $MMTCO_2e$

annually; nearly 30% of the Region's gross GHG emissions. These lands function as both carbon sinks and climate buffers, regulating temperatures, absorbing floodwaters, filtering pollutants, and maintaining soil stability and biodiversity. Beyond mitigation, its natural systems underpin the Region's resilience, ecological integrity, and community health. Recognizing these values, the GWCCAP introduces a comprehensive set of five measures that leverage natural processes to reduce emissions, strengthen local resilience, and improve environmental equity:

1. ANWL1, Increase Urban and Tree Canopy: Expand the network of urban trees and shrubs to increase canopy cover by 15% in urbanized areas, cooling hot asphalt corridors, improving air quality, and enhancing neighborhood livability.
2. ANWL2, Permanently Protect Forestland: Protect 20,000 acres of forestland permanently through the use of Conservation Restrictions and Easements to prevent conversion to housing, commercial, and solar developments.
3. ANWL3, Climate-Smart Resiliency Gardens: Promote the conversion of 10,000 acres of manicured lawns into climate-smart resilient gardens, replacing water- and fossil-fuel intensive turf with native food, rain, and pollinator gardens that improve stormwater infiltration, biodiversity, and soil carbon storage.
4. ANWL4, Municipal Resiliency Pockets: Transform 15,000 acres of underutilized municipal lands into "Resiliency Pockets", such as dense micro-forests, community gardens, and pocket parks designed to mitigate urban heat and stormwater flooding while enhancing community cohesion.
5. ANWL5, Reduce Synthetic Pesticide and Fertilizer Usage: Support regenerative agriculture and Integrated Pest Management while reducing synthetic pesticide and fertilizer usage on 9,000 acres of land to cut emissions from nitrogen-based inputs while restoring soil health.

Commercial and Residential Buildings represent both the Region's greatest challenge and its most transformative opportunity in achieving net-zero GHG emissions by 2050. Together, residential and commercial buildings account for nearly 30% of total regional emissions, largely due to reliance on fossil fuels for space and water heating. Residential buildings alone emit more than 2.6 $MMTCO_2e$ annually, stemming primarily from the combustion of heating oil, propane, and natural gas. While grid decarbonization will help reduce some emissions over time, without intervention, building-related emissions are projected to remain steady or rise modestly through mid-century. The Region's existing building stock, over half which predates 1980, suffers from outdated heating systems, poor insulation, and energy inefficiency, making deep retrofits, electrification, and performance-based building codes critical to achieving carbon neutrality. This sector's strategies take a comprehensive, lifecycle-based approach that addresses both operational emissions and embodied carbon:

1. CRB1, Strategic Mixed-Use Reform: Promote compact, mixed-use, and transit-oriented development to reduce VMT by 30-40% and limit greenfield expansion by 70-80%, aligning land use with transportation and housing policy.
2. CRB2, Weatherization, Retrofits, and Electrification: Weatherize, deep retrofit, and electrify existing buildings prioritizing municipal and public facilities.
3. CRB3, Circular Construction, Deconstruction, and Reuse: Advance a circular construction economy, emphasizing deconstruction, material reuse, and salvage markets to reduce waste and preserve embodied carbon.
4. CRB4, Sustainable Materials and Green Construction: Mainstream sustainable materials and green construction practices, embedding energy modeling, passive design, and low-carbon procurement into public and private development.

5. CRB5, Strengthen Codes and Capacity: Strengthen building codes, incentives, and community engagement, driving region-wide adoption of the Massachusetts Specialized Opt-in Energy Code and comparable Connecticut standards, while ensuring public participation and workforce readiness.

The Industry sector is a critical but challenging component of the Greater Worcester Region's climate action strategy, representing a mix of legacy manufacturers, newer biomanufacturing firms, and supply-chain and logistics operations. As the Region works to reach net-zero industrial emissions by 2050, its approach balances emissions reduction, economic competitiveness, and innovation. The GWCCAP acknowledges that industry is a significant and growing source of emissions, both globally, statewide, and at the regional level, and that regional growth makes proactive action essential. To meet long-term targets, the Region will:

1. I1, GHG Emissions Reporting and Planning: Mandate GHG emissions reporting and long-term decarbonization planning for large industrial buildings, expanding Massachusetts's Large Building Energy Reporting framework to facilities as small as 15,000 square feet by 2040.
2. I2, Industrial Material Efficiency and Waste Circularity Network: Establish a regional Industrial Circularity Accelerator to replace the current "take-make-dispose" model with a cradle-to-cradle system, enabling 60% solid-waste diversion by 2050 through reuse hubs, shared infrastructure, zoning overlays, and material-exchange platforms.
3. I3, Electrification and Energy Efficiency: Expand electrification, energy efficiency, and zero-emission mobility, targeting 60% electrification of large industrial facilities and a 35% reduction in energy use, along with widespread EV charging deployment and industrial-fleet electrification.

If successfully implemented, the Greater Worcester Region should expect to achieve 1.9 $MMTCO_2e$ GHG emissions reductions by 2030 and 5.4 $MMTCO_2e$ by 2050 with the measures alone. Paired with the 3.4 $MMTCO_2e$ carbon sequestration capacity of the Region's existing natural and working lands, the Greater Worcester Region will meet it's net-zero emissions target by 2050, providing for a cleaner and more resilient future. However, achievement of the Greater Worcester Region's 2050 net-zero emissions target hinges not only on technology and infrastructure, but also on the Region's capacity to attract, train, and retain a large, skilled workforce to carry out these 28 measures. Every major measure, from heat-pump deployment to grid modernization and regenerative land management, all require a broad range of specialty occupations, many of which are already in short supply. Priority occupations, such as electricians, HVAC technicians, wastewater operators, civil engineers, construction laborers, and solar installers, will all be needed within the Region to meet the scope of demands in this GWCCAP.

Four major workforce challenges exist currently in the Region that could impact the implementation of this plan:

1. Limited access to vocational and pre-apprenticeship programs, with long waitlists and insufficient adult-training capacity.
2. Complex and overlapping licensure and certification requirements that slow worker entry and discourage career-switchers.
3. Restricted apprenticeship rations and limited apprenticeship seats, especially in electrical and HVAC trades that are mission-critical to decarbonization.
4. Job-quality barriers, including child-care constraints, transportation challenges, and low entry-level wages in some sectors.

Each of these barriers threaten to delay building electrification, renewable energy expansion, EV-fleet deployment, and industrial decarbonization, potentially jeopardizing the Region's ability to meet its GHG emissions reduction benchmarks. Without reform, the Region risks a structural labor bottleneck in the very trades that will define the clean-energy economy.

To prevent this, the Region should seek to implement four strategic workforce development opportunities that will expand labor supply and improve worker retention. First, expand and modernize vocational and pre-apprenticeship pipelines, including mobile training labs, adult night programs, expanded technical high school capacity and new clean-energy curricula. Second, streamline and align licensure and certification pathways across Massachusetts and Connecticut, including reciprocity agreements and modular credentialing for technologies like heat pumps, EV charging, and advanced refrigerants. Third, reform the apprenticeship system, including allowing higher supervision ratios and hybrid apprenticeship models that blend classroom learning with paid on-the-job training. Finally, improve job quality and worker supports, especially childcare, transportation access, and housing; all factors that disproportionately limit entry for women, caregivers, low-income residents, and rural workers who could help fill labor gaps if these barriers were removed.

Together, these strategies form a workforce blueprint that is as essential to decarbonization as any infrastructure investment or policy mandate. If the Region expands training capacity, reforms credentialing, strengthens employer partnerships, and improves job quality, it can generate a robust pipeline of priority clean-energy occupations. Conversely, failure to act will widen labor shortages, slow clean-energy deployment, weaken the economic and equity benefits of the transition, and prevent the Region from meeting its net-zero emissions targets.

# 0.1 Acknowledgements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## 0.3 Key Terms

### Acronyms

| | |
|---|---|
| **AD** | Anerobic Digestion |
| **AEEP** | Agricultural Environmental Enhancement Program |
| **BAU** | Business as Usual |
| **BOD** | Biochemical Oxygen Demand |
| **BRT** | Bus Rapid Transit |
| **BUILD** | Better Utilizing Investments to Leverage Development |
| **C+D** | Construction and Demolition |
| **C3** | Commonwealth Cares for Children |
| **CBO** | Community-Based Organization |
| **CCAP** | Comprehensive Climate Action Plan |
| **CCGP** | Community Connectivity Grant Program (CCGP) |
| **CFI** | Charging and Fueling Infrastructure |
| **$CH_4$** | Methane |
| **CHEAPR** | Connecticut Hydrogen and Electric Automobile Purchase Rebate |
| **CHP** | Combined Heat and Power |
| **CMAQ** | Congestion Mitigation and Air Quality |
| **CMRPC** | Central Massachusetts Regional Planning Commission |
| **$CO_2$** | Carbon Dioxide |
| **COA** | Council on Aging |
| **COD** | Chemical Oxygen Demand |
| **CPRG** | Climate Pollution Reduction Grant |
| **CT DEEP** | Connecticut Department of Energy and Environmental Protection |
| **CT DOA** | Connecticut Department of Agriculture |
| **CTE** | Career and Technical Education |
| **DCFC** | Direct Current Fast Charging |
| **EGU** | Electricity Generation and/or Use |
| **EPD** | Environmental Product Declaration |
| **EPR** | Extended Producer Responsibility |
| **EUI** | Energy Use Intensity |
| **EV** | Electric Vehicle |
| **EVSE** | Electric Vehicle Supply Equipment |
| **FERC** | Federal Energy Regulatory Commission |
| **FSA** | Farm Service Agency |
| **GHG** | Greenhouse Gas |
| **GIS** | Geographic Information Systems |
| **GW** | Gigawatt |

| | |
|---|---|
| **GWCCAP** | Greater Worcester Comprehensive Climate Action Plan |
| **GWPCAP** | Greater Worcester Priority Climate Action Plan |
| **HDV** | Heavy-Duty Vehicle |
| **HVAC** | Heating, Ventilation, and Air Conditioning |
| **ICEV** | Internal Combustion Engine Vehicle |
| **ISO NE** | Independent System Operator New England |
| **LBER** | Large Building Energy Reporting |
| **LDV** | Light-Duty Vehicle |
| **MA CZM** | Massachusetts Office of Coastal Zone Management |
| **MA DCR** | Massachusetts Department of Conservation and Recreation |
| **MA DOER** | Massachusetts Department of Energy Resources |
| **MA DPU** | Massachusetts Department of Public Utilities |
| **MA EEA** | Massachusetts Executive Office of Energy and Environmental Affairs |
| **MAC** | Municipal Assistance Coordinator |
| **Mass CEC** | Massachusetts Clean Energy Center |
| **Mass DEP** | Massachusetts Department of Environmental Protection |
| **MBTA** | Massachusetts Bay Transportation Authority |
| **MDAR** | Massachusetts Department of Agriculture |
| **MDV** | Medium-Duty Vehicle |
| **MEMA** | Massachusetts Emergency Management Agency |
| **MHD** | Medium- and Heavy-Duty |
| **MLP** | Municipal Light Plant |
| **MMT$CO_2$e** | Million Metric Tons of Carbon Dioxide Equivalent |
| **MMWEC** | Massachusetts Municipal Wholesale Electric Company |
| **MOR-EV** | Massachusetts Offers Rebates for Electric Vehicles |
| **MRF** | Materials Recovery Facility |
| **MRPC** | Montachusett Regional Planning Commission |
| **MRTA** | Montachusett Regional Transit Authority |
| **MSA** | Metropolitan Statistical Area |
| **MSW** | Mixed Solid Waste |
| **MT$CO_2$e** | Metric Tons of Carbon Dioxide Equivalent |
| **MVP** | Municipal Vulnerability Preparedness |
| **MW** | Megawatt |
| **MWh** | Megawatt-hour |
| **$N_2O$** | Nitrous Oxide |
| **NECCOG** | Northeastern Connecticut Council of Governments |
| **NECTD** | Northeastern Connecticut Transit District |
| **NPS** | National Park Service |
| **NRCS** | National Resources Conservation Service |
| **PAYT/SMART** | Pay-As-You-Throw/Save-Money-And-Reduce-Trash |

| | |
|---|---|
| **PPA** | Power Purchase Agreement |
| **PV** | Photovoltaic |
| **RDP** | Recycling Dividends Program |
| **RIRRC** | Rhode Island Resource Recovery Corporation |
| **RISRP** | Rhode Island School Recycling Project |
| **RMV** | Registry of Motor Vehicles |
| **RPA** | Regional Planning Agency |
| **RPC** | Regional Planning Council |
| **RTA** | Regional Transit Authority |
| **SMART** | Solar Massachusetts Renewable Target |
| **SMR** | Small Modular Reactor |
| **SMRP** | Sustainable Materials Recovery Program |
| **SRA** | Source Reduction Assistance |
| **SRF** | State Revolving Fund |
| **SRTS** | Safe Routes to School |
| **SS4A** | Safe Streets and Roads for All |
| **SVA** | Small Vehicle Area |
| **TDM** | Transportation Demand Management |
| **TURI** | Toxics Use Reduction Institute |
| **TW** | Terawatt |
| **TWh** | Terawatt-hour |
| **UBP** | Unit Based Pricing |
| **US EPA** | United States Environmental Protection Agency |
| **US HUD** | United States Department of Housing and Urban Development |
| **USDA** | United States Department of Agriculture |
| **USFS** | United Stated Forest Service |
| **VAPG** | Value-Added Producer Grant |
| **VMT** | Vehicle Miles Traveled |
| **WEA** | Wind Energy Area |
| **WestCCOG** | West Connecticut Council of Governments |
| **WRTA** | Worcester Regional Transit Authority |
| **WWTP** | Waste Water Treatment Plant |
| **ZEV** | Zero-Emission Vehicle |

## Definitions

**Anaerobic Digestion (AD)**: The process by which anaerobic microbes within the a sealed tank or vessel degrade or break down organic matter to obtain energy and nutrients for growth and reproduction.

**Biochemical Oxygen Demand (BOD)**: A measure of the amount of oxygen required by aerobic microorganisms to decompose organic matter in water, serving as an important indicator of water quality and pollution levels.

**Biodiversity**: The variety of living organisms in a particular area, including animals, plants, fungi, and microorganisms.

**Biogas**: A gas produced from organic materials like animal waste, and food scraps. It is usually a combination of methane and carbon dioxide.

**Biomass**: Organic matter used as fuel.

**Biosolids**: Solid organic matter recovered from a sewage treatment process and used as fertilizer.

**Brightfield**: A solar energy project built on a brownfield. These energy projects repurpose underutilized or environmentally compromised land for clean energy generation.

**Brownfield**: A property where the presence or potential presence of a hazardous substance, pollutant, or contaminant may complicate its expansion, redevelopment, or reuse. These sites were often previously used for industrial, commercial, or waste disposal purposes and require assessment and cleanup before they can be safely redeveloped. Brownfields can be repurposed for uses in renewable energy projects like brightfields with proper remediation.

**Carbon Sequestration**: The process of capturing and storming atmospheric carbon dioxide to reduce its concentration and combat climate change.

**Carbon Sink**: A carbon sink is any natural or artificial system that absorbs and stores more carbon dioxide ($CO_2$) from the atmosphere than it releases. Common examples include forests, oceans, wetlands, and soils, which capture $CO_2$ through processes like photosynthesis or oceanic absorption. Carbon sinks play a crucial role in mitigating climate change by reducing greenhouse gas concentrations and helping to balance the global carbon cycle.

**Chemical Oxygen Demand (COD)**: a measure of how much oxygen can be utilized by reactions in a given volume of a solution.

**Circular Construction**: A sustainable building approach where materials and components are designed, used, and recovered in closed loops. It prioritizes reuse, recycling, and minimal waste to reduce environmental impact and preserve resources over a building's life cycle.

**Circular Economy**: A model of resource production and consumption in any economy that involves sharing, leasing, reusing, repairing, refurbishing, and recycling existing materials and products for as long as possible.

**Circularity Accelerator**: A program to advance a circular economy and resource efficiency in the building sector aimed at sustainable resource development.

**Closed-Loop Manufacturing**: A production process where used materials are recovered, remanufactured, or recycled back into production, minimizing raw material extraction and waste.

**Cluster Development**: A planning approach that groups buildings on part of a site while preserving the rest as open space, farmland, or natural habitat. It reduces infrastructure costs, conserves and protects resources, and fosters more walkable, community-focused neighborhoods.

**Co-Generation/Combined Heat and Power (CHP)**: A system that produces heat and electricity simultaneously in a single plant. This can also refer to generating from multiple energy sources such as organic waste and bio solids.

**Community Solar**: A shared solar energy system in which multiple participants benefit from the energy generated by a single solar array, often located off-site.

**Comprehensive Climate Action Plan (CCAP)**: A narrative climate planning report that provides an overview of all GHG sources/sinks and sectors following industry standard protocols. The CCAP will establish near-term and long-term GHG emission reduction targets and identify GHG reduction measures to achieve those goals.

**Conservation Restriction/Easement**: A legally enforceable agreement whose purpose is to ensure permanent protection of areas with specific conservation values.

**Cradle-to-Cradle (C2C)**: A regenerative design framework where products and materials are created for continuous reuse, recycling, or safe return to the environment, eliminating the concept of waste.

**Decarbonization**: The process of reducing and eliminating greenhouse gas emissions, primarily by shifting from fossil fuels to clean energy, improving efficiency, and adopting low-carbon technologies to achieve a sustainable, net-zero economy.

**Deciduous Forest**: An area characterized by trees that lose their leaves at the end of each growing season.

**Deconstruction**: The process of carefully dismantling a building or structure to recover and reuse materials, rather than demolishing it and sending debris to a landfill. It conserves resources, reduces waste, and supports recycling and circular construction practices.

**Deforestation**: The permanent and intentional clearing of forest land, often for agriculture, grazing, logging, and development.

**Embodied Carbon**: The total greenhouse gas emissions associated with the production, transportation, construction, maintenance, and eventual disposal of a building, product, or material. It includes emissions from all stages of the supply chain, such as extracting raw materials, manufacturing components, and transporting goods, before the building or product is even in use.

Addressing embodied carbon is critical in sustainable design and construction because it can represent a large portion of a project's total climate impact.

**Emission-Free Energy Certificates (EFECs)**: Certificates by which power suppliers pay for the sole credit for the carbon offsets of specific clean energy production from more reliable clean energy infrastructure such as nuclear power plants.

**Evapotranspiration**: The sum of all processes by which water moves from the land surface to the atmosphere through evaporation, when water turns into water vapor and rises into the atmosphere, and transpiration, when plants absorb water through their roots and release it as vapor through tiny pores.

**Evergreen Forest**: An area characterized by broad-leaved trees that retain their foliage year-round.

**Extended Producer Responsibility (EPR)**: A policy approach that assigns producers responsibility for the end-of-life of products. This can include both financial responsibility and operational responsibility, though the amount and type may differ. Producers are required to provide funding and/or services that assist in managing covered products after the use phase.

**Green Infrastructure**: Nature-based solutions (e.g., bioswales, rain gardens, permeable pavements) that manage stormwater, improve air quality, and reduce environmental impacts in industrial districts.

**Greenfield Development**: The construction of new buildings or infrastructure on previously undeveloped land, such as farmland or open countryside, rather than redeveloping existing urban or industrial sites.

**Greenhouse Gas (GHG) Inventory**: A summary of all GHG emission sources and sinks by sector and the associated emissions quantified using commonly accepted protocols. The CCAP must include a comprehensive inventory of GHG emissions and sinks for the following sectors: industry, electricity generation/use, transportation, commercial and residential buildings, agriculture, natural and working lands, and waste and materials management.

**Greenhouse Gases (GHGs)**: Heat-trapping gases like carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$) that contribute to climate change through industrial processes and waste decomposition.

**Growth Boundaries**: Planning tools that define a geographic limit for urban development to prevent sprawl and greenfield development, as wells as protect natural resources. By concentrating growth within the boundary, they prevent uncontrolled growth, encourage efficient land use, support public transit, and promote sustainable, compact communities.

**Impermeable/Impervious Surface**: Hard, non-porous materials, such as asphalt, concrete, and roofs that prevent water from absorbing into the ground.

**Industrial Circularity Accelerator Program**: A coordinated initiative for the Greater Worcester region to map waste streams, support collaboration, and fund cradle-to-cradle industrial practices.

**Industrial Symbiosis**: A collaborative approach where one industry's waste or by-products become inputs for another, lowering emissions and material costs (e.g., using food processing waste in an anaerobic digester).

**Infill Development**: The process of building or redeveloping on vacant, underused, or blighted parcels of land within already developed urban areas, rather than expanding into greenfield sites. It leverages existing infrastructure, promotes compact growth, reduces urban sprawl, and can revitalize neighborhoods by adding housing, businesses, or public amenities in areas with established services and transportation.

**In-Line Hydropower**: Hydropower generated by turbines which are in pipes that transfer water from high elevations to low elevations.

**Integrated Pest Management**: A science-based, environmentally-friendly approach to managing pests focusing on prevention and non-chemical methods.

**Levelized Cost of Electricity**: The average cost of constructing and operating an electricity-generating resource over its projected lifetime per unit of electricity generated.

**Lifecycle Emissions**: The total greenhouse gas emissions associated with a product's entire life cycle, from raw material extraction and production to transportation, use, and disposal.

**Liming**: The application of calcium- and magnesium-rich materials in the form of chalk, limestone, and marl to neutralize soil acidity for the purpose of improving plant growth.

**Linear Economy**: A system where resources are extracted to make products that eventually end up as waste and are thrown away. Products and materials are generally not used to their full potential in a linear economy and, as the name suggests, always move in one direction – from raw material to waste.

**Low-Carbon Economy**: An economic system that reduces greenhouse gas emissions by using renewable energy, improving efficiency, and adopting sustainable practices while supporting growth and development.

**Material Flow Audit**: A systematic analysis of material and waste streams to identify opportunities for recovery, reuse, or repurposing.

**Microgrid**: A localized electric grid with defined electrical boundaries acting as a single controllable entity that can operate connected to the traditional grid or independently.

**Micro-Hydropower**: Hydroelectric power infrastructure which produces less than 100 KW of electricity.

**Mixed Solid Waste (MSW)**: Heterogeneous and commingled solid waste, which may include readily biodegradable organic wastes, as well as other organic wastes which are not readily biodegradable and may also contain inorganic, non-compostable wastes.

**Miyawaki Forest**: Biodiverse, native, and small-sized forests that grow quickly, re-establish full ecosystems, and are more dense than conventional forests.

**Modular Credentialing**: A system of stackable credentials, which are short, competency-based qualifications that allow individuals to gain new skills on-demand without the need to commit to long-term or expensive training.

**Modular Recycling Units**: Small-scale, flexible recycling systems deployed near industrial hubs to process waste locally and reduce transport emissions.

**Municipal Light Plant (MLP)**: An electric utility which is owned, maintained, and operated by a municipality.

**Net-Zero Industrial Neighborhoods**: Industrial areas designed to produce or procure as much renewable energy as they consume annually while integrating microgrids, green infrastructure, and circular material flows.

**Non-Powered Dam**: A dam which is not currently utilized for hydroelectric power.

**Overlay Zoning**: A planning tool that applies additional requirements or incentives to specific geographic areas (e.g., industrial corridors) without changing base zoning to support circular systems and green infrastructure.

**Particulate Matter**: A mixture of solid particles and liquid droplets found in the air.

**Photosynthesis**: A process used by plants to convert light energy, water, and carbon dioxide into chemical energy in the form of glucose.

**Pollinator Garden**: A garden designed with native vegetation to provide food, water, and shelter for pollinators like bees, birds, and butterflies.

**Power-Purchase Agreement (PPA)**: A legal contract between an energy generator and a purchaser (such as a utility or a municipality) to buy electricity at agreed-upon terms over a set period.

**Priority Development Areas (PDAs)**: Locations identified by CMRPC, MRPC, and NECCOG as best suited for focused growth and investment, with infrastructure, transit access, and community support for compact, mixed-use development.

**Public-Private Partnership**: An agreement between public agencies and private sector companies to finance, build, and operate infrastructure projects.

**Pumped Hydro**: An energy storage technology in which energy is used to raise a large amount of water to a high elevation, is stored in this water, and then is re-produced as electricity as the water is released and travels downwards through turbines to a lower elevation.

**Quasi-Public Entity**: A publicly chartered body that provides a public service and is overseen by an appointed board, commission, or committee. Typically, these entities do not rely on the State's General Fund to operate.

**Rain Garden**: A depressed area that collects rainwater and allows it to soak into the ground, reducing runoff and filtering pollutants, typically designed with native grasses and flowers.

**Reciprocity Agreements**: Mutual arrangements or pacts between two or more entities, such as states, to exchange privileges or credentials for individuals from one entity in the other.

**Regenerative Agriculture**: A holistic farming system focused on soil health, biodiversity, and water quality.

**Renewable Energy Certificates (RECs)**: Certificates by which power suppliers pay for the sole credit for the carbon offsets of clean energy production from specific renewable energy infrastructure, including wind and solar facilities, which has variable production based on conditions such as weather.

**Small Modular Reactor (SMR)**: advanced nuclear reactors that are smaller than conventional nuclear power reactors and have a power capacity between 5 and 300 MW. SMRs are designed to be factory-built, transportable, and scalable, which makes them faster to deploy and more adaptable to different locations. They also have advanced safety systems and can operate in places where conventional reactors are not feasible.

**Smart Growth**: a planning and development approach that promotes sustainable, efficient, and community-focused land use. It emphasizes compact, walkable neighborhoods, mixed-use development, preservation of open space and natural resources, diverse housing options, and transportation choices that reduce car dependency. The goal is to strike a balance between economic growth, environmental protection, and quality of life, while curbing urban sprawl and fostering resilient, vibrant communities.

**Solar Canopy**: A structure that supports solar panels above parking lots or other paved areas that provide both electricity and shade.

**Solar Radiation**: The electromagnetic energy emitted from the sun.

**Stomatal Uptake**: The process essential to photosynthesis where plants absorb gases, like carbon dioxide, through small pores called stomata.

**Synthetic Fertilizer**: Plant food manufactured from inorganic chemicals such as nitrogen, phosphorous, and potassium, that provide a fast and concentrated source of nutrients.

**Tipping Fee**: The charge levied for disposing of solid waste. This fee is paid by the waste generator, be it an individual, business, or municipality, to the waste processer for accepting and managing their waste.

**Transfer of Development Rights**: A land-use planning tool that allows property owners in designated conservation or preservation areas (sending areas) to sell their development rights to developers in areas targeted for higher-density growth (receiving areas). This approach protects farmland, open space, and environmentally sensitive lands while directing development to locations with existing infrastructure and services.

**Transit-Oriented Development (TOD)**: A planning and design strategy that creates compact, walkable, mixed-use communities centered around high-quality public transit systems. TOD aims to reduce car dependency, encourage sustainable transportation, and foster vibrant neighborhoods by integrating housing, jobs, retail, and public spaces within a short walk of transit stations.

**Unit Based Pricing (UBP)**: Also known as Pay-As-You-Throw (PAYT)/Save-Money-And-Reduce-Trash (SMART), UPB is a system in which residents pay for mixed solid waste (MSW) management services per unit of waste discarded rather than solely through a fixed fee or property tax.

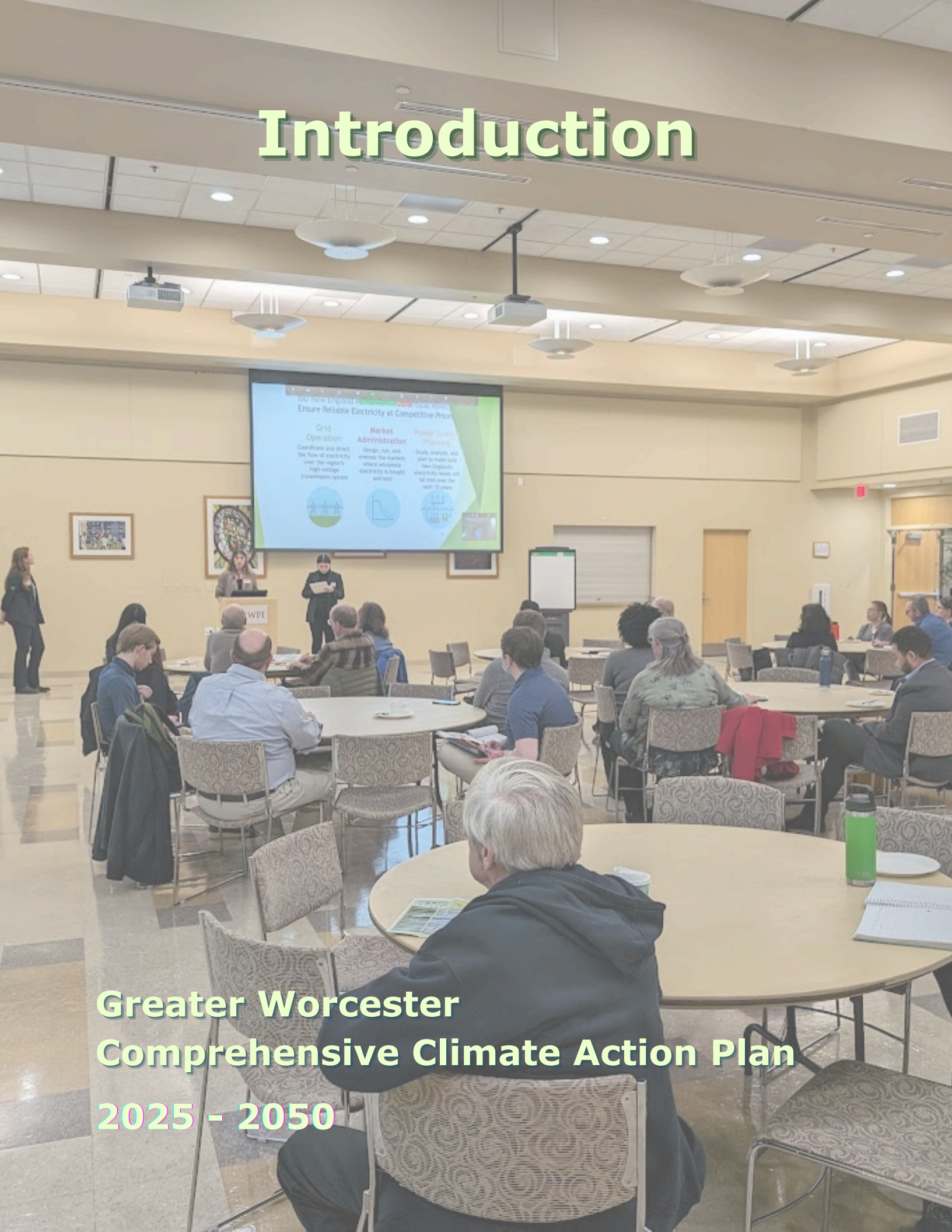
**Urban Heat Island Effect**: A phenomenon where areas with highly concentrated, heat-absorbing impervious surfaces and limited vegetation, typically in cities or urban areas, are significantly warmer than nearby rural or vegetated areas.

**Waste Valorization**: Converting waste materials into valuable products, such as creating biogas from food waste or using industrial by-products in construction materials.

**Watt**: A unit of electric power, with a megawatt equaling 1 million watts and a terawatt equaling 1 million megawatts.

**Watt-hour**: A unit of electric power generated or used over an hour, with a megawatt-hour equaling 1 million watt-hours and a terawatt-hour equaling 1 million megawatt-hours.

# Introduction




## Greater Worcester Comprehensive Climate Action Plan

## 2025 - 2050

1

# INTRODUCTION

## 1.1 CPRG Overview

The Climate Pollution Reduction Grant (CPRG) program, authorized by the Inflation Reduction Act (IRA), provides states, local governments, tribes, territories, and metropolitan statistical areas (MSAs) with a unique opportunity to develop and implement robust greenhouse gas (GHG) reduction strategies. In August 2022, $5 billion was set aside from the IRA for the Environmental Protection Agency (EPA) to create the CPRG program, providing $250 million in planning grants for the development of climate action plans. Another $4.6 billion was allocated for competitive implementation grants to bring projects identified through this planning process to life. The CPRG planning process takes a total of four years to complete and is comprised of various milestones including:

1. Priority Climate Action Plan – Submitted March 1, 2024
2. Comprehensive Climate Action Plan – Due December 1, 2025
3. Status Report – Due Mid-2027

Priority Action Plans focus on short-term, implementable projects that look out to 2035. Comprehensive Climate Action Plans focus on long-term projects, strategies, policies, and procedures to bring GHG emissions in the region to net-zero by 2050. The status report submitted at the end of the four-year grant period reflects the completed work and what is still needed for the region to stay on pace for a net-zero emission future.

The EPA announced the CPRG program in March 2023, and in May 2023, the Central Massachusetts Regional Planning Commission (CMRPC) applied to be the lead entity for the Worcester MA – CT MSA, referred to throughout this plan as the Greater Worcester Region. In August 2023, CMRPC was awarded a $1 million planning grant and work began on the Greater Worcester Priority Action Plan (GWPCAP) in partnership with the Montachusett Regional Planning Commission (MRPC) and the Northeast Connecticut Council of Governments (NECCOG). The GWPCAP determined twenty priority measures for reducing emissions that aligned with the public's needs and concerns for the region and was submitted to the EPA in March 2024. Following the submittal in March, CMRPC began working on a comprehensive climate action plan which aims to reduce greenhouse gas emissions and other harmful pollutants to net-zero by 2050.

## 1.2 Purpose and Scope

First and foremost, the GWCCAP provides a clear, data-driven pathway to reduce GHG emissions across six key sectors: Waste and Materials Management; Electricity Generation and/or Use; Transportation; Agricultural, Natural, and Working Lands; Commercial and Residential Buildings; and Industry. This enables the Greater Worcester Region to align with state GHG reduction mandates. In addition, the GWCCAP can also provide:

> **Climate Adaptation and Resilience**: Support actions that also mitigate urban heat, flooding, and extreme weather.

**Improved Public Health**: Improve air quality, reduce asthma rates, and build heat resilience in densely populated, urban, and pollutant-burdened areas.

**Economic Development and Job Creation**: Stimulate clean energy and climate-resilient job creation.

**Community Engagement and Buy-In**: Build consensus, trust, and long-term support for climate action.

**Regional Collaboration**: Strengthen collaboration among municipalities and state agencies.

**Access to Funding**: Unlock access to federal state, and local climate resilience grants.

**Long-Term Investment**: Provide a strategic roadmap for decarbonized infrastructure investments.

For the Greater Worcester Region, the development of this GWCCAP represents both a strategic necessity and a transformative opportunity. Through targeted emissions reduction, equitable investment, and robust regional planning, the plan aims to create healthier, sustainable, and more resilient communities throughout the region.

## Regional Context

The planning area for the Greater Worcester Region includes eighty communities in Central Massachusetts and Eastern Connecticut. This includes all of Worcester County, Massachusetts, all of Windham County, Connecticut, one town in Tolland County, Connecticut, one town in New London County, Connecticut, and five towns in Middlesex County, Massachusetts. The region also includes Fort Devens, a regional enterprise zone and a census designated place. The following communities fall within the Greater Worcester project area:

| | | |
|---|---|---|
| Ashburnham, MA | Ashby, MA | Ashford, CT |
| Athol, MA | Auburn, MA | Ayer, MA |
| Barre, MA | Berlin, MA | Blackstone, MA |
| Bolton, MA | Boylston, MA | Brookfield, MA |
| Brooklyn, CT | Canterbury, CT | Chaplin, CT |
| Charlton, MA | Clinton, MA | Douglas, MA |
| Dudley, MA | East Brookfield, MA | Eastford, CT |
| Fitchburg, MA | Gardner, MA | Grafton, MA |
| Groton, MA | Hampton, CT | Hardwick, MA |
| Harvard, MA | Holden, MA | Hopedale, MA |

| | | |
|---|---|---|
| Hubbardston, MA | Killingly, CT | Lancaster, MA |
| Leicester, MA | Leominster, MA | Lunenburg, MA |
| Mendon, MA | Millbury, MA | Millville, MA |
| New Braintree, MA | North Brookfield, MA | Northborough, MA |
| Northbridge, MA | Oakham, MA | Oxford, MA |
| Paxton, MA | Petersham, MA | Phillipston, MA |
| Plainfield, CT | Pomfret, CT | Princeton, MA |
| Putnam, CT | Royalston, MA | Rutland, MA |
| Scotland, CT | Shirley, MA | Shrewsbury, MA |
| Southbridge, MA | Spencer, MA | Sterling, MA |
| Sterling, CT | Sturbridge, MA | Sutton, MA |
| Templeton, MA | Thompson, CT | Townsend, MA |
| Union, CT | Upton, MA | Uxbridge, MA |
| Voluntown, CT | Warren, MA | Webster, MA |
| West Boylston, MA | West Brookfield, MA | Westborough, MA |
| Westminster, MA | Winchendon, MA | Windham, CT |
| Woodstock, CT | Worcester, MA | |

The Greater Worcester MA-CT CPRG Planning Region is not completely synonymous with the Worcester MA-CT Metro Area. The municipalities of Ashby, Townsend, Shirley, Groton, and Ayer in Massachusetts as well as Union and Voluntown in Connecticut are located within the former and not the latter, while the municipalities of Southborough and Milford in Massachusetts are located within the latter and not the former. In this regional context section, the maps and tables relate to the Greater Worcester MA-CT CPRG Planning Region, while the charts relate to the Worcester MA-CT Metro Area.

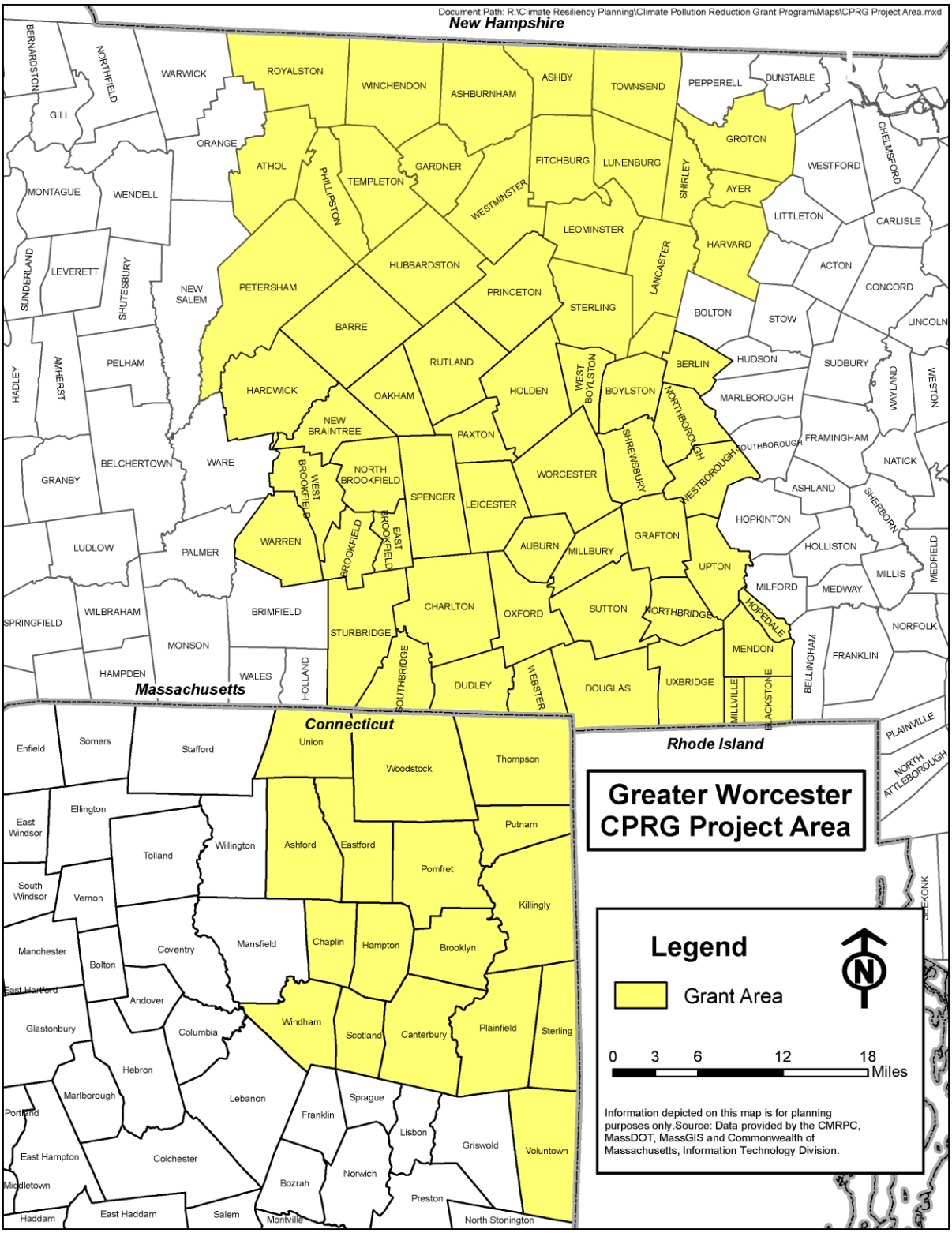



*Figure 1. The Greater Worcester Planning Region*

## The Greenhouse Effect

The Earth's natural greenhouse effect is vital to sustain life on our planet. When the sun warms Earth, some solar radiation reflects off of the planet and back out into space. The natural Greenhouse Effect occurs when "greenhouse gases," such as carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, and water vapor, trap solar radiation in Earth's atmosphere close to the surface. At naturally occurring levels, the heat trapping properties of atmospheric greenhouse gases are essential to trap solar radiation that has bounced off Earth and is headed back to space. This warms the planet to the perfect level to sustain terrestrial life. According to National Aeronautics and Space Administration (NASA), without the naturally occurring amount of greenhouse gases, Earth's temperature would instantly drop by over 30°F, throwing off the balance of the entire Earth's ecosystems.[i]

However, just as essential as the presence of greenhouse gases in the atmosphere is having the right amount of them. The naturally occurring greenhouse effect includes the ideal amount of heat trapping gases to keep Earth's climate balanced - not too hot and not too cold. Just like having too few atmospheric greenhouse gases will make the planet too cold, having too many of these gases in the atmosphere will make it too warm. Increase in temperature will also throw all climatological processes, such as rain, storms, sea level, ice-melt, and more, out of balance.

This is where the problem of the modern day arises. The amount of atmospheric greenhouse gases has fluctuated normally over hundreds of millennia. However, since the mid-19$^{th}$ century, human societies have been adding more greenhouse gases to the atmosphere every day. As a result, in the last less than two hundred years, climate scientists have observed a warming trend accelerated to a rate much faster than Earth has seen in the preceding hundreds of thousands of years. The start of this unprecedented, rapid warming of Earth is correlated with the start of the Industrial Revolution in the mid-1800s.[ii] This is when humans began mass combustion of fossil fuels to harness energy, while simultaneously removing naturally occurring carbon sinks through activities such as forest clearing.

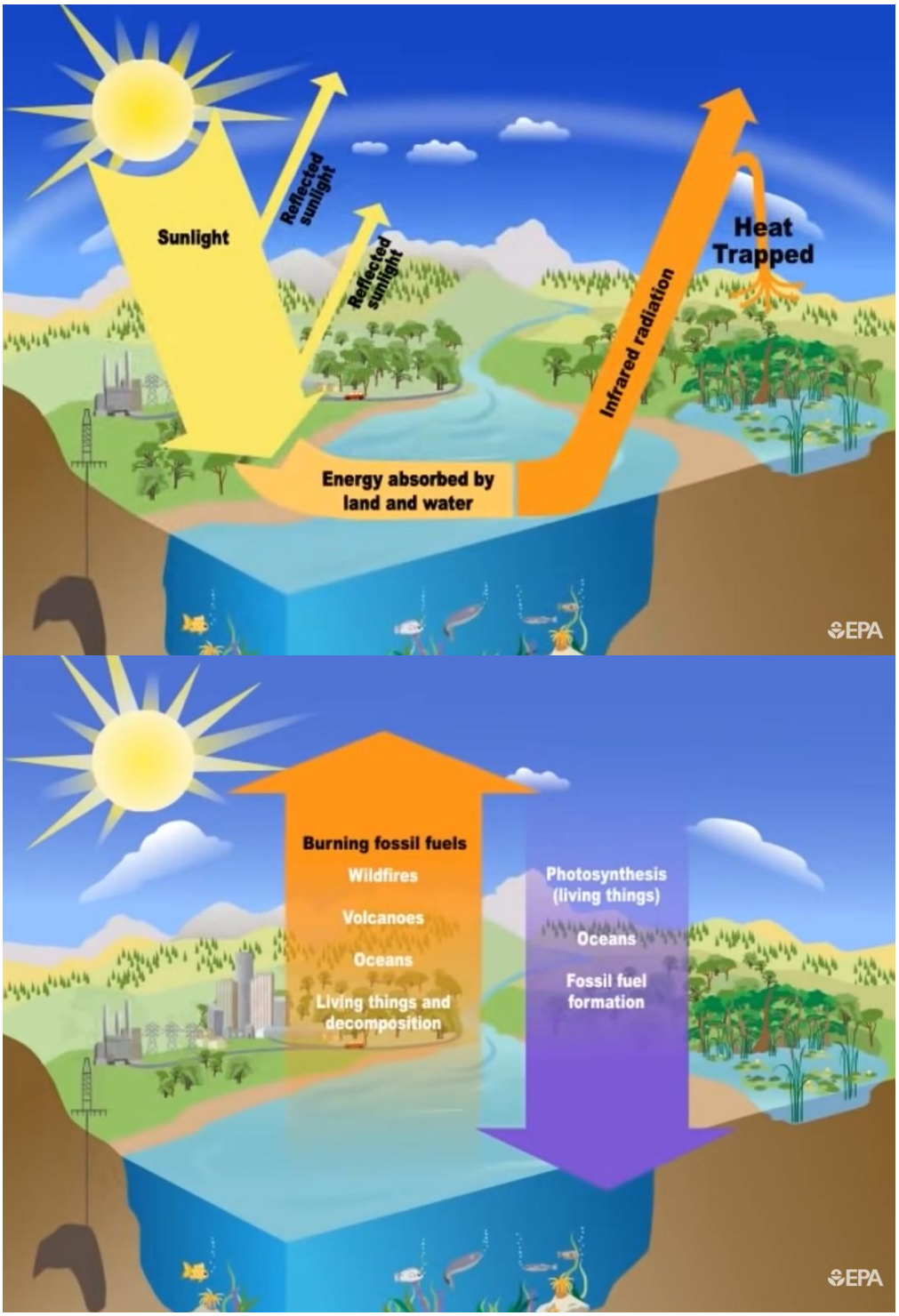



*Figure 2. Diagram depicting how human activities emit excess greenhouse gases into the atmosphere.* [iii]

Figure 2 is an illustration of how human activities emit excess greenhouse gases, such as carbon dioxide and methane (represented by the gaseous clouds) into the atmosphere as a byproduct of combustion of fossil fuels. With the addition of these excess greenhouse gases into the atmosphere, too much solar radiation is trapped close to Earth, throwing off the natural greenhouse effect maintaining Earth's temperature. The science of this issue warrants action across all human society

to utilize other, non-air polluting technology to harness energy, and to be innovative to develop society while preserving carbon sinks.

# Climate Change Projections for the Region

## Massachusetts

**Temperature:** According to the Massachusetts Climate Assessment from 2022, Massachusetts has experienced a 3.5°F increase in average annual temperatures since 1900. The current statewide average temperature, provided by the NOAA (National Oceanic and Atmospheric Administration), is 50.3°F but varies by region. Historically, temperatures are lower in Western Massachusetts and higher in the East. Future climate projections show an overall expected increase in average temperature for most of Massachusetts, with Eastern and Central Massachusetts likely seeing the greatest rise in average temperature. Central Massachusetts could see average temperatures rise between 5.4-6.3°F by 2050.[iv] An increase in average annual temperatures means more intense summers with more frequent heat waves. Warmer temperatures are connected to impaired human health, increased incidence of drought, reduced agriculture yields, species range shifts, and damaged infrastructure.[v]

**Precipitation**: The Massachusetts Climate Assessment from 2022 indicates an overall statewide increase in precipitation by 2070, but seasonal patterns will vary drastically. Central Massachusetts could see annual precipitation increases ranging from 0-24%.[vi] Due to higher temperatures, the moisture holding capacity of the atmosphere increases, causing greater variety in precipitation patterns.[vii] Central Massachusetts is especially vulnerable to climate hazards associated with varying precipitation patterns. By the mid-century, the annual river flood chance could be two times more likely within Central Massachusetts, increasing the chance of dam failures and flooding in downstream areas.[viii] Dam failure is a concerning hazard in Central Massachusetts. Based on MassGIS data, Central Massachusetts currently has 104 "High Hazard" dams and 250 "Significant Hazard" dams in the region. The combination of increased precipitation and hazardous dams could lead to disastrous flooding causing property damage and severe injury or death.

## Northeast Connecticut

**Temperature**: Average temperatures in Connecticut are projected to increase by 5°F by 2050 compared to the 1970-1999 baseline.[ix] Additionally, the number of days above 90°F are expected to increase from an average of 5 days to an average of 25 days by 2050. These projections show an increased risk of drought and major flooding in Connecticut. Droughts will affect the agriculture industry in Northeast Connecticut and town water needs in rural areas. The region could be forced to place restrictions on public, commercial, or industrial water consumption. In extreme cases, wildfires could occur in the region if the current emissions trend continues in the future.[x]

**Precipitation**: According to the Connecticut Institute for Resilience & Climate Adaptation (CIRCA), annual total precipitation across the state and the NECCOG planning region is projected to increase by 4-5 inches (~8.5%) by the midcentury (2040-2069) and by 4.5-5.5 inches (~10%) by the late century (2070-2099).[xi] The Connecticut Governor's Council on Climate Change (CG3) Phase 1 Report predicts less snow and more rain due to the increase of moisture capacity in the atmosphere and warmer temperatures.[xii] Additionally, flooding is common in Northeastern Connecticut due to the abundance of rivers in the region. Due to the development patterns near rivers, flooding is one of

the major hazards in the area[xiii] Flooding can affect the entire region and cause significant property damage and possibly injuries or death. The NECCOG region contains 9 "High Hazard" dams and 28 "Significant Hazard" dams with hundreds of smaller dams. Increased precipitation can cause higher rates of dam failures that result in sudden and severe onset flooding.[xiv]

## Ongoing Planning Efforts

Towns, cities, businesses, non-profits, and other organizations in the Greater Worcester Region have and will continue to prioritize planning efforts to fortify the region as a resilient and sustainable place. In Massachusetts, most communities take part in the Green Communities program. Once municipalities receive their Green Communities designation, they can take advantage of financial assistance to implement energy efficiency projects in municipal buildings and municipal fleet electrification upgrades. In addition, communities who complete the Municipal Vulnerability Preparedness (MVP) program planning process can become designated as an MVP Community. The MVP program enables communities to understand their infrastructural, societal, and environmental concerns caused or worsened by climate change impacts and provides funding to MVP Communities to implement nature-based solutions to build resilience in these areas. All Massachusetts communities must also complete an Open Space and Recreation Plan update every ten years to understand how land is used and protected for recreation and conservation purposes. Municipalities in both Connecticut and Massachusetts are required to regularly update Hazard Mitigation Plans to receive funding from the Federal Emergency Management Agency (FEMA). These programs and plans were considered in the creation of this GWCCAP.

# 1.3 Approach to Developing the CCAP

At the start, CMRPC developed a website to disseminate information about the Greater Worcester Region CPRG planning efforts. This website includes information about the grant program, CMRPC's planning efforts and progress as a lead entity, and a calendar of events. The calendar was regularly updated throughout the early stages of this planning process and continues to be an outreach resource. This website also hosted a copy of the GWPACP. The data on the Greater Worcester Region CPRG website is in the process of transitioning to CMRPC's main website and will host this GWCCAP when finalized.

Direct engagement began with a series of ten free public workshops throughout the Greater Worcester Region as part of the CPRG process. The goals of these workshops were to receive public feedback on what priority short-term, implementable, effective climate pollution reduction actions were favored in the region and to inform the public about the CPRG program. All six of the climate polluting sectors identified by the EPA (Waste and Materials Management; Electricity Generation and Use; Transportation; Agricultural, Natural, and Working Lands; Commercial and Residential Buildings; and Industry) were discussed at each of these workshops. Workshop attendees were asked to be ambitious and imaginative in brainstorming ideas for how they would like to see federal CPRG implementation grant dollars spent to benefit their communities and the Greater Worcester Region.

These ten public engagement workshops were held in the region between November 2023 and February 2024 and are detailed in the table below. CMRPC staff completed six workshops in the six sub-regions of the Southern Worcester County between November 2023 and January 2024.

Following these six workshops, NECCOG hosted three workshops in Eastern Connecticut and MRPC hosted one hybrid workshop in Northern Worcester County. To promote these workshops, CMRPC, MRPC, and NECCOG staff posted flyers throughout their respective regions in town halls, libraries, community centers, convenience stores, pizza shops, post offices, senior centers, schools and more. Promotional materials were also shared through email blasts, social media outlets, and on organizations' websites.

*Table 1. List of Public Engagement Workshops*

| Region | Location | Date | Time | Modality |
|---|---|---|---|---|
| CMRPC West | West Brookfield Town Hall, West Brookfield, MA | Wednesday, November 15, 2023 | 6:00 pm - 9:00 pm | In-person |
| CMRPC Northeast | Shrewsbury Public Library, Shrewsbury, MA | Thursday, November 30, 2023 | 6:00 pm - 8:30 pm | In-person |
| CMRPC Southwest | Gladys E. Kelly Public Library, Webster, MA | Thursday, December 7, 2023 | 6:00 pm - 8:30 pm | In-person |
| CMRPC North | Quabbin Regional Middle High School,Barre, MA | Monday, December 18, 2023 | 6:00 pm - 8:00 pm | In-person |
| CMRPC Southeast | Northbridge Town Hall, Northbridge, MA | Wednesday, January 10, 2024 | 6:00 pm - 8:00 pm | In-person |
| CMRPC Central | Worcester Polytechnic Institute Campus Center, Worcester, MA | Thursday, January 18, 2024 | 6:00 pm - 9:00 pm | Hybrid |
| NECCOG | Thompson Library and Community Center, Thompson, CT | Monday, January 29, 2024 | 6:00 pm - 7:30 pm | In-person |
| NECCOG | Plainfield Town Hall, Plainfield, CT | Tuesday, January 30, 2024 | 6:00 pm - 7:30 pm | In-person |
| NECCOG | Windham Town Hall, Windham, CT | Wednesday, January 31, 2024 | 6:00 pm - 7:30 pm | In-person |
| MRPC | Montachusett Regional Planning Commission Office, Leominster, MA | Friday, February 16, 2024 | 6:30 pm - 9:00 pm | Hybrid |

The public engagement workshops had a similar structure overall, but some aspects of the workshops were altered to accommodate different subregions and various levels of attendance. The general workshop structure was threefold:

- First, RPA staff presented a 15-minute slideshow explaining the CPRG program and timeline, greenhouse gas effect, difference between air pollution and climate pollution, broad-level impacts of climate change, six climate polluting sectors, and workshop logistics and activities.
- Next, workshop attendees participated in discussions facilitated by RPA staff brainstorming priority climate pollution reduction actions they wanted to implement in their communities.
- Finally, attendees participated in voting activities. In the first activity, they ranked draft goals for the GWPCAP in each climate polluting sector by their priority and importance. Attendees were also able to propose new goals. For the second activity, attendees were given two "tickets" which they could "invest" in the sector or sectors that they wanted prioritized in the GWPCAP. Attendees utilized informational posters, climate data maps and

packets, and conversations with fellow attendees and RPA staff to inform their investment voting.

Utilizing feedback and ideas gathered during these ten workshops, CMRPC staff drafted a list of 20 priority climate pollution reduction actions. These actions spanned five out of the six climate polluting sectors as Industry was not identified as a major priority sector in the region during this initial round of outreach. CMRPC then published a survey in which residents and stakeholders could rank each action as very high priority, high priority, neither high nor low priority, low priority, or very low priority. This survey was open from February 9 through February 26, 2024, and was distributed via email to workshop attendees and promoted on CMRPC's social media outlets. Results from this first survey were utilized to rank the 20 GWPCAP reduction measures in order of priority.

Following submittal of the GWPCAP, the Greater Worcester team launched a follow-up survey to refine the actions suggested in the plan and to generate additional strategies to incorporate . Like the first survey, this follow-up was distributed via email and promoted on CMRPC's social media outlets. In addition, CMRPC staff attended tabling events throughout the Greater Worcester Region to promote the survey, discuss the GWPCAP results, and gather additional input for the development of the plan. These tabling events occurred between June 2024 through August 2025 and are detailed below.

*Table 2. List of Tabling Events*

| Location | Date | Time |
|---|---|---|
| Wachusett Mountain, Princeton MA | Thursday, June 13, 2024 | 4:00 pm - 7:15 pm |
| Worcester Common Oval, Worcester, MA | Thursday, July 11, 2024 | 11:00 am - 2:00 pm |
| Town Common, West Brookfield, MA | Wednesday, July 17, 2024 | 2:30 pm - 6:00 pm |
| Worcester Common Oval, Worcester, MA | Thursday, July 25, 2024 | 11:00 am - 2:00 pm |
| Senior Center, Westborough, MA | Saturday, July 27, 2024 | 10:00 am - 12:00 pm |
| Big Bunny Market, Southbridge, MA | Saturday, August 3, 2024 | 10:00 am - 2:00 pm |
| University Park, Clark University, Worcester, MA | Saturday, August 10, 2024 | 9:00 am - 12:00 pm |
| Memorial Beach, Webster, MA | Tuesday, August 13, 2024 | 5:00 pm - 7:00 pm |
| Town Hall, Shrewsbury, MA | Thursday, August 22, 2024 | 1:30 pm - 6:30 pm |
| Spencer Country Inn, Spencer, MA | Thursday, September 12, 2024 | 6:00 pm - 8:30 pm |
| Worcester Common Oval, Worcester, MA | Wednesday, June 25, 2025 | 11:00 am - 3:00 pm |
| Worcester Common Oval, Worcester, MA | Monday, July 7, 2025 | 11:00 am - 3:00 pm |
| Worcester Common Oval, Worcester, MA | Wednesday, August 6, 2025 | 11:00 am - 3:00 pm |

In addition to gathering input from community members on potential strategies to incorporate into the GWCCAP, CMRPC staff also facilitated 56 interviews with regional stakeholders and technical advisors. During interviews, staff shared the suggested actions with the stakeholders and asked for their overall thoughts on all of the sector-specific measures as well as:

- how to make the measures easier to implement;
- what existing programs, projects, or actions are missing from the GWPCAP and should be included;
- who should be involved in the implementation of these measures;

- what policy recommendations should be incorporated into the GWCCAP to help implement these measures or facilitate GHG emissions reductions;
- how to minimize or prevent disbenefits of implementing these measures on underserved populations;
- what cost barriers should be kept in mind; and
- what funding programs are currently available to implement these measures.

As the GWCCAP GHG emissions reduction measures were drafted and updated, some of these interviews shifted from general feedback to sector and/or measure-specific vetting discussions. All feedback collected was utilized to refine the draft strategies into a set suite of GHG emissions reduction measures intended to help the Greater Worcester region achieve net-zero emissions by 2050.

*Table 3. List of Stakeholder and Technical Advisor Interviews*

| Name | Organization/Agency | Date | Topic Area(s) |
|---|---|---|---|
| Craig Della Penna | Norwottuck Network | August 8, 2024 | Shared-Use Paths |
| Miranda Hotham | City of Worcester, Zero Waste Coordinator | August 9, 2024 | Local Implementation |
| Gretchen Carey | MassRecycle | August 13, 2024 | Waste Hauling |
| Lorenzo Macaluso | Recycling Works MA, Chief Growth Officer | August 13, 2024 | Waste Management, Disposal Regulations |
| Mary Knittle | WCAC | August 14, 2024 | Weatherization |
| Tory McBrien | WasteZero, CT Program Coordinator | August 16, 2024 | Waste Management, Unit-Based Pricing |
| Taylor Bennett | National Grid | August 19, 2024 | Electricity/Energy |
| Lori Timmerman and Amanda Formica | MassSave/National Grid | August 19, 2024 | Energy Savings |
| Jon Fitch | Town of West Boylston, MLP | August 22, 2024 | Municipal Power Generation |
| Gabe Shapiro | All in Energy Inc., Co-Founder/Co-Executive Director of Partnerships | August 23, 2024 | Clean Energy |
| Ellie Garland | RMI | August 27, 2024 | Net-Zero, Methane Waste Reduction |
| Alex Salcedo | MassBike, Worcester Program Manager | August 27, 2024 | Bike Improvements |
| Chris Dempsey | Speck/Dempsey | August 28, 2024 | Transportation |
| Tom Lesure | Energy Conservation Inc. | August 28, 2024 | Energy |
| Stef Covino | Blackstone Watershed Coalition | August 29, 2024 | Watershed, Ecological Restoration |
| Katherine Lee Goyette | Conservation Law Foundation | September 4, 2024 | Policy |
| Jon Weaver | Massachusetts Biomedical Initiatives | September 5, 2024 | Biomedical, Financing |

| | | | |
|---|---|---|---|
| Ryan Bradley and Kurt Steiner | National Grid, EV Ambassador | September 17, 2024 | Electric Vehicles, EV Charging Infrastructure |
| Jeuji Diamondstone and Deb Powers | RENEW Worcester Group | September 26, 2024 | Residential Buildings |
| Grace Sliwoski | Regional Environmental Council (REC), Director of Programs | October 3, 2024 | Urban Farming, Food Access |
| Chelsey Patriss | Health Equity Partnership of North Central MA (CHNA9), Executive Director | October 15, 2024 | Rural Transportation |
| Ellen Sprink-Ferrante | Mass Gardeners Association | October 22, 2024 | Gardening, Landscaping |
| Michael Walsh | Groundwork Data, Founding Partner | October 25, 2024 | Clean Energy |
| Conor Miller | Black Earth Compost, Partner/CEO | October 25, 2024 | Composting, Organic Waste Management |
| Randy Jordan | Jordan Dairy Farm | October 29, 2024 | Anaerobic Digesters |
| Margo Valdes | Athena Building Performance, Inc. | October 30, 2024 | Residential Buildings, Weatherization |
| Karin Valentine Goins | WalkBike Worcester | November 1, 2024 | Biking Improvements |
| Don Musial | Win Waste Innovations | November 26, 2024 | Ash, Landfill |
| Kathleen Krider | CT Community Action Agency, Community Engagement and Resource Management | December 4, 2024 | Community Engagement |
| Justin Hollander | Tufts University and Real Rapid Transit for Worcester, MA | December 12, 2024 | Bus Rapid Transit |
| John Tourtelotte | Rivermoor Energy | January 17, 2025 | Electricity/Energy |
| Rich Marcello and Ellen Sachs Leicher (Chair) | Harvard Climate Action Initiative, Committee Members | January 22, 2025 | Resiliency |
| Jim Corwin | RI Schools Recycling Project, Co-Director | May 13, 2025 | School Composting Site Visit |
| Chris Sidwa and Chris Cotulio | Urban Mining Industries | June 3, 2025 | Pozzolan Concrete Manufacturing |
| Jim Corwin and Warren Heyman | RI Schools Recycling Project, Co-Directors | June 4, 2025 | School Composting Programming |
| Jenni Minner | Cornell University, Director of Graduate Studies and Associate Professor in the Department of City and Regional Planning | June 11, 2025 | Buildings, Waste Management |
| Gretchen Worth | Susan Christopherson Center for Community Planning, Project Director | June 11, 2025 | Buildings, Waste Management |
| Jeff Turgeon | MassHire Central, Executive Director | June 24, 2025 | Workforce Development |

| | | | |
|---|---|---|---|
| Darnell Dunn | Worcester Chamber of Commerce, Director of Business Recruitment | June 26, 2025 | Workforce Development, Industry |
| Natalia Escobar-Pemberthy | Clean Energy & Environment Legacy Transition (CELT), CELT Program Manager | July 1, 2025 | Clean Energy |
| Katie Yoder | Town of Southbridge MA, Town Planner | July 9, 2025 | Local Implementation |
| Fiona Coughlan | Town of Grafton MA, Town Planner | July 15, 2025 | Local Implementation |
| Erin Quaiel | City of Worcester | July 17, 2025 | Co-Benefits |
| Ryan Murphy and Annina Kennedy-Yoon | Climate Jobs Massachusetts, Executive Director and Offshore Wind Specialist | July 25, 2025 | Workforce Development |
| Susanna Bohme | MA Community Labor United, Research Director | July 25, 2025 | Workforce Development |
| Michael Andrus | Upper Blackstone Clean Water, Deputy Director | August 1, 2025 | Waste Water Treatment |
| Jared Rhodes | RI Resource Recovery Corporation, Director of Policy and Programs | August 7, 2025 | Regional Waste Management Entity |
| Marianne Larossi | Trustees of Reservations, Land Conservation Specialist | August 18, 2025 | Land Preservation |
| Chris Sidwa | Urban Mining Industries | August 21, 2025 | Pozzolan Concrete Manufacturing |
| Sean McKeon | Princeton Municipal Light Department | September 10, 2025 | Wind Turbines |
| Christopher Roy, Kathryn Roy, Jason Viadero, and Tom Barry | Massachusetts Municipal Wholesale Electric Company | September 22, 2025 | Electricity |
| Jon Patterson | Groton Electric | October 8, 2025 | Battery Electric Storage Systems |
| Julie Smith-Galvin | Relevate Power LLC | October 15, 2025 | Hydropower |
| Kristen Patneaude, Stephen Estes-Smargiassi, Denise Breiteneicher, Eben Nash | Massachusetts Water Resources Authority | October 17, 2025 | Hydropower |
| Phil Arnold and Hunter Gold | Nature's Classroom | November 3, 2025 | Solar Power |
| Ruben Flores-Marzan | ISO New England | November 19, 2025 | Electricity |

# Introduction Endnotes

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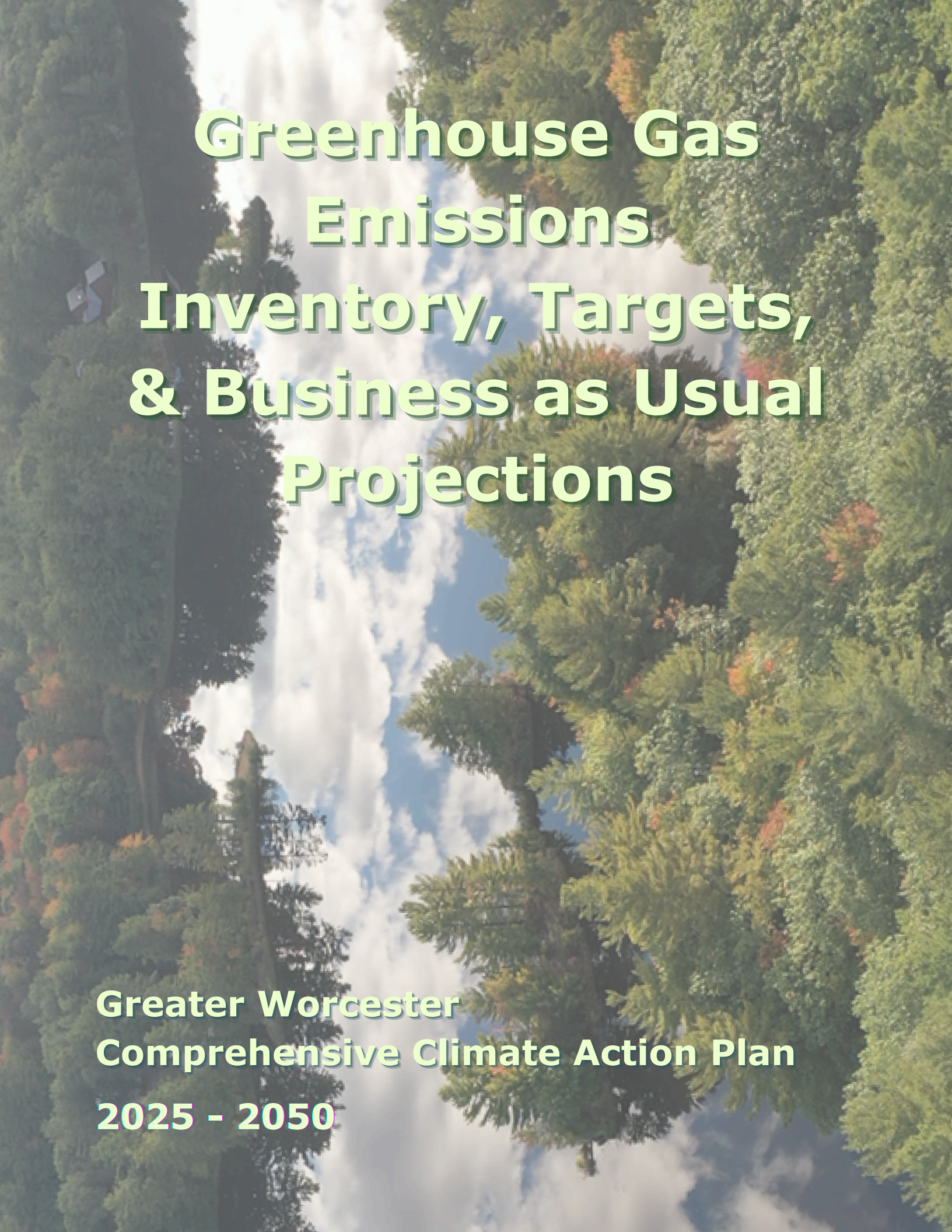

# Greenhouse Gas Emissions Inventory, Targets, & Business as Usual Projections

**Greater Worcester**
**Comprehensive Climate Action Plan**

**2025 - 2050**

# Greenhouse Gas (GHG) Emissions Inventory, Targets, And Business as Usual Projections

## 2.1 GHG Emissions Inventory Summary

To understand the Greater Worcester Region's emissions, a greenhouse gas (GHG) emissions inventory was conducted for the year 2022, building upon the 2017 GHG emissions inventory which was completed as part of the Priority Climate Action Plan (PCAP). This inventory estimates the carbon dioxide, methane, and nitrous oxide emissions from a wide array of emitting sources, using publicly available datasets and standardized equations. While these gases naturally exist in the environment, the burning of fossil fuels for human activities (such as driving a car or heating a building) is accelerating the rate at which these GHGs are being emitted. This, in turn, is causing the rate at which heat is being trapped in Earth's atmosphere to increase, leading to long-term shifts in temperature and climate.

GHG emissions are typically quantified in units of metric tons of carbon dioxide equivalent ($MTCO_2e$) or millions of $MTCO_2e$ ($MMTCO_2e$). Global warming potentials for methane and nitrous oxide are then used to normalize these greenhouse gases to $CO_2$. The following equation is generally used to calculate emissions:

**Activity Data** (e.g., kWh, gallons) **X** **Emissions Factors** (e.g., MTCO2e/kWh, $MTCO_2e$/gallon) **=** **Emissions ($MTCO_2e$)**

6.65 $MMTCO_2e$
were emitted in 2022 by the Greater Worcester Region, including residential, commercial, and municipal activities.

This GHG emissions inventory includes a comprehensive set of emissions sources, across six unique sectors. The sector of emissions sources, key data that informed emissions calculations, and the result of those calculations can be found in Table 4.

*Table 4. GHG Emissions Inventory Sectors, Key Data, and Resulting Emissions*

| Sector | Key Data | Emissions (MMT CO2e) |
|---|---|---|
| **Stationary Energy** | Residential and commercial/industrial usage (natural gas, fuel oil, propane), off-road equipment | 4.3 |
| **Electricity** | Residential & commercial/industrial usage, transmission and distribution losses (investor-owned utilities, municipal utilities, and community aggregation) | 1.20 |
| **Transportation** | Passenger vehicles, commercial vehicles, MBTA commuter rail, freight rail | 3.74 |
| **Waste** | Landfilled and incinerated waste, composted and anaerobically digested waste, wastewater | 0.19 |
| **Industrial Processes** | Many of the industrial process sources included in the MA DEP GHG inventories are not applicable to the MSA or have a wide range of use types and therefore could not be appropriately scaled down and allocated to the MSA. | N/A |
| **Agriculture** | Fertilizer and agricultural soils, enteric fermentation, and manure management | 0.05 |
| **Natural & Working Lands** | Forest caron sequestration | (2.83) |
| | **Gross Emissions (MMT $CO_2$e)** | 9.48 |
| | **Total Net Emissions (MMT $CO_2$e)** | 6.65 |

Figures 3 and 4 summarize the distribution of 2022 emissions inventory results by sector and subsector. The three largest emitting sectors in the MSA include stationary energy (45%), transportation (39%), and electricity (13%). The 3 largest subsectors consist of passenger vehicles (32%), residential buildings (22%), and commercial & industrial buildings and manufacturing industries (21%) as the highest emitting subsectors.

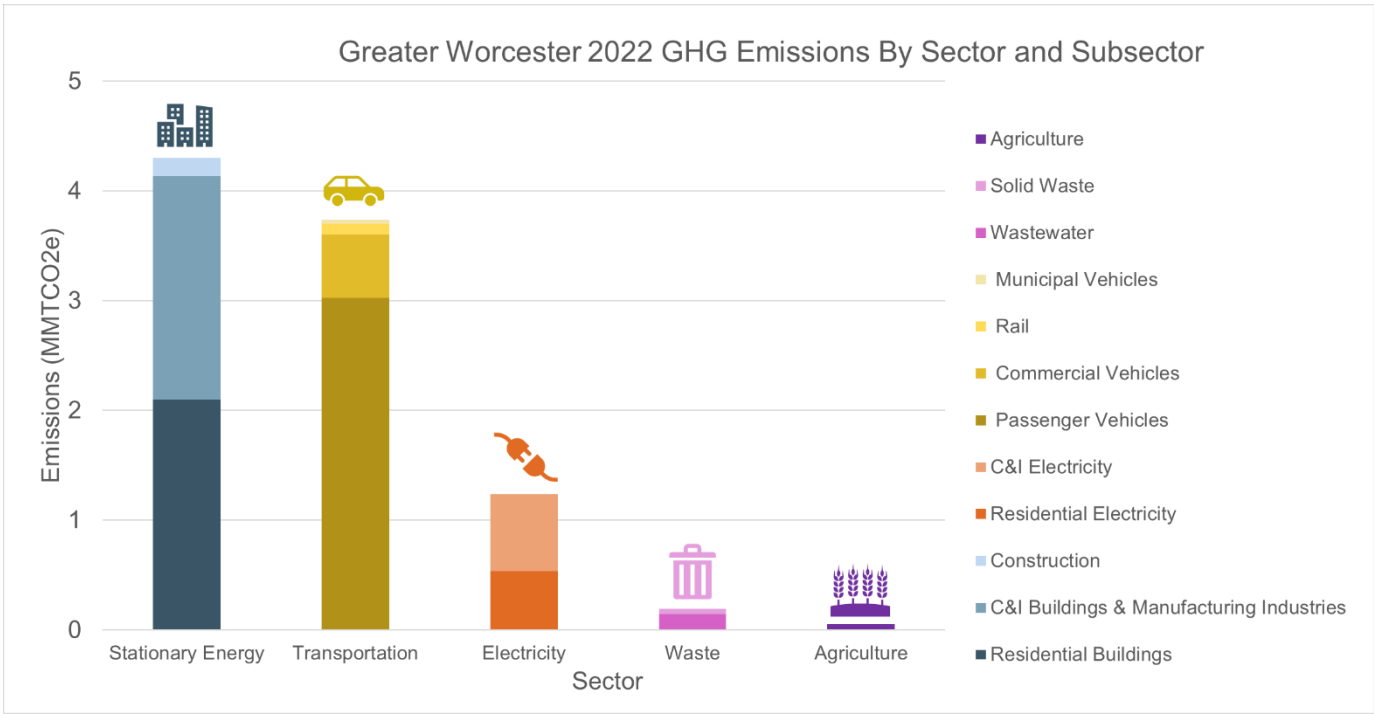


*Figure 3. 2022 GHG Emissions Inventory Results by Sector*

Additional information about data sources and methodology can be found in the Appendix.

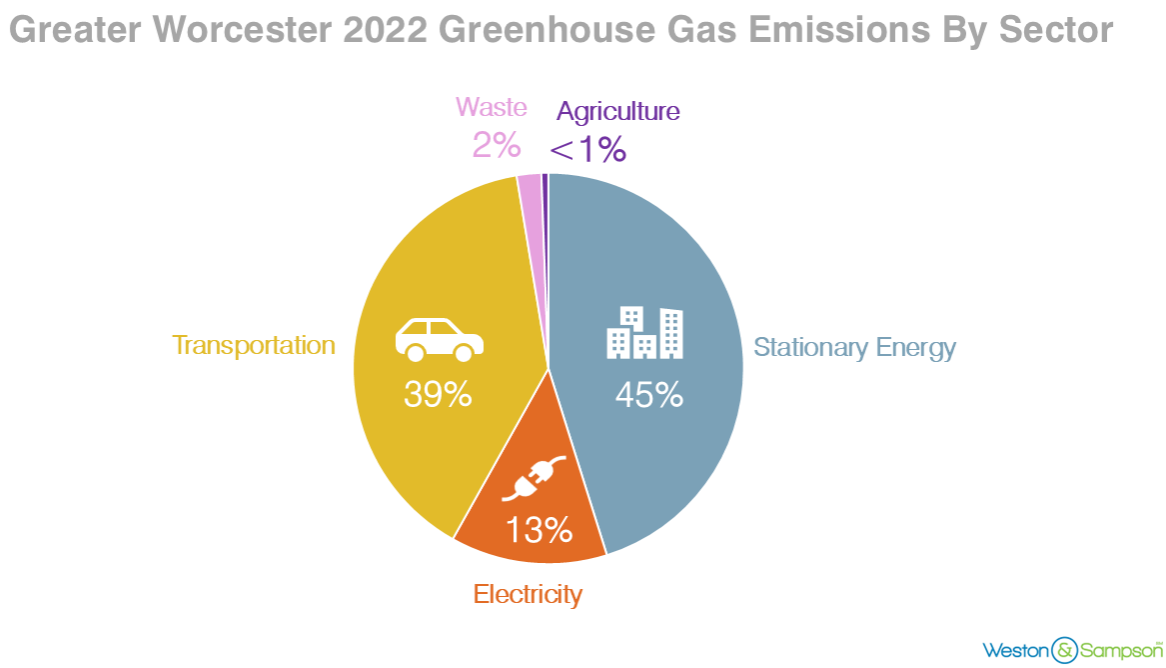


*Figure 4. GHG Emissions by Subsector*

## 2.2 Co-Pollutant Inventory

A baseline co-pollutants emissions inventory year has been conducted for 2020. To determine an estimate of the Criteria Air Pollutants (CAPs) and Hazardous Air Pollutants (HAPs) emitted, data from the 2020 National Emissions Inventory (NEI) database was analyzed.[xv] Quantifying these CAP and HAP sources show a more holistic picture of the total air pollutants emitted by and consequently impacting the MSA. The general methodology for determining the quantity of CAP and HAP emissions in 2020 consisted of downloading county specific data and allocating a percentage of the co-pollutant emissions based on population. The following sectors were assessed for this inventory, as they relate to the sectors quantified in the GHG inventory methodology:

- Agriculture - Fertilizer Application
- Fuel Comb - Commercial/Institutional - Natural Gas
- Fuel Comb - Commercial/Institutional - Oil
- Fuel Comb - Industrial Boilers, ICEs - Natural Gas
- Fuel Comb - Industrial Boilers, ICEs - Oil
- Fuel Comb - Residential - Natural Gas
- Fuel Comb - Residential - Oil
- Mobile - Locomotives
- Mobile - Non-Road Equipment - Diesel
- Mobile - Non-Road Equipment - Gasoline
- Mobile - Non-Road Equipment - Other
- Mobile - On-Road Diesel Heavy Duty Vehicles
- Mobile - On-Road Diesel Light Duty Vehicles
- Mobile - On-Road non-Diesel Heavy Duty Vehicles
- Mobile - On-Road non-Diesel Light Duty Vehicles
- Waste Disposal

CAPs emissions estimated as part of this co-pollutants inventory include the following:

- Ammonia
- Carbon Monoxide
- Lead
- PM10 Primary (Filt + Cond)
- PM2.5 Primary (Filt + Cond)
- Sulfur Dioxide
- Volatile Organic Compounds

**Over 80 HAPs** were included in the quantification of HAP emissions in this inventory.

*Table 5. Co-Pollutant Baseline Emissions Inventory 2020*

| Co-Pollutant Baseline Emissions Inventory 2020 | |
|---|---|
| **Criteria Air Pollutants** | **Hazardous Air Pollutants** |
| **64,498 metric tons** | **1,203 metric tons** |

## 2.3 GHG Reduction Targets and Business-As-Usual Projections

In 2009, the Commonwealth of Massachusetts established GHG reduction targets requiring the state to reduce emissions to 80 percent below 1990 emissions levels by 2050 (Massachusetts General Laws Chapter 21N). In Chapter 8 of the Acts of 2021, the state enhanced these commitments by mandating a 50% reduction in GHG emissions below 1990 levels by 2030, a 75% reduction by 2040, and net zero emissions by 2050, with the caveat that emissions must be at or below 85% below 1990 levels.

In addition to these targets, the state set forth a 2050 Decarbonization Roadmap and Clean Energy and Climate Plan that set the target of a fully decarbonized electricity supply by 2050. This 2050 decarbonization strategy set both economy wide emissions reductions targets and subsector specific (i.e., buildings, transportation, etc.) targets.

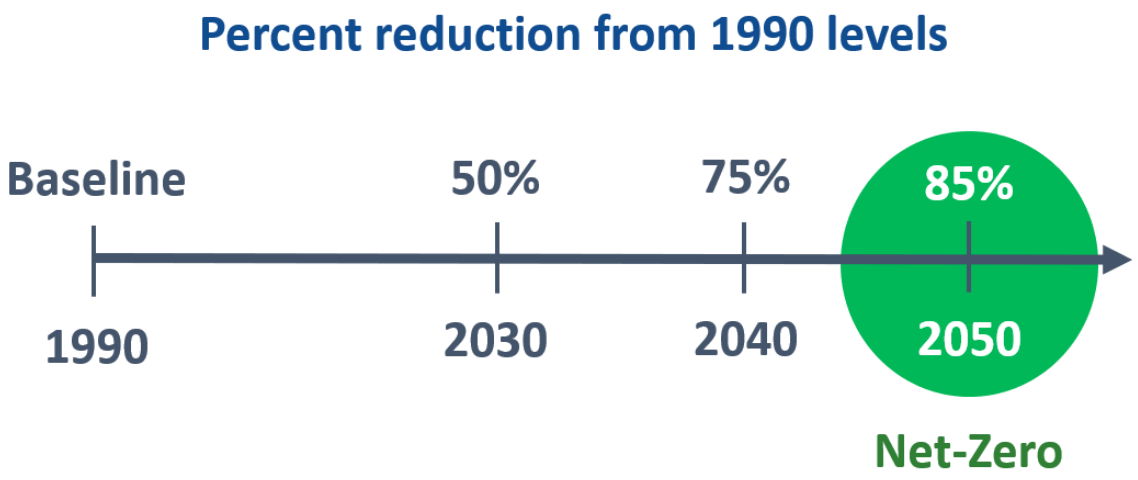


*Figure 5. Massachusetts Reduction Targets*

To align emissions reduction targets of the region with Massachusetts statewide mandates, the regional 2022 emissions inventory was back cast to estimate emissions levels in 1990 using statewide annual emissions inventories. It is estimated that the region produced about 14 MMTCO2e in 1990 and has experienced a reduction in emissions since this time. Figure 5 shows the estimated historical emissions and business-as-usual (BAU) scenario through 2050. The BAU reflects a downward trend in emissions and demonstrates that the region would come close to the 2030 target in around 2038 if no further action was taken than what was assumed in the BAU. The BAU was determined using the Energy Policy Simulator and downscaled to the project area.

To achieve a 50 percent reduction in 2030 from 1990 levels, the region needs to reduce an estimated 2.6 MMTCO2e from the 2022 inventory levels. A total of 7.5 MMTCO2e by 2050 from the 2022 levels is needed to achieve the 85 percent reduction target. Figure 6 shows the target achievement scenario where all targets are met compared to the BAU.

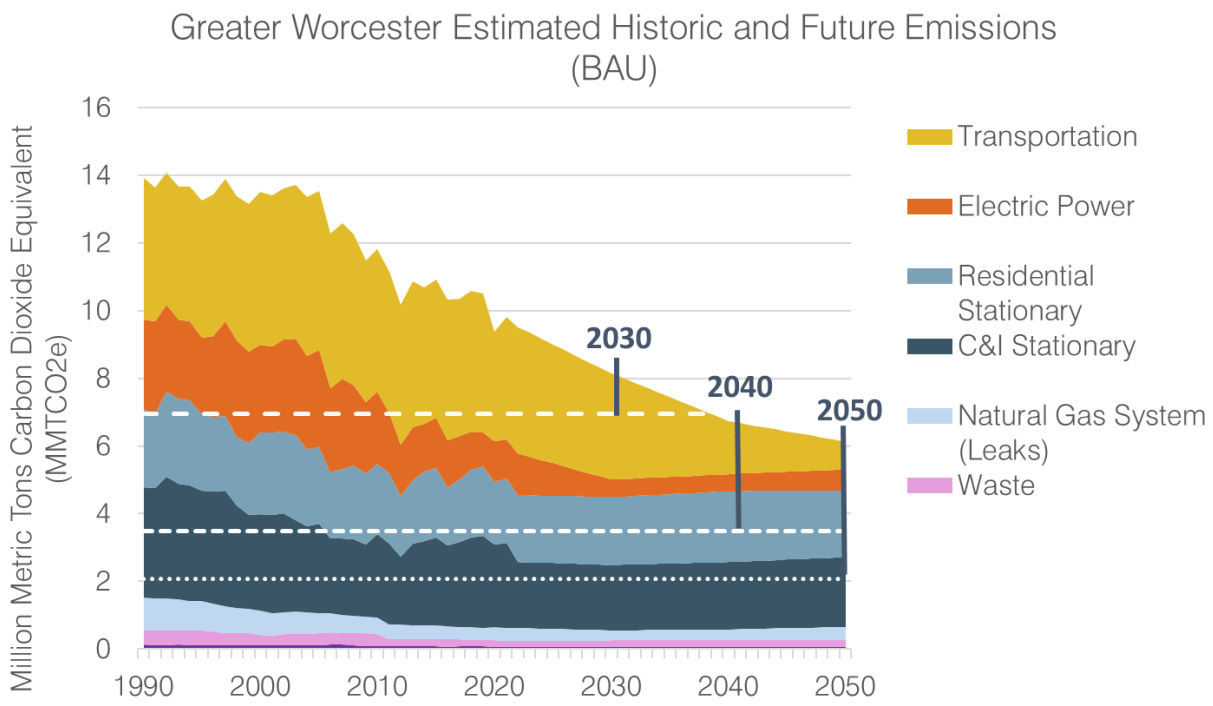


*Figure 6. Greater Worcester estimated historic emissions and business-as-usual emissions scenario by sector*

This business-as-usual data spans from 1990 through 2050 and reflects estimated emissions trajectories without the implementation of additional aggressive climate mitigation measures. It includes emissions from all major sectors including stationary energy, electricity, transportation, waste, and agriculture, along with carbon sequestration from natural and working lands (NWL). The projections are informed by state-level modeling and are adapted to the regional scale to support planning efforts aligned with the Commonwealth of Massachusetts' and State of Connecticut's climate mandates.

## Overview of Projected Emissions

GHG emissions in the Greater Worcester Region have seen a general decline since peaking in the early 2000s. This decline reflects improvements in energy efficiency, fuel switching, and a cleaner electric grid. The BAU projections reflect continued emissions from residential and commercial stationary energy use, electricity generation, transportation, and waste management. While emissions from electric power are projected to decline modestly under BAU assumptions due to renewable energy deployment, emissions from heating fuels and transportation remain relatively high. However, absent significant new policies and investments, these emissions are projected to stabilize or decline slowly, falling short of the reductions necessary to meet net-zero targets by 2050.

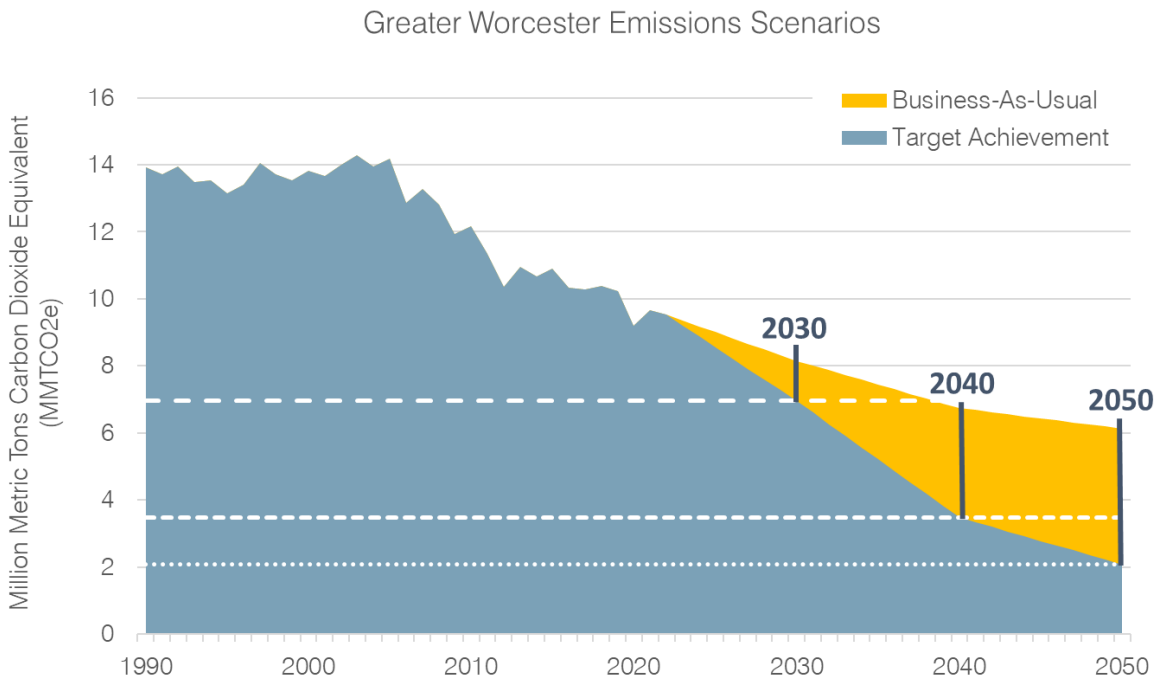


*Figure 7. Business-as-usual and target achievement emissions scenario comparison*

Additional information pertaining to the 2022 GHG emissions inventory, scenarios, and measure reductions can be found in the appendix.

# GHG Emissions Inventory Endnotes

[xv] EPA National Emissions Inventory https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data

# GHG Emissions Reduction Roadmap

## Greater Worcester Comprehensive Climate Action Plan

2025 - 2050

# GHG Emissions Reduction Roadmap

The roadmap contained within this chapter outlines 28 discrete GHG emission reduction measures across the six core sectors of Waste and Materials Management, Electricity Generation and Use, Transportation, Agricultural, Natural, and Working Lands, Commercial and Residential Buildings, and Industry. Each measure contained within this roadmap includes the following implementation features:

- ⇨ **Key Objectives** – The overarching goals of the measure broken down into more tangible and measurable themes.
- ⇨ **Geographic Scope** – A short description of the expected geographic location or scope of the measure. Some measures may be proposed to be implemented across the entire Greater Worcester Region, while others may be targeted to specific communities or geographies.
- ⇨ **Implementation Authority and Responsibilities** – A listing of potential project partners with the authority to implement some or all the actions contained within the proposed measure and a brief description of their anticipated responsibilities.
- ⇨ **Implementation Timelines and Milestones** – A schedule with key milestones for implementing the measure over the Short (2025 – 2030), Medium (2030 – 2040), and Long (2040-2050) Terms.
- ⇨ **Metrics for Tracking Progress** – A listing of measurable indicators that will provide transparent ways to track progress and success of measure implementation.
- ⇨ **Quantified GHG Emissions Reduction** – The near-term (2030) and long-term (2050) projections of GHG emissions reductions compared to BAU projections if the measure is successfully implemented. More detailed calculations and assumptions used to estimate the quantified GHG emissions reductions is located in the Appendix.
- ⇨ **Measure Costs** – The estimated total cost or range of costs to implement the proposed measure. More detailed calculations and assumptions used to estimate the total costs to implement each measure is located in the Appendix.
- ⇨ **Intersection with Other Funding Availability** – A listing of funding sources available from federal, state, local, and private sources that could be leveraged to implement the proposed measure. More details about each potential funding source can be found in the Appendix.

Additionally, each sector closes with a Benefits Analysis detailing the anticipated co-pollutant reductions, direct or indirect benefits, and any potential disbenefits that may be achieved through the implementation of these measures. Quantified estimates of co-pollutant reductions include a combined total of particulate matter (PM 2.5), nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), volatile organic compounds (VOCs), and air toxins. Each sector contains a co-benefit table with direct benefits, signified by a blue "x", and indirect benefits, signified by a green "x".

## GHG Reduction Measure Quantification Overview

The possible emissions reductions associated with the measures included in this plan have been quantified for 2030 and 2050 and categorized as emissions reductions or as increased carbon sequestration, as shown in Table X.

*Table 6. Estimated Emissions Reductions from Greater Worcester CCAP Measures*

| Table X Estimated Emissions Reductions from Measures | | |
|---|---|---|
| **Measure Type** | **2030** | **2050** |
| Emissions Reduction | 1.7 $MMTCO_2e$ | 4.8 $MMTCO_2e$ |
| Carbon Sequestration* | 0.2 $MMTCO_2e$ | 0.6 $MMTCO_2e$ |

**Excludes Measure ANWL 2 which permanently protects existing forested lands to avoid double counting*

The measure implementation scenario is visualized in Figure 8 and demonstrates the achievement of net-zero by 2050. With the reductions from the measures, the estimated total emissions produced in 2050 is 3.4 $MTCO_2e$. While this is higher than the 2.1 $MMTCO_2e$ target, the MSA has a considerable amount of carbon sequestration which is also assumed to increase when implementing measures from natural and working lands related measures. Forest lands in the MSA are estimated to sequester 2.8 $MMTCO_2e$ annually (assumed to be consistent between 1990 and 2022) and was assumed to increase up to 3.4 $MMTCO_2e$ by 2050 based on the proposed measures.

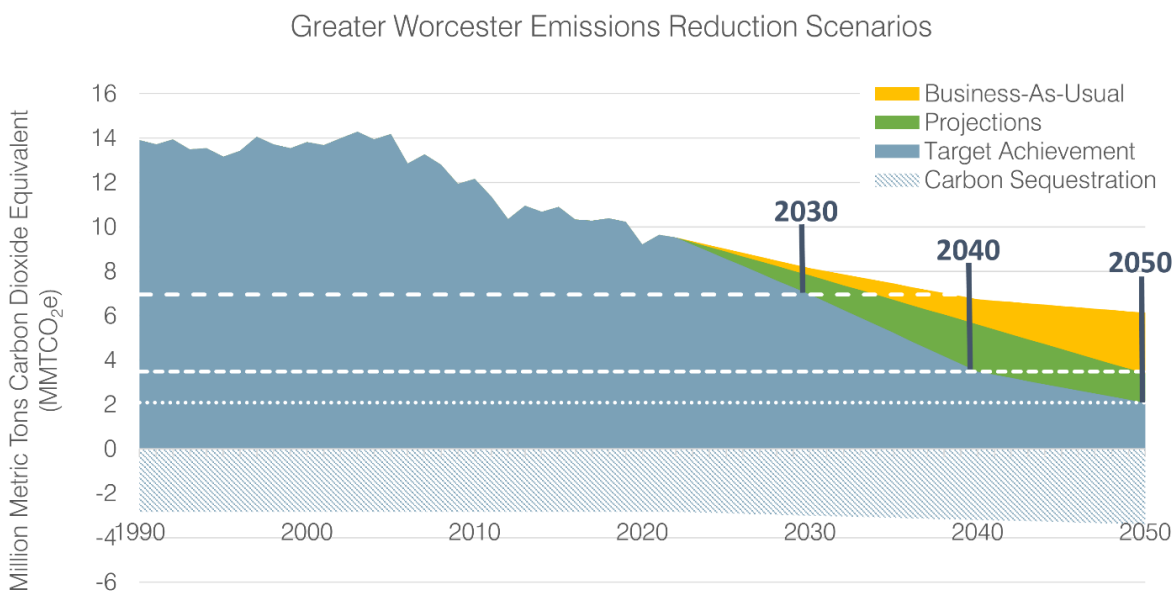


*Figure 8. Business-as-usual, GHG reduction measures, and target achievement emissions scenario comparison*

Achieving net-zero GHG emissions by 2050 across the Greater Region will require a comprehensive, multi-sector approach that mobilizes action far beyond any single program or initiative. Success will depend on implementing a wide variety of measures in a coordinated and sustained manner. At the same time, meaningful progress will only be possible with contributions from Massachusetts and Connecticut state agencies, private-sector partners, community institutions, and individual households whose choices and investments collectively shape regional emissions. The roadmap outlined in this chapter provides a clear and actionable pathway that will position the Greater Worcester Region to succeed in reaching net-zero by the mid-century utilizing a multi-sector and multi-partner framework.

# Waste & Materials Management

Greater Worcester
Comprehensive Climate Action Plan

2025 - 2050

## 3.1 Waste and Materials Management

The economic system that is marked by overconsumption and nowhere is that more evident than in waste streams. In 2022 each resident of the Region produced 0.75 tons of waste on average, nearly three times the global average of 0.27 Tons per person[16], with much of that waste either landfilled or incinerated.[17]

Overall, waste accounts for a small percentage of the current emissions from the Region: just 2% of GHG emissions come from this sector, primarily from wastewater treatment and the solid waste disposal of organic materials, with the greenhouse gases emitted being in the form of methane and CO2.[18] However, there is a greater problem on the horizon that can already be seen in the towns in the Connecticut portion of the Region. Landfills are running out of space and waste will have to be shipped, increasing carbon costs as well as financial burden. Presently, Connecticut has no additional landfill space and is shipping out 960,000 tons of Mixed Solid Waste (MSW) at an estimated cost of $94 million annually in tipping fees alone.[19] This financial cost is expected to rise to $4.8 billion annually by 2050.[20] This does not account for the carbon cost of shipping waste by truck or by train to landfills and other disposal sites as far as Ohio and Virginia, nor the human cost of shipping waste for final disposal in impoverished areas.

Ultimately a holistic systems change is required to develop a circular economy of waste[21]. This differs from our current model which is a fairly linear path from raw materials to waste, by taking steps to prevent materials from being wasted in the first place . This can be done through improvements in design, production, and distribution; reducing waste at the consumption and use stage by allowing for reuse, repurposing, refurbishing and remanufacturing materials; recycling materials that are no longer useful into other useful products; recovering resources from the waste stream for further valorization, and finally disposing of waste once all other avenues of use and reuse have been exhausted. This circular economy can be applied to every single waste stream, and when it comes to comprehensive strategies the old adage of trash and treasure has never been more true. The subsequent strategies build off each other and are required to synergize with each other, building towards a comprehensive waste plan to reduce GHG emissions.

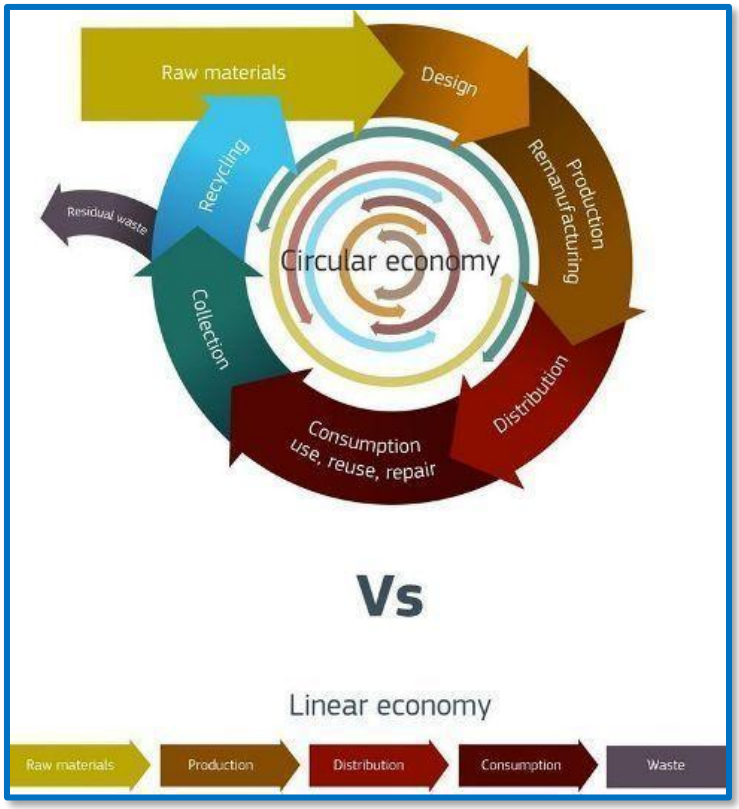


*Figure 9: Diagram of a Circular Economy*

*Table 7. Measure Summary Table for Waste and Materials Management*

| Measures | GHG Emission Reductions in 2030 Compared to the BAU ($MTCO_2e$) | GHG Emission Reductions in 2050 Compared to the BAU ($MTCO_2e$) | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|---|---|
| WMM1: Organics Waste Diversion | 286 | 5,440 | 19 | 358 |
| WMM2: Net-zero Wastewater Treatment and Anaerobic Digestion | 13,537 | 96,704 | 8 | 58 |
| WMM3: Comprehensive Extended Producer Responsibilities (EPR) Legislation | 553 | 10,498 | 12 | 225 |
| WMM4: Comprehensive Unit Based Pricing Legislation | 8,102 | 14,182 | 101 | 304 |
| WMM5: Regional Resource Recovery Network | 294 | 5,291 | 6 | 114 |

## WMM1: Organics Waste Diversion

Organics Waste Diversion from landfilling is a simple goal that is complex in its implementation. The goal of this strategy is to dispose of organic waste into composting or anaerobic digestion, diverting 95% of it from landfills by 2050. There are laws in Massachusetts that ban "disposal or incineration or transfer for disposal at a solid waste disposal facility" of commercial organic material[22] from organic waste producers.[23] Connecticut has a similar law in place that goes into greater detail and requires organic waste be separated and diverted to nearby organic waste composting facilities.[24] It applies to "each commercial food wholesaler or distributor, industrial food manufacturer or processor, supermarket, resort, conference center or institution[25] that generates an average projected volume of not less than twenty-six tons per year of source-separated organic materials."[26] In 2026 this definition will expand to include "each public or non-public school building or educational facility" that houses students K-12[27].

Connecticut's addition of schools can lead to a whole systems approach starting with an elementary, middle, and high school climate program to educate students on waste prevention, reduction, recycling, and reuse, as well as sustainable degrowth practices. This curriculum will focus on all aspects of climate change throughout the child's time within the school system. As part of a holistic education, schools will also establish policies and procedures for internal waste separation and school gardens that accept the compost and digestate from offsite or onsite facilities that process the organic waste.

The state legislatures should expand their ban on organics disposal to include residences, as they very often produce significant amounts of organic waste that enters the waste stream to be disposed of and landfilled.

## Key Objectives

- ⇨ Pilot organic waste separation at K-12 schools as part of a broader climate education program.
- ⇨ Expand legislation that bans disposal of organic waste produced at residences.
- ⇨ Achieve widespread adoption of organic waste separation across all municipalities and school districts.

## Geographic Scope

The scope of this strategy expands across the Region. Other regions and states will be involved based on how waste moves.

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC and NECCOG** – Coordinate adoption of organic waste separation across disparate states and municipalities, as well as with waste haulers, piloting school waste separation, and assisting with the siting and facilitation of organic waste recycling facilities
- ⇨ **Local School Districts, Municipal Institutions, Community Colleges, and Vocational Agricultural Programs** – Adopt organic waste separation on site; educate students and others on waste separation practices for the local organic waste facility.
- ⇨ **State Legislatures** – Pursue legislative action supporting organic waste bans and strengthens existing organic waste bans.
- ⇨ **Massachusetts Department of Environmental Protection (MassDEP)** – Provide grant funding and technical assistance to public entities for organic waste diversion.
- ⇨ **Connecticut Department of Energy and Environmental Protection (CT DEEP)** – Provide grant funding and technical assistance to public entities for organic waste diversion.
- ⇨ **Commercial and Public Waste Haulers** – Provide waste hauling services for organic waste from organic waste producers to Organic Waste Processing Facilities.
- ⇨ **Organic Waste Processing Facilities** – Provide clear information about what types of organic waste they can take.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Pilot Organic Waste Diversion program in 1-3 schools, prioritizing elementary and middle schools. Grow and develop this program within that district.
- ⇨ Pursue legislative actions to strengthen and expand on food waste reduction measures such as incorporate food recovery from the waste streams[28]
- ⇨ Educate and perform outreach to schools and institutions about organic waste separation, as well as to the broader public.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Increase adoption of organic waste diversion in schools, achieving partial to full adoption in 50% of the Region's institutions, businesses, and residences.
- ⇨ Adoption of organic waste disposal in 30% of educational institutions.
- ⇨ Pursue legislative action to include residences in the organic waste ban, closing the loophole for multifamily residential waste stream diversion.
- ⇨ Educate and perform outreach to the broader public about existing organic waste diversion and future initiatives.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Full adoption of Organic Waste Diversion in schools, businesses, and other institutions

### Metrics for Tracking Progress

- ⇨ Total tons of organic waste being landfilled.
- ⇨ Total tons of organic waste diverted from landfill
- ⇨ Number of schools adopting waste separation practices
- ⇨ Number of institutions adopting waste separation practices

### Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 286 $MTCO_2e$, and by 2050 it will reduce emissions by 5,440 $MTCO_2e$. The estimated emissions reductions reflect a diversion of organic waste from landfill or incineration, and methane capture through anaerobic digestion.

### Measure Costs

~$5.2 Million

### Intersection with Other Funding Availability

- ⇨ Sustainable Materials Recovery Program (SMRP) Municipal Grant, MA DEP
- ⇨ Sustainable Materials Management Round 2 (SMMR2) Grant Program, CT DEEP
- ⇨ Recycling & Reuse Business Development Grant, MA DEP
- ⇨ Massachusetts Recycling Loan Fund, MA DEP

### Case Study: The RI School Recycling Project (RISRP)

The RI School Recycling Project (RISRP) is a Rhode Island based non-profit organization whose mission is to demonstrate the environmental benefits of reducing, recovering and recycling in schools through project-based learning[29]. This organization has developed a scalable model for food waste diversion from schools through participatory learning, food waste audits, and student driven food waste separation and food recovery in elementary schools. According to their own metrics, schools that have adopted this program have reduced food waste by 22%, creating a corresponding reduction in carbon emissions by 205.4 $MTC0_2e$[30]. Participating schools have also seen a significant reduction in overall waste generation in schools by simply separating their organic waste from their waste stream, causing the program to be close to cost neutral when accounting for tipping fees. At one school in the program, prior to sorting, the school was generating 170 tons per year of waste. After implementing the program, the school was producing 22.1 tons, a reduction of 87% of total waste generated.[31]

*Figure 10: Students at LaPerche Elementary School in Lincoln, Rhode Island performing on-site waste separation at lunch led by student "Climate Rangers"*

## WMM2: Net-zero Wastewater Treatment and Anaerobic Digestion

Wastewater treatment represents the bulk of the emissions from waste, with most of the emissions coming from the biogenic degradation of the wastewater, releasing carbon dioxide, methane and nitrous oxide, three potent greenhouse gasses.[32] The remaining carbon emissions from wastewater come from the high onsite power demands for the various treatment processes of the wastewater before it can be safely released[33].

Existing technologies and process improvements at Wastewater Treatment Plants (WWTPs) can make them not only net-zero in terms of carbon emissions but can make WWTPs sources of clean energy generation through utilization of anaerobic digestion. Anaerobic Digestion (AD) is the process by which anaerobic microbes within a sealed tank or vessel degrade or break down organic matter to obtain energy and nutrients for growth and reproduction[34]. An engineered AD system creates a controlled environment that efficiently converts biodegradable organic materials (such as wastewater) into biogas and produces a stabilized residual effluent (digestate) that can be put to beneficial use[35]. The functions of an AD system include:

- ⇨ Converting biodegradable organic matter into biogas, which can be sold as a fuel or combusted for on-site energy use.
- ⇨ Reducing biochemical oxygen demand (BOD) and chemical oxygen demand (COD)
- ⇨ Reducing odors
- ⇨ Converting organic nitrogen into more plant-available forms that can be used as fertilizer
- ⇨ Reducing pathogens
- ⇨ Capturing CH4 that otherwise would be released[36]

While primarily used for agricultural power generation and waste reduction, the benefits of AD lend themselves to wastewater treatment decarbonization. By incorporating combined heat and power (CHP) systems[37], along with nitrogen and phosphorus recovery[38], WWTP's can further improve energy generation through co-generation, where digesters are able to take in organic solid waste, providing a sustainable solution for both energy generation and waste processing[39]. There is also the possibility of standalone ADs for municipalities as a means for local renewable energy generation and organic waste recovery, acting as a viable destination for the organic waste being separated in measure 1.

Both case studies for existing Agricultural and Wastewater Treatment Anaerobic Digestion are found in the Region. In Clinton, MA, a WWTP utilizes anaerobic digestion to generate biogas that it uses in dual boilers to maintain digester temperatures[40]. Agriculturally, Jordan's Dairy Farms in both Rutland and Spencer are successful examples of agricultural digesters, converting animal waste and separated organic waste into renewable energy and fertilizer[41]. There are many opportunities for Anaerobic Digester adoption in the Massachusetts portion of the Region at wastewater treatment plants as well as near organic waste producers. Additionally, Connecticut enacted an Organic Waste Disposal Ban; there is an opportunity to increase the effectiveness of the ban by adding ADs in rural areas as demonstrated in Windham County[42].

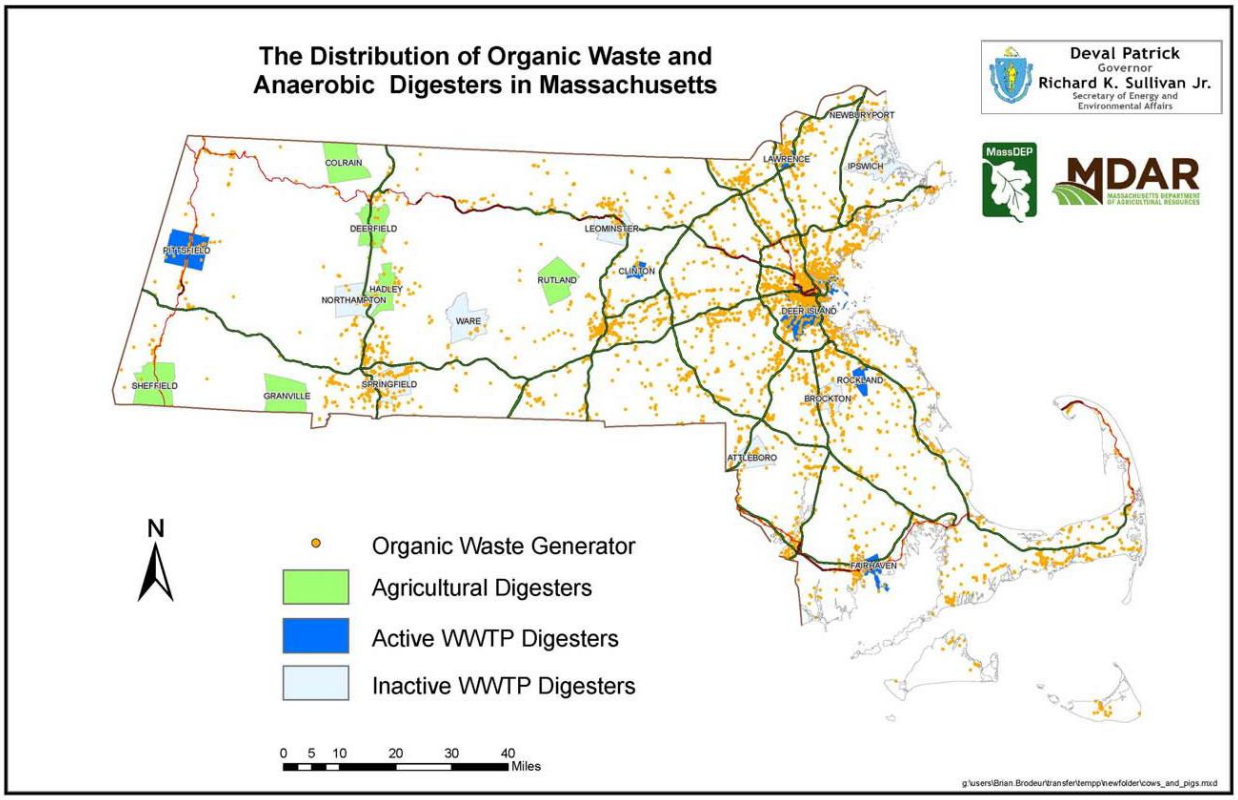


*Figure 11. Distribution of Organic Waste and Anerobic Digesters in Massachusetts*

Existing WWTPs in the Region are already looking into net-zero strategies and Anaerobic Digestion. The Upper Blackstone Clean Water WWTP already utilizes its site as a host for solar and has plans to expand solar production onsite. Itis in phase 2 of planning for a regional biosolids management facility with the Narragansett Bay Commission and Springfield Water & Sewer Commission to process biosolids (aka sludge) from their respective facilities into a stabilized product[43].

## Key Objectives

- ⇨ Install or retrofit anaerobic digesters and other energy production or energy saving improvements at Wastewater Treatment Plants that incorporate co-generation among other carbon reductions to bring all WWTPs to Net or Near Net Zero
- ⇨ Expand utilization of anaerobic digestion at agricultural facilities and build new municipally or publicly owned anaerobic digesters.
- ⇨ Produce 5% of the Region's energy needs through anaerobic digestion.

## Geographic Scope

Anaerobic Digesters have specific siting requirements to make them economically viable. Prioritization should be given to wastewater treatment facilities due to having readily available digestible organic waste.

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC and NECCOG** – Coordinate with wastewater treatment plants to apply for grant funding for retrofits. Works with municipalities and agricultural enterprises.
- ⇨ **Wastewater Treatment Plant Operators** - Identify areas of improvement for GHG emissions reduction as well as siting and installing anerobic digesters.
- ⇨ **Municipalities** – Adopt friendly zoning ordinances for anerobic digestion wherever feasible. Builds community digesters at municipally owned facilities and recycling sites
- ⇨ **Agricultural Enterprises** – Adopt agricultural anerobic digestion as an additional revenue stream
- ⇨ **State Legislatures** – Pursue legislative action supporting anerobic digestion as a green energy source.
- ⇨ **Massachusetts Department of Environmental Protection (MassDEP)** – Provide grants and technical assistance to public entities for anerobic digestion and net-zero retrofits
- ⇨ **Massachusetts Department of Agricultural Resources (MDAR)** – Provide grants and technical assistance to agricultural enterprises and public entities for anerobic digestion projects
- ⇨ **Connecticut Department of Energy and Environmental Protection (CT DEEP)** – Provide grants and technical assistance to public entities for anerobic digestion and net-zero retrofits
- ⇨ **Connecticut Department of Agriculture (CT DOAG)** - Provide grants and technical assistance to agricultural enterprises and public entities for anerobic digestion projects
- ⇨ **Connecticut Resource Conservation and Development (CT RC&D)** - Provide grants and technical assistance to agricultural enterprises and public entities for anerobic digestion projects
- ⇨ **Municipal Light and Power Departments** – Operate anerobic digester power plants or work with anerobic digester operators to procure green power.
- ⇨ **Power Utilities** – Build out and develop power distribution infrastructure to handle the new capacity of green power generation

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Assemble a regional working group to write an Anerobic Digestion Feasibility Study that identifies priority sites for implementation.
- ⇨ Perform site analysis for WWTPs that do not have active ADs to determine cost and siting considerations for digesters, CHP, and other retrofits to reduce carbon emissions.
- ⇨ Provide technical and grant assistance to 2-3 agricultural entities; perform feasibility studies and site analysis for public and private entities.
- ⇨ Educate and perform outreach to municipalities, farms, and wastewater treatment plants about anerobic digestion.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Retrofit and upgrade 1-2 AD facilities at WWTPs that are currently inactive, such as the Leominster Wastewater Treatment Plant, that include co-generation capabilities as well as other emissions reduction strategies.
- ⇨ Achieve 50% reduction of carbon emissions of WWTPs
- ⇨ Install 6 Community/Agricultural/WWTP Digesters near organic waste producers
- ⇨ Achieve 2% of power needs through Anaerobic Digestion

**Long Term Actions, Years 2040 – 2050**

- ⇨ Achieve 95%+ reduction of carbon emissions of WWTPs
- ⇨ Install 20+ Community/Agricultural/WWTP Digesters near organic waste producers
- ⇨ Achieve 5% of power needs through anaerobic digestion

### Metrics for Tracking Progress

- ⇨ KWh of Energy used at wastewater treatment plants
- ⇨ KWh of energy produced by anaerobic digesters
- ⇨ Number of anaerobic digesters installed and capacity of those digesters

### Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by13,537 $MTCO_2e$, and by 2050 it will reduce emissions by 96,704 $MTCO_2e$. The estimated emissions reductions reflect an increased share of electricity from renewable energy each year sourced from anaerobic digestion.

### Measure Costs

~$700 Million - $1.7 Billion

### Intersection with Other Funding Availability

- ⇨ Farm Loans, USDA
- ⇨ Rural Development Loan and Grant Assistance, USDA
- ⇨ Sustainable Materials Recovery Program (SMRP) Municipal Grant, MA DEP
- ⇨ State Revolving Fund (SRF) Financial Assistance Program, MA DEP
- ⇨ Agricultural Energy Grant Program (ENER), MA EEA
- ⇨ Clean Water Fund, CT DEEP
- ⇨ Sustainable Materials Management Round 2 (SMMR2) Grant Program, CT DEEP

## WMM3: Comprehensive Extended Producer Responsibility

The cost of collecting, sorting and processing waste has fallen on taxpayers and local governments. Meanwhile, the companies producing materials such as single use plastics, electronics, bulky items, hazardous chemicals and other difficult to dispose of materials, can shift the costs and inefficiencies to the end consumers and taxpayers.

Extended producer responsibility (EPR) laws shift this financial burden onto producers, the companies that manufacture, package, and sell consumer goods, requiring them to pay fees for the waste their products generate. Connecticut and Massachusetts have both introduced EPR bills in their respective legislatures. Connecticut currently has four operational statutory EPR programs that cover architectural paint, electronic devices, mattresses, and mercury thermostats. Programs for gas cylinders and tires are forthcoming.[44] Massachusetts has created a commission to study EPR and will be reviewing paint, mattresses, batteries, electronics, and plastics and packaging.[45] Legislators should consider California laws as an example as they additionally include textiles, batteries, single use packaging, pharmaceuticals and sharps, and carpets.[46]

The current strategy for EPR legislation adopts a piecemeal approach, and what is covered by one state's EPR legislation may not be covered by another. The Region needs comprehensive EPR legislation that addresses all waste produced, requires the use of 100% recyclable or compostable material which will ensure that these materials can be recovered, and provides funding to recover these materials and to dispose of them safely when they cannot be recovered.

### Key Objectives

- ⇨ Reduce the amount of single use plastics being produced and used
- ⇨ Reduce utilization of virgin materials in production
- ⇨ Increase funding for waste management of hard to dispose of waste
- ⇨ Increase circularity of the waste economy by improving recovery and recyclability of products sold

### Geographic Scope

This measure should be implemented statewide across Massachusetts and Connecticut to be effective.

### Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC and NECCOG** – Educate chambers of commerce and other entities about EPR and perform public outreach.
- ⇨ **State Legislatures** – Pursue legislative action supporting comprehensive EPR.
- ⇨ **Commercial and Industrial Producers and Sellers** – Follow EPR legislation.

### Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Develop EPR working group to perform education and outreach activities.
- ⇨ Massachusetts to adopt EPR Legislation for single use plastics, batteries, mattresses, paint and electronics
- ⇨ Connecticut to expand existing EPR to include gas cylinders and tires

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Educate and perform outreach to expand existing EPR legislation
- ⇨ Massachusetts to adopt EPR legislation to include sharps and pharmaceuticals, tires, mercury thermostats, gas cylinders, textiles, carpets,
- ⇨ Connecticut to adopt EPR legislation to include sharps and pharmaceuticals, tires, textiles, carpets, and single use plastics and packaging

**Long Term Actions, Years 2040 – 2050**

- ⇨ Massachusetts and Connecticut adopt fully comprehensive EPR legislation that applies to all waste produced in their respective states.

## Metrics for Tracking Progress

- ⇨ Total amount of waste being landfilled or incinerated versus recovered or recycled
- ⇨ Percentage of producers in compliance with EPR legislation

## Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 553 $MTCO_2e$, and by 2050 it will reduce emissions by 10,498 $MTCO_2e$. The estimated quantity of recyclable plastics and papers generated and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. The rate of assumed waste diversion is 5% in 2030 and 95% in 2050.

## Measure Costs

Not quantifiable

## Intersection with Other Funding Availability

- ⇨ C-MORE Grant Program: Reducing Embodied Greenhouse Gas Emissions for Construction Materials and Products, US EPA
- ⇨ Source Reduction Assistance Grants, US EPA
- ⇨ Business Grants, Toxics Use Reduction Institute (TURI)
- ⇨ Research Grants, TURI
- ⇨ Community Grants, TURI

## WMM4: Comprehensive Unit Based Pricing Legislation

Unit Based Pricing (UBP), also known as Pay-As-You-Throw (PAYT) or Save-Money-And-Reduce-Trash (SMART), is a system in which residents pay for municipal solid waste (MSW) management services per unit of waste discarded. When residents pay directly for waste disposal services, they are provided with a financial incentive to reduce their waste through recycling, composting, and source reduction[47]. This is not a new strategy in waste management; as early as 1991 municipalities in Massachusetts were adopting UBP programs and seeing immediate reductions in waste and increases in recycling and composting.[48]

Traditional payment schemes for waste disposal typically take the form of either a municipal tax or flat fee. Tax based fees are collected through local property taxes and are not distinguished from other property tax revenues[49]. Flat fees are collected from residents for waste management services on an annual or semi-annual basis[50]. Since both payment schemes do not consider the volume of waste produced, they provide no incentive to reduce the amount of waste generated per household. This leads to a higher cost for municipalities, as the tipping fees they pay are volumetric. Beyond cost savings, the waste quantity reductions of UBP are substantial: every municipality that has adopted UBP has seen reductions in the total amount of waste generated by 40% to 60% without exception.[51]

In municipalities where UBP has already been adopted there is still room for improvement. While measure WMM1 addresses this to some extent, adopting curbside organic waste collection can enhance the cost savings of these programs in addition while diverting organic waste from the mixed solid waste stream. For example, in 2012, the towns of Wenham and Hamilton in Massachusetts, whose combined population was just under 15,000, jointly piloted a weekly organic waste pickup program which resulted in a combined savings of $40,000.00 for those towns.[52] Additionally, towns with UBP can expand this program to include multi-family dwellings of 7 units or more, an area often excluded in many PAYT programs.[53] The most effective and equitable way to implement this expansion is to adopt a bag-based system such as Worcester's yellow trash bag model in which residents purchase special trash bags. This ensures that residents, regardless of housing type, contribute fairly to waste disposal costs.[54]

### Key Objectives

- ⇨ Reduce total amount of waste being produced per municipality
- ⇨ Increase separation of waste into appropriate streams for recovery, reuse, and recycling

### Geographic Scope

UBP adoption is typically done on a town-by-town basis within the states of Connecticut and Massachusetts. Subsequently for this strategy a town-by-town approach will be required as it concerns municipal haulers. When it comes to towns with private waste haulers, statewide legislation requiring PAYT/UBP will have to be enacted to ensure that reductions in waste are achieved. Adoption has been greater in MA than in CT, with 38 of 51 cities and towns in Worcester County having adopted some version of PAYT/UBP.[55] As of writing, none of the towns in the CT portion of the MSA have adopted any form of PAYT/UBP.[56]

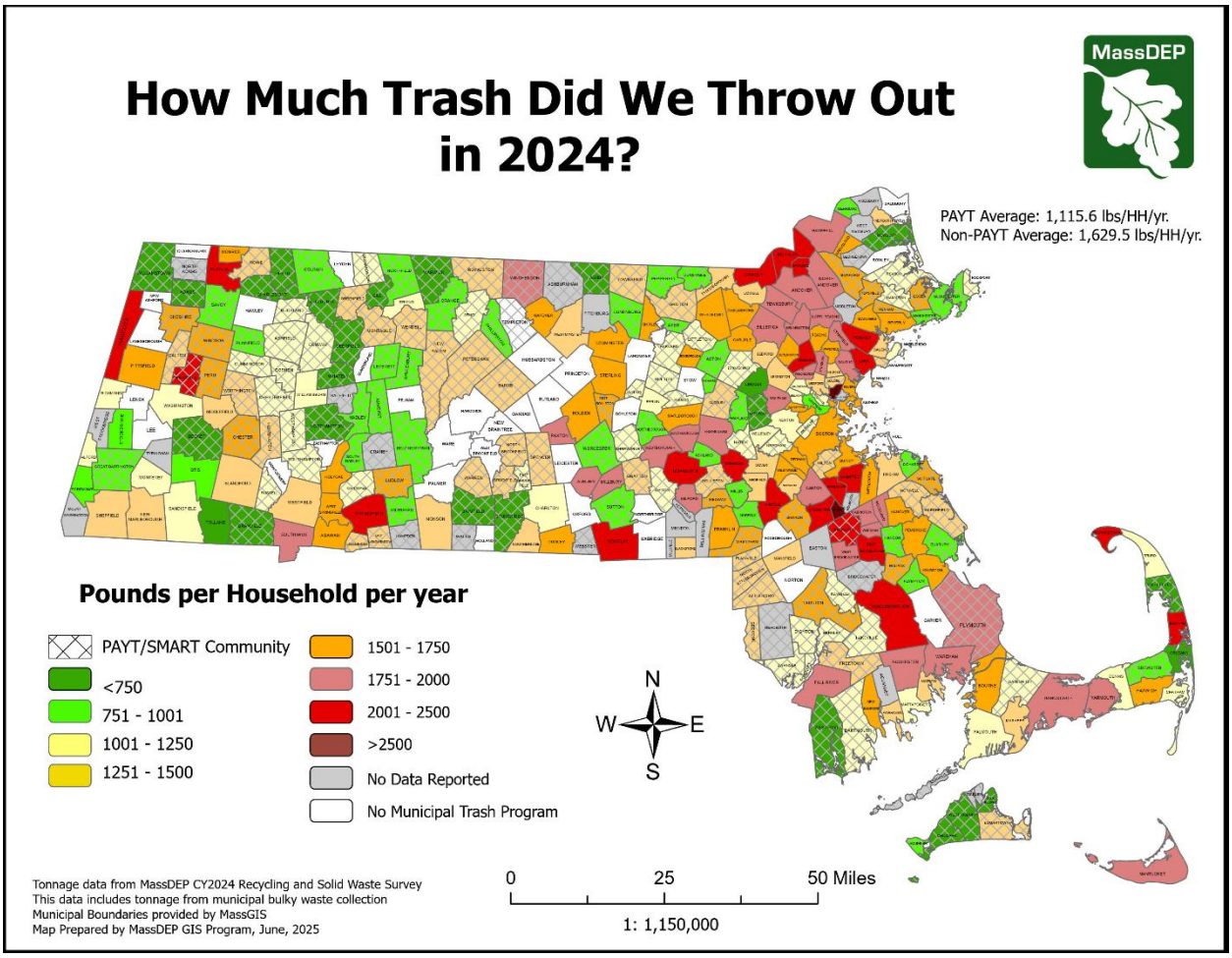


*Figure 12 How Much Trash Did We Throw Out in 2024?*

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC and NECCOG** – Coordinate adoption of UBP across municipalities; coordinate with waste haulers, and assist with the siting and facilitation of organic waste recycling facilities
- ⇨ **Municipalities** – Adopt UBP that works for the conditions of the municipality, and expand and improve upon those programs.
- ⇨ **State Legislatures** – Pursue legislative action supporting UBP.
- ⇨ **Massachusetts Department of Environmental Protection (Mass DEP)** – Provide grant funding and technical assistance to public entities for waste diversion.
- ⇨ **Connecticut Department of Energy and Environmental Protection (CT DEEP)** – Provide grant funding and technical assistance to public entities for waste diversion.
- ⇨ **Materials Recovery Facilities (MRFs)** – Take in and sort waste as separated by UBP programs.
- ⇨ **Commercial and Public Waste Haulers** – Provide waste hauling services for separated waste streams to their respective destinations and MRFs.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Educate and perform outreach to municipalities about the benefits of UBP
- ⇨ Adopt UBP in 3 municipalities in the Connecticut portion of the Region.
- ⇨ Adopt UBP in 42 municipalities in the Massachusetts portion of the Region.
- ⇨ Pilot curbside organic waste collection in 1 municipality with existing UBP
- ⇨ Add multifamily residence requirements in 1 municipality

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Continue to educate and perform outreach to municipalities about the benefits of UBP
- ⇨ Adopt UBP in 9 municipalities in the Connecticut portion of the Region.
- ⇨ Adopt UBP in 48 municipalities in the Massachusetts portion of the Region.
- ⇨ Add curbside organic waste collection in 10% of municipalities that have adopted UBP
- ⇨ Add multifamily residence requirements in 10% of municipalities that have adopted UBP

**Long Term Actions, Years 2040 – 2050**

- ⇨ Adopt UBP in all municipalities in the Connecticut portion of the Region.
- ⇨ Adopt UBP in all municipalities in the Massachusetts portion of the Region.
- ⇨ Add curbside organic waste collection in 90% of municipalities that have adopted UBPAdd multifamily residence requirements in 90% of municipalities that have adopted UBP

## Metrics for Tracking Progress

- ⇨ Number of municipalities who have adopted UBP
- ⇨ Amount of waste reduced following adoption

## Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 8,102 $MTCO_2e$, and by 2050 it will reduce emissions by 14,182 $MTCO_2e$. The population in the MSA which is not already served by a Pay-As-You-Throw/SMART program was estimated and an assumed 0.9 short tons per person per year was used to calculate the estimated baseline waste, aligned with the approach used in the 2022 GHG Inventory. The rate of reduction of waste was assumed at 20% in 2030 and 60% in 2050.

## Measure Costs

~$13.4 - $28.7 Million

## Intersection with Other Funding Availability

- ⇨ Sustainable Materials Recovery Program (SMRP) Municipal Grant, MA DEP
- ⇨ SMRP Municipal Technical Assistance, MA DEP
- ⇨ SMRP Recycling Dividends Program Funds, MA DEP

## WMM5: Regional Resource Recovery Network

The final strategy of this sector ties together the existing strategies with an overarching framework to ensure that the strategies can be enacted. For the purposes of this measure, a Regional Waste Management Entity refers to municipalities located within a specific geographic boundary that join together to delegate waste management responsibilities to a central authority, association, or organization.[57] This entity would be tasked with overseeing a robust Regional Resource Recovery Network that connects previously independent and disconnected municipalities, waste haulers, recyclers, compost, and anaerobic digestion facilities, transfer stations and materials recovery facilities (MRFs). This would enable municipalities to benefit from economies of scale while also increasing coordination between these entities.

According to Western Connecticut Council of Governments (WestCOG), Regional Waste Management Entities can also ensure that public outreach and education initiatives are unified, and that messaging is consistent from municipality to municipality. The entity would also focus on educating businesses and institutions about existing recycling and waste diversion incentives, as well as supporting municipalities with education and technical assistance on the planning and implementation of new Unit-Based Pricing programs.

In addition, the entity would manage waste reduction programs that already exist at the state and local levels with a focus on including businesses, schools, institutions, and senior centers. This would ensure that all sectors of the community are involved in the waste reduction, reuse, and incentives education process. Beyond coordination, connection, and education, this entity could offer substantial economic and operational benefits. Economies of scale will be more easily achieved for organic waste diversion and the overall waste reduction, saving municipalities money on disposal costs and composting contracts in the long-term. Joint procurement of services is beneficial for improving limited municipal capacity for many of the smaller, more rural towns in the Region.
Looking forward, this entity could also expand to handle certain types of waste directly, by establishing cost-neutral operations within a decentralized network of facilities. These facilities would fill gaps in waste management and produce locally sourced recovered materials such as: recycled steel and aluminum stock from separated scrap metal and aluminum; recoverable rare metals from spent single use and old batteries to make into new batteries; onsite power, heating and organic fertilizer through anaerobic digestion; particle board, chip board, and engineered lumber products from wood waste and recovered brick, masonry, asphalt, gravel and glass from C+D materials produced locally; ground glass pozzolans from recyclable glass and ceramics, and many other recoverable materials that can be reutilized. This network, managed by the Regional Waste Management Entity, should serve as a laboratory for innovation in waste reuse, recycling and recovery.

### Case Study: Rhode Island Resource Recovery Corporation

Created in 1974 by the Rhode Island General Assembly, the Rhode Island Resource Recovery Corporation is a quasi-public[58] agency whose mission is to provide safe, environmentally compliant, clean and affordable solid waste and recycling services for the Rhode Island community[59]. This agency is entirely self-funded through tipping fees charged to commercial waste haulers and the sale of recovered materials, allowing them to subsidize tipping fees to municipalities and to offer "free" programs and services. These include the composting of municipal leaf and yard debris, education programs, and the Eco-Depot household hazardous waste collection program[60]. Resource

Recovery's 1,200-acre facility in Johnston is home to several major operations: a Materials Recycling Facility (MRF); a Small Vehicle Area (SVA) which offers easy access to special and bulky item recycling and disposal services; a leaf and yard debris composting program, and the Central Landfill which feeds a landfill-gas-to-energy plant across the street, preventing the release of methane into the atmosphere. Additionally, Resource Recovery operates off-site, Eco-Depot collection events for household hazardous waste. This model could serve as a template for a Regional Waste Management Entity in the Region.

## Key Objectives

- ⇨ Consolidate waste management services under a single entity tasked with ensuring these strategies are enacted
- ⇨ Reorganize how waste is moved and processed throughout the Region to reduce inefficiencies and waste.
- ⇨ Increase adoption of a circular economy

## Geographic Scope

This should be region-wide, beginning in Massachusetts and spreading into Connecticut as the appropriate agreements are put in place with the municipalities.

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC and NECCOG** – Coordinate the creation of a resource recovery network across municipalities; coordinate with waste haulers, and assist with the siting and facilitation of organic waste recycling facilities
- ⇨ **State Legislatures** – Pursue legislative action supporting or creating a resource recovery network.
- ⇨ **Massachusetts Department of Environmental Protection (Mass DEP)** – Provide grant funding and technical assistance to a resource recovery network for waste reduction and disposal.
- ⇨ **Connecticut Department of Energy and Environmental Protection (CT DEEP)** – Provide grant funding and technical assistance to a resource recovery network for waste reduction and disposal.
- ⇨ **Materials Recovery Facilities (MRFs)** – Participate in a resource recovery network
- ⇨ **Commercial and Public Waste Haulers** – Provide waste hauling services for separated waste streams to their respective destinations and MRFs.
- ⇨ **Waste Disposal and Recovery Sites** – Participate in a resource recovery network

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Create a Regional Resource Recovery Working Group to define the outlines of what a Regional Waste Management Entity would look like.
- ⇨ Complete Phase I Feasibility Study for a Regional Waste Management Entity
- ⇨ Survey municipalities about interest in Regional Waste Management Entity
- ⇨ Begin Phase II Study for a Regional Waste Management Entity

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Conclude Phase II Study and Phase III Implementation, establishing a Regional Waste Management Entity that provides public education, coordinates waste management resources and connects municipalities with waste haulers, transfer stations and end points for waste management.
- ⇨ Expand on the capabilities of the Regional Waste Management Entity to fill gaps in waste processing within the Region. This could be through public private partnership, grant funding to specific waste processors or the creation of a waste processing facility operated by the Regional Waste Management Entity.
- ⇨ Regional Waste Management Entity achieves partial self-funding, being able to cover 30-60% of its operating costs

**Long Term Actions, Years 2040 – 2050**

- ⇨ The Regional Waste Management entity fills all capability gaps for processing waste into usable materials within the region.
- ⇨ The Regional Waste Management Entity achieves 90-100% Self Funding
- ⇨ The Resource Recovery Network as a whole is able to reduce waste disposal for all types of waste by 95%

## Metrics for Tracking Progress

- ⇨ Percentage of total tons of waste being landfilled or incinerated by type versus being recovered
- ⇨ Adoption and Implementation of Strategies 1-4
- ⇨ Amount of waste being shipped out of the Region versus being processed in the Region

## Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 294 $MTCO_2e$, and by 2050 it will reduce emissions by 5,291 $MTCO_2e$. The estimated quantity of construction and demolition, electronics, and bulky material waste generated in the Region and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. A percentage of this was assumed to be diverted in 2030 and 2050. The rate of assumed waste diversion is 5% in 2030 and 90% in 2050.

## Measure Costs

Not quantifiable.

## Intersection with Other Funding Availability

- ⇨ Farm Loan Programs, USDA
- ⇨ Rural Energy for America Program (REAP) Renewable Energy Systems & Energy Efficiency Improvement Guaranteed Loans & Grants, USDA
- ⇨ Value-Added Producer Grants, USDA
- ⇨ Business & Industry Loan Guarantees, USDA
- ⇨ Advanced Biofuel Payment Program, USDA
- ⇨ C-MORE Grant Program: Reducing Embodied Greenhouse Gas Emissions for Construction Materials and Products, US EPA
- ⇨ Source Reduction Assistance Grants, US EPA
- ⇨ Clean Water State Revolving Fund (SRF) Program, US EPA
- ⇨ Agricultural Environmental Enhancement Program (AEEP), MDAR

- ⇨ Green Communities Grants, MA DOER
- ⇨ Commonwealth Organics-To-Energy, Mass CEC
- ⇨ Financial Assistance, MassDevelopment
- ⇨ Massachusetts Renewable Energy Portfolio Standard, MA DOER
- ⇨ Sustainable Materials Recovery Program (SMRP) Municipal Grant, MA DEP
- ⇨ SMRP Municipal Technical Assistance, MA DEP
- ⇨ SMRP Recycling Dividends Program Funds, MA DEP
- ⇨ Recycling & Reuse Business Development Grant, MA DEP
- ⇨ Massachusetts Recycling Loan Fund, MA DEP
- ⇨ Reduce, Reuse, Repair Micro-Grant, MA DEP
- ⇨ Sustainable Materials Management Round 2 (SMMR2) Grant Program, CT DEEP
- ⇨ Business Grants, TURI
- ⇨ Research Grants, TURI
- ⇨ Community Grants, TURI
- ⇨ Catalytic Capital Closed Loop Infrastructure Strategy, Closed Loop Partners

## Benefits Analysis: Waste and Materials Management

The overall waste sector contributes a small proportion of GHG Emissions within the Region. The implementation of these measures will lead to a reduction in co-pollutants detrimental to people's health. Specifically, the co-pollutants emissions reductions that these measures will lead to include:

*Table 8. Waste and Materials Management Co-Pollutant Reductions*

| Measures | Co-Pollutant Emission Reductions in 2030 (MT) | Co-Pollutant Emission Reductions in 2050 (MT) |
|---|---|---|
| WMM1: Organics Waste Diversion | 19 | 358 |
| WMM2: Net Zero Wastewater Treatment and Anerobic Digestion | 8 | 58 |
| WMM3: Comprehensive Extended Producer Responsibility | 12 | 225 |
| WMM4: Comprehensive Unit Based Pricing Legislation | 101 | 304 |
| WMM5: Regional Resource Recovery Network | 6 | 114 |

By utilizing these measures to address waste within the system several co-benefits will be achieved. Chief among these is improved fiscal resiliency. As noted previously, Connecticut has no additional landfill space and is shipping 960,000 tons of Mixed Solid Waste (MSW) at an estimated cost of $94 million annually in tipping fees alone.[61] This financial cost is expected to rise to $4.8 billion annually by 2050.[62] This offers a warning of things to come for the Region should we continue on the path of a linear economy of production to consumption to landfill or incineration. Each of the measures has a direct or indirect benefit to fiscal resiliency, as a reduction in waste being landfilled or burned is an increase in the service life of those facilities.

Moving towards a circular economy will stimulate job growth in the waste sector and this is reflected in all these strategies. Changing from a linear economy to a circular one will require additional labor to reuse, recycle and recover useful materials from what had been thought of as waste. The additional co-benefits of these measures (improved climate resilience, improved access to services and decreased energy costs) are more measure-specific. The goals set by these measures can be achieved with existing technology, and the key to success lies in embracing change.

*Table 9. Waste and Materials Management Co-Benefits Summary*

| Measures | Improved Fiscal Resiliency | Job creation | Improved climate resilience | Improved access to services | Decreased energy costs |
|---|---|---|---|---|---|
| WMM1: Organics Waste Diversion | X | X | X | | |
| WMM2: Net Zero Wastewater Treatment and Anerobic Digestion | X | X | X | X | X |
| WMM3: Comprehensive Extended Producer Responsibility | X | X | | | X |
| WMM4: Comprehensive Unit Based Pricing Legislation | X | X | | X | X |
| WMM5: Regional Resource Recovery Network | X | X | X | X | |

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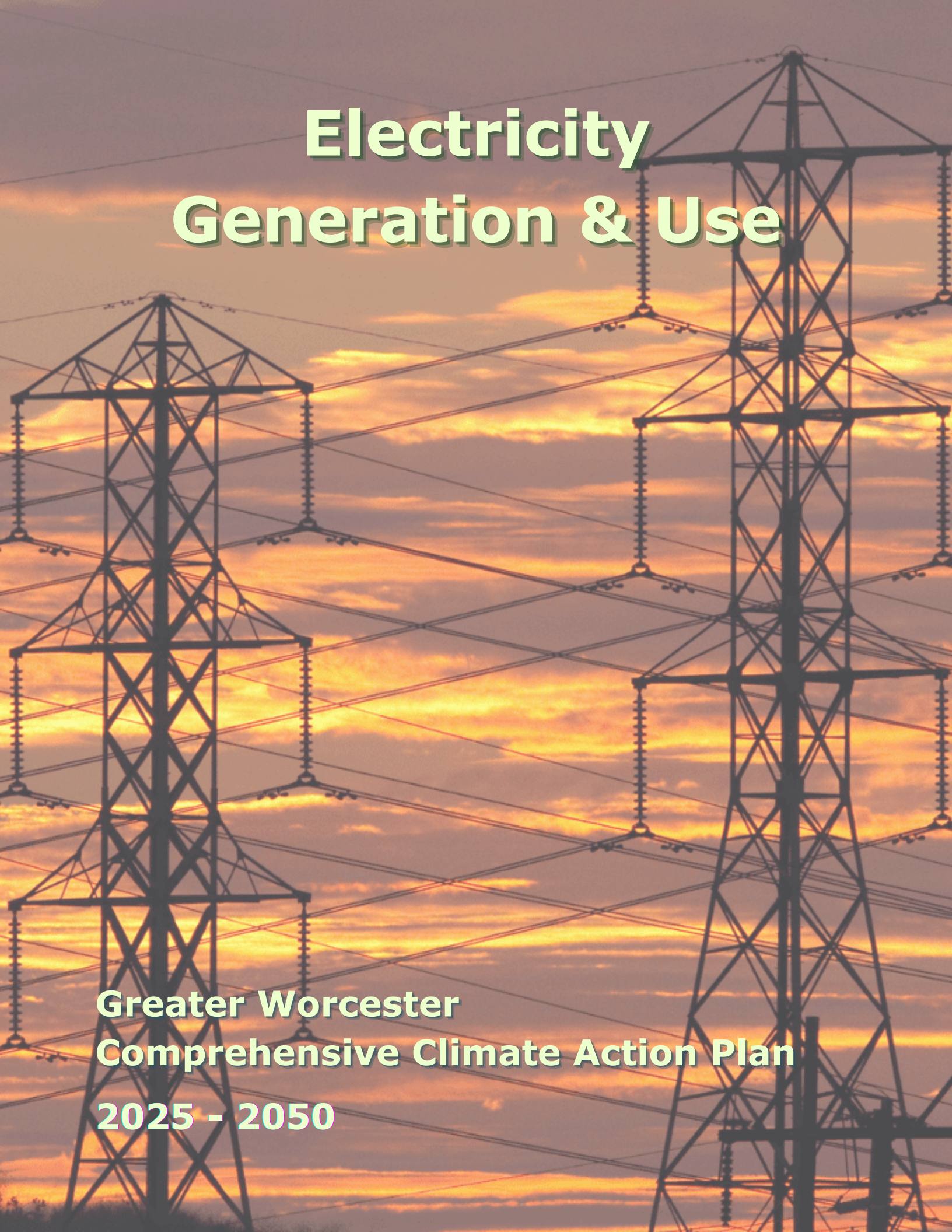

# Electricity Generation & Use

Greater Worcester
Comprehensive Climate Action Plan

2025 - 2050

## 3.2 Electricity Generation and Use

Electricity is crucial in people's everyday lives as well as for institutions and the economy within the Greater Worcester Region. Electricity generation and use is currently the third highest emitting sector in the Region, with an estimated 1.24 MMTCO2e emitted in 2022 according to this plan's baseline inventory. Electricity demand in the Region is anticipated to increase with vehicles and homes electrifying as part of the clean energy transition. The Region should increase electricity generation and use while also eliminating fossil fuel-generated electricity from its energy mix to meet its greenhouse gas emissions reduction goals as part of the effort to mitigate climate change.

According to this plan's 2022 baseline inventory, 13% of greenhouse gas emissions in the Region stem from electricity generated by fossil fuels. To achieve the Region's climate pollution reduction goals of net zero emissions by 2050, a variety of non-emitting electricity generation and storage resources should be explored and utilized. These resources include solar power and energy storage, which were included in electricity sector strategies in the Greater Worcester Priority Climate Action Plan, as well as wind power, hydroelectric power, and nuclear power which are both generated in the Region and distributed from generation sources outside of the Region. By utilizing a number of different technologies as part of the clean energy transition, the Region can diversify its energy mix, becoming more resilient; with this strategy in place, if one of these technologies ends up being more difficult to adopt than anticipated, the use of fossil fuel-generated electricity will still be eliminated. The Region's municipal light plants play and should increasingly play an important role in the generation and use of clean energy in the Region; their flexibility and direct responsiveness to community cost-savings and sustainability needs can make it easier to site and procure clean energy in the communities they serve.

It is important to note that the goals for percentages of electricity and power use in the Region in 2050 included in this chapter are averages; the day-to-day percentages of energy from different sources in the electric grid fluctuate, and this fluctuation increases when more generation sources such as solar and wind facilities which vary in production with weather and the time of day are connected to the grid. Through collaborations between regional stakeholders and stakeholders outside of the Region to implement the strategies in this chapter, the Region's electricity mix can become more efficient, can become less costly, and can better serve residents who have faced burdens from a fossil fuel-dominated electricity system.

*Table 10. Measure Summary Table for Electricity Generation and Use*

| Measures | GHG Emission Reductions in 2030 Compared to the BAU ($MTCO_2e$) | GHG Emission Reductions in 2050 Compared to the BAU ($MTCO_2e$) | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|---|---|
| EGU1: Solar Power Generation | 197,081 | 459,343 | 122 | 290 |
| EGU2: Wind Power Generation | 52,555 | 330,727 | 32 | 209 |
| EGU3: Nuclear Power Generation | 105,110 | 459,343 | 65 | 290 |
| EGU4: Energy Storage Systems | 13,139 | 91,869 | 8 | 58 |
| EGU5: Hydro-Power Solutions | 65,694 | 404,222 | 41 | 255 |

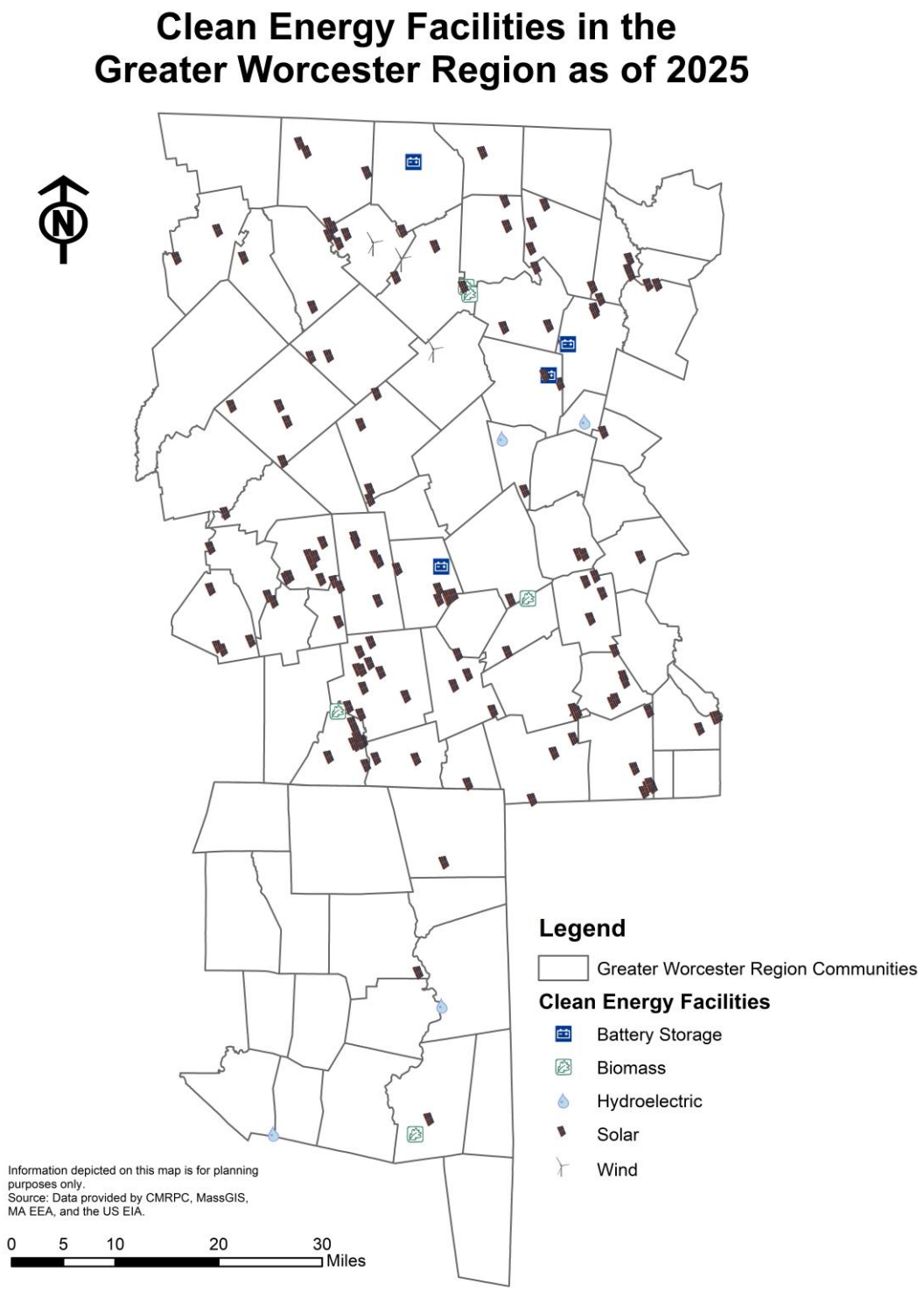


*Figure 13. Clean Energy Facilities in the Greater Worcester Region as of 2025*

*Please note that this map is not comprehensive and that there are clean energy facilities discussed in this chapter and its appendices which are not included in it.*

## EGU1: Solar Power Generation

Power generation should be diverted away from fossil fuels through the installation of 2.77 TWh of solar generation and storage systems over already paved or underutilized surfaces including parking lot canopies, brownfields, landfills, and rooftops. This should generate energy to supply 25% of the electricity and power use in the region in 2050.

The solar transition should prioritize expanding rooftop photovoltaics (PV) on residential, commercial, industrial, and municipal buildings. The development and encouragement of community solar opportunities will allow renters, multifamily households, and low-income residents to benefit from clean energy even if they cannot install panels on their own properties. Financial and technical support programs are key to enabling widespread adoption of solar energy. Solar energy may also be purchased and imported from solar producers outside of the region to meet the 2.77 TWh target.

Massachusetts currently ranks 10th in the nation for solar net generation, with solar accounting for 24% of the total in-state electricity net generation in 2023. Massachusetts is 13th in the nation for total installed solar capacity, which came in at 5,476.59 MW[63] In 2024.

### Key Objectives

- ⇨ Plan for, design, permit, construct, operate, and maintain new solar canopies over paved surfaces and brownfields. Connect the electricity generated from these facilities with the broader electricity grid. Support community solar development within the region and encourage enrollment in programs like Solarize Mass or other group-buy initiatives to reduce upfront costs for homeowners and small businesses.
- ⇨ Upgrade the regional electricity system to accommodate the intermittent nature of solar energy, including by using energy storage systems to store solar energy. Coordinate outreach and education efforts with local governments to raise awareness of solar opportunities and benefits and to support green workforce training programs in installation, maintenance, and solar system monitoring.

### Geographic Scope

As of 2023, rooftop solar accounts for 40 GW of Massachusetts' solar potential.[64] Development should avoid forested areas, prime agricultural land, and green space to preserve ecological integrity. Instead, solar siting should focus exclusively on rooftop, parking areas, and other underutilized areas within the Region. The urban and suburban areas of the Region have dense commercial and industrial corridors, municipal buildings, households, educational campuses, and large healthcare facilities which offer extensive rooftop space, as well as parking areas suitable for canopy systems. There are also several capped landfills and brownfields that present opportunities for solar redevelopment without encroaching on green space.

### Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, and NECCOG -** Coordinate regional siting efforts for solar on underutilized land. Support municipal planning, zoning, and permitting to help streamline adoption of solar. Organize public outreach and community engagement for equitable development of solar.

- ⇨ **Massachusetts Department of Energy Resources (DOER) and Connecticut Department of Energy and Environmental Resources (CT DEEP)** - Oversee renewable energy policy, incentive programs (e.g., SMART 3.0, CT Solar for All), and technical assistance for municipalities and regional organizations.
- ⇨ **Massachusetts Clean Energy Center (MassCEC)** - Provide funding, technical support, and data tracking for solar and other clean energy projects. Administer grants that enable local and regional planning organizations to pursue siting projects.
- ⇨ **Public Housing Authorities and the Massachusetts Department of Housing and Community Development (DHCD)** - Oversee public and affordable housing facilities, which can host rooftop solar projects. Help to make sure low-income households and renters can access clean energy.
- ⇨ **Municipal Light Plants, Electricity Distribution Companies, ISO New England** – Connect electricity generated by larger solar fields with customers through the electricity grid.
- ⇨ **CT Department of Energy and Environmental Protection Public Utilities Energy Authority** - Oversee the Residential Renewable Energy Solutions (RRES) Program that provides renewable energy tariffs to compensate residential solar owners for the addition of solar energy to the grid.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Secure plan approval and commitment from regional partners.
- ⇨ Begin and substantially complete rooftop solar installations across the region, including those on municipal buildings, public schools, and large commercial and industrial facilities; partner with municipal light plants on these installations where applicable.
- ⇨ Develop regional solar permitting guides and model zoning bylaws; assist municipalities in adopting streamlined solar permitting processes.
- ⇨ Apply for and secure federal and state funding (e.g., IRA tax incentives, SMART 3.0, MassCEC grants) to support accelerated rooftop deployment.
- ⇨ Launch outreach campaigns to promote residential solar incentives, group purchasing programs, and community solar enrollment opportunities.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Coordinate group procurement and shared solar programs to enable solar access for municipalities and residents without viable rooftops.
- ⇨ Conduct GIS-based solar suitability analyses to identify and prioritize underutilized land (e.g., brownfields, landfills) for solar development.
- ⇨ Prioritize new installations that include energy storage and/or deliver co-benefits to vulnerable communities.[65]

**Long Term Actions, Years 2040 – 2050**

- ⇨ Expand solar projects to multi-family housing, low-income neighborhoods, and public housing after responsible siting.
- ⇨ Prioritize large-scale brightfield development by installing solar arrays on capped landfills, decommissioned industrial sites, and other remediated contaminated lands, especially those previously identified as suitable through siting assessments.
- ⇨ Coordinate with state and federal agencies to address permitting, liability, and technical considerations associated with brightfield installations.
- ⇨ Complete final wave of solar installations to meet the 2.77 TWh generation target for 2050.

## Metrics for Tracking Progress

- ⇨ Number and capacity of solar projects at the planning, design, and permitting phase that plan to generate energy used in the Region, calculated by type (rooftop, canopy, brownfield, landfill, etc.) and as a regional total
- ⇨ Number of solar installations completed in the Region, calculated by type (rooftop, canopy, brownfield, landfill, etc.) and as a regional total
- ⇨ Total installed solar generation capacity (MW) in the Region
- ⇨ Annual solar energy generation (MWh or TWh) and percentage of the Region's electricity use sourced from solar energy
- ⇨ Percentage of the Region's solar-generated electricity that is stored at any one time at energy storage facilities
- ⇨ Number of Municipal Light Plant solar energy projects installed in the Region
- ⇨ Number of solar installations located in or serving vulnerable communities in the Region[66]

## Case Study

Syncarpha Capital, a Northeast-based developer, constructed a ballast-mounted solar facility on a 50-acre landfill in Tewksbury, Massachusetts, which began operations in February 2022. This "Solar Garden" is tapped into local National Grid-operated transmission systems and provides clean energy to the City of Everett, Massachusetts, Tufts University, and local residents on the National Grid lines through Syncarpha's Community Solar Program.

This brightfield development project has a 2.0 MW alternating current battery storage system, and all together produces enough energy to power 400 homes on a yearly basis. The PV modules are supported by concrete-mounted ballasts, which is integral to brightfield development as these kinds of ballasts do not pierce the cap of the landfill. Eligible Massachusetts residents receiving energy from National Grid can subscribe to this community solar project.[67]

*Figure 14. Ballast-Mounted Solar Array atop the Rocco Landfill, Tewksbury, MA*

## Quantified GHG Emission Reduction

The projected greenhouse gas emissions reduction totals from avoided use of fossil fuels as opposed to the business-as-usual scenario for the solar energy measure is 197,081 $MTCO_2e$ in 2030 and 308,677 $MTCO_2e$ in 2050.

### Measure Costs

~$88.2 Million

### Intersection with Other Funding Availability

- ⇨ Technical Assistance to Brownfields (TAB) Communities Program, US EPA
- ⇨ Clean Electricity Investment Tax Credit, US IRS
- ⇨ Clean Electricity Production Tax Credit, US IRS
- ⇨ RE-Powering America's Land Initiative, US EPA
- ⇨ InnovateMass Grant, MassCEC
- ⇨ Solar Massachusetts Renewable Target (SMART) 3.0 Program, MA DOER

## EGU2: Wind Power Generation

Power generation should be diverted away from fossil fuels through offshore wind energy production and the installation of onshore wind turbine systems. Onshore wind energy from both in-Region and out-of-Region sources should generate energy for 3.5% of electric power use in the Region in 2050. The Region should tap into offshore wind production from the northeast USA and eastern Canada to generate energy for 14.5% of its electric power use in 2050. Wind power should make up 18% of the total power utilized in the Region.

There are two main types of wind energy technology, onshore wind and offshore wind. Offshore wind is more productive than onshore wind due to more consistent high wind speeds occurring over the ocean than on land. However, it is also harder to site, construct, and operate than onshore wind because it can cause conflicts with other offshore uses and is more difficult to develop.[68]

Wind energy is an underutilized resource which has great potential to generate a large amount of the Region's energy mix. United States Energy Information Administration data shows that, as of 2023, wind energy made up 0.75% of Massachusetts' electric grid mix[69] and 0.02% of Connecticut's electric grid mix.[70]

### Key Objectives

- ⇨ Plan for, design, permit, construct, operate, and maintain new and expanded existing onshore wind generation facilities in the Region. Connect the electricity generated from these facilities with the broader regional electricity grid.
- ⇨ Coordinate with regional partners outside the Region to connect the regional energy grid with onshore and offshore wind generation facilities so that the Region can utilize power generated by these facilities. Support the planning, design, and permitting, as well as the construction, operation, and maintenance of these facilities.
- ⇨ Educate regional stakeholders and the public about the climate pollution reduction and co-pollutant emission reduction benefits of wind energy technology. In addition, educate regional stakeholders and the public about strategies for overcoming barriers to wind energy development and for preventing potential environmental and societal disbenefits of this technology.
- ⇨ Upgrade the regional electricity system to accommodate the intermittent nature of wind energy, including by using energy storage systems to store wind energy.

### Geographic Scope

An analysis from the United States Department of Energy and the National Renewable Energy Laboratory has shown that the hilly areas in the northern part of the Region, and especially the areas near Mount Wachusett, are the most suitable for the development of onshore wind power facilities.[71] There are six onshore wind facilities with nine turbines currently present in the Region.[72] There is also potential for the expanded use of out-of-Region onshore wind from areas with higher onshore wind potential in the Region; several municipal light plants in the Region currently procure power from the Berkshire Wind Power Project in Hancock, Massachusetts.[73]

There are two main offshore wind lease areas off the coast of New England. One of these areas is off the southeastern coast and includes the Massachusetts and Massachusetts-Rhode Island Wind

Energy Areas (WEAs). The other is the Gulf of Maine wind lease area off the eastern coast. Development of wind energy is at a more advanced state in the southeastern lease area, with several projects having already been built or being under construction, including the under-construction Vineyard Wind 1 project that will provide energy to Massachusetts and the under-construction Revolution Wind project that will provide energy to Connecticut as well as Rhode Island. Electricity generated from offshore wind projects in these lease areas will be distributed to the Region via underwater cables, through cable landings along the coast, and to the regional grid.[74] There is also potential for the Region to import offshore wind energy from Nova Scotia, Canada.[75]

## Implementation Authority and Responsibilities

- ⇨ **Municipal Light Plants and private landowners** – Provide the land for and, in the case of MLPs and some private landowners, the staff to operate and maintain onshore wind power facilities.
- ⇨ **Local governments** – Update zoning and permitting processes to streamline the construction of local onshore wind projects.
- ⇨ **Private wind energy companies** – Provide site planning, design, materials, and construction staff for onshore and offshore wind power facilities and assist with the maintenance of these facilities. Help connect electricity generated by offshore wind power facilities with customers through operating and maintaining offshore cables.
- ⇨ **CMRPC, MRPC, and NECCOG** – Provide broad-scale planning, educational initiatives, coordination, grant-writing, grant management, and/or procurement in support of onshore wind development in the Region and of tapping the Region into offshore wind electric power.
- ⇨ **Municipal Light Plants, Electricity Distribution Companies, and ISO New England** – Connect electricity generated by onshore and offshore wind power facilities with customers through the electricity grid.
- ⇨ **Agencies of the States of Massachusetts and Connecticut and the United States and Canadian Federal Government** – Provide necessary permitting, grant funding, and contracts for onshore and offshore wind projects.
    - State agencies involved in necessary permitting, grant funding, and contracts for onshore wind include **MassCEC, DOER, DPU, and DEEP**. The aforementioned state agencies as well as the **Massachusetts Office of Coastal Zone Management (CZM) and the Massachusetts Division of Marine Fisheries** are involved in necessary permitting, grant funding, and contracts for offshore wind.
    - United States federal agencies involved in necessary permitting, grant funding, and contracts for onshore wind include **the United States Department of Energy Wind Energy Technologies Office and Office of Energy Efficiency and Renewable Energy**. The aforementioned federal agencies as well as **the Bureau of Ocean Energy Management** are involved in necessary permitting, grant funding, and contracts for offshore wind.
    - Canadian federal agencies involved in necessary permitting, grant funding, and contracts for offshore wind include **Natural Resources Canada, the Canada Energy Regulator, and the Canadian Energy Center.**

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Convene a roundtable in the Region on the opportunities and challenges of onshore wind development.
- ⇨ Establish or enhance wind energy educational opportunities in the Region's high schools, trade schools, colleges, and universities.
- ⇨ Apply for and receive grant funding for the siting, design, permitting, and construction of a pilot new onshore wind facility or an expansion of an existing facility in the Region. Consider siting this facility in a municipal light plant community and providing its power to MLP communities. Include this project as part of a larger project that includes energy storage and resiliency benefits as well as benefits to vulnerable populations. Complete permitting for and begin construction of this facility.[76]
- ⇨ Utilizing the Massachusetts' Wind Energy Model Zoning Bylaw, collaborate to adopt wind energy zoning bylaws in communities across the region, prioritizing communities with high onshore wind capacity potential.[77]
- ⇨ Begin planning for the replacement of inefficient and technologically obsolete onshore wind turbines in the Region.
- ⇨ Coordinate to tap into electric power generated by the soon-to-be-completed Vineyard Wind 1 and Revolution Wind projects.
- ⇨ Coordinate to ensure that future offshore wind transmission agreements bringing power to the Region are finalized sooner in the offshore wind development process than they have in the past and include contingencies for issues such as price hikes and project delays.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Informed by the aforementioned pilot onshore wind project, develop additional onshore wind energy projects in the Region. Prioritize projects that include energy storage and resiliency benefits as well as provide benefits to vulnerable populations.[78]
- ⇨ Complete the replacement of inefficient and technologically obsolete onshore wind turbines in the Region.
- ⇨ Tap into onshore and additional offshore wind energy projects.
- ⇨ Coordinate storage of electricity produced by wind energy in energy storage facilities in the Region.
- ⇨ As the scale of onshore and offshore wind projects continues to grow, increase coordination between wind facility operators and energy distribution companies to more fully integrate wind-generated electricity into the grid.
- ⇨ Through regional collaboration, work to create more sustainable financing models for onshore wind energy projects that are not reliant on grant funding for individual projects.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Informed by previous projects, develop and tap into additional onshore wind energy projects to produce 0.39 TWh of electricity for the Region. Prioritize projects that include energy storage and resiliency benefits as well as provide benefits to vulnerable populations.[79]
- ⇨ Tap into additional offshore wind energy projects that provide 1.61 TWh of electricity for the Region.

## Metrics for Tracking Progress

- ⇨ Number of onshore and offshore wind projects at the planning, design, and permitting phase that plan to generate energy used in the Region, calculated separately and in total
- ⇨ Number of onshore and offshore wind turbines installed that generate energy used in the Region, calculated separately and in total

- ⇨ Percentage of the Region's electricity use which is sourced from onshore and offshore wind power, calculated separately and in total
- ⇨ Percentage of the Region's offshore and onshore wind-generated electricity that is stored at any one time at energy storage facilities, calculated separately and in total
- ⇨ Number of Municipal Light Plant wind energy projects installed in the Region
- ⇨ Number of onshore wind energy projects co-located with energy storage in the Region
- ⇨ Number of wind energy industry jobs in the Region
- ⇨ Number of wind industry jobs in vulnerable communities in the Region
- ⇨ Number of onshore wind energy projects located in vulnerable communities

## Case Study

Mount Wachusett Community College in Gardner, Massachusetts meets 100% of its yearly energy needs through energy produced by two 1.65 MW wind turbines and returns additional electricity these turbines generate back to the power grid. This wind energy project cost $9 million and was funded by United States Department of Energy grants and clean energy bonds. Learning about the turbines is integrated into the college's Natural Resources Technology program, and the turbines are a key pillar of the institution's commitment to sustainability.[80]

*Figure 15. The Mount Wachusett Community College Wind Turbines*

## Quantified GHG Emission Reduction

The projected greenhouse gas emissions reduction totals from avoided use of fossil fuels as opposed to the business-as-usual scenario for this wind energy measure are 52,555 $MTCO_2e$ in 2030 and 330,727 $MTCO_2e$ in 2050.

## Measure Costs

~$148.9 Million

## Intersection with Other Funding Availability

- ⇨ Wind Energy Technologies Office Funding Opportunities, US DOE
- ⇨ Office of Energy Efficiency and Renewable Energy Funding Opportunities, US DOE
- ⇨ Small Wind Turbines (Residential) Tax Credit, US EPA
- ⇨ Offshore Wind Works Grants and Community of Practice, MassCEC
- ⇨ Pooled Loan Program, Massachusetts Municipal Wholesale Electric Company (MMWEC)
- ⇨ Clean Energy Grants, Barr Foundation

## EGU3: Nuclear Power Generation

If proven feasible, one small-scale modular nuclear reactor should generate energy for 25% of electricity/power use in the Region in 2050. Small modular reactors (SMRs) are a new generation of nuclear reactors that can generate between 200 and 300 megawatts (MW) of power, depending on their design. These reactors are energy dense, as they have a lower spatial footprint (typically around a third of the size (or smaller) of typical nuclear power plants) and a high energy production potential. This makes them ideal in areas where large nuclear power plants are not feasible. They also use a range of coolants, including light water, liquid metal, or molten salt.[81] SMRs use nuclear fission reactions that generate heat that can be used to generate electricity. There is a higher interest in SMR technology globally as it has proven to be safer, more versatile, and has a smaller environmental footprint than other nuclear power programs.[82]

If an in-region SMR is deemed infeasible, or to supplement production, the Region should secure nuclear electricity from out-of-region sources to meet up to 25% of electricity demand by 2050. Imported nuclear energy would come from existing or planned facilities, especially those within the northeast region - Millstone Unit 3 in Connecticut (providing 40% of Connecticut's energy) and Seabrook Station in New Hampshire, partially owned by MMWEC and two Massachusetts municipal utilities.[83] MMWEC members are able to access this nuclear power in Joint Operating Agreements, where participating MLPs pay percentage share for the operating costs of nuclear facilities, gain entitlements to power for these payments, and get emissions-free energy certificates (EFECs). Importing nuclear energy from outside of the northeast may also be necessary to fill the gaps to meet up to 25% of the electricity demand.

### Key Objectives

- ⇨ Conduct a comprehensive feasibility study for siting and operating a small modular reactor (SMR) within the Region.
- ⇨ Coordinate with regional and federal authorities to secure permitting and grid integration.
- ⇨ Develop educational materials for stakeholders on the safety and climate benefits of SMR deployment.
- ⇨ Coordinate the Region to out-of-region nuclear generation through procurement agreements with ISO New England.
- ⇨ Identify and support any municipal utilities looking to expand nuclear power integration into their energy portfolios.
- ⇨ Educate municipalities, residents, and other stakeholders on the climate and grid reliability benefits of nuclear energy, and address safety and waste concerns.
- ⇨ Align nuclear integration efforts with decarbonization, energy storage, and climate resilience strategies at regional and state levels.

### Geographic Scope

An in-region SMR site would be identified through a regional siting and environmental study. Pending feasibility and regulatory approval, ideal locations would have existing transmission access, industrial zoning, and low environmental or population risk.

### Implementation Authority and Responsibilities

***Development of an in-Region SMR***

- ⇨ **CMRPC, MRPC, NECCOG** - Coordinate the regional feasibility study for siting the SMR, lead regional planning and coordination among the various stakeholders involved in the process, assist the municipalities involved with the regulatory processes, and provide technical assistance through grant-writing, grant management, and procurement of a SMR.
- ⇨ **DOER** - Help to assess the role of the SMR in achieving the Massachusetts greenhouse gas reduction goals, work with RPAs to develop policies and incentives to support SMR deployment, coordinate with the Executive Office of Energy and Environmental Affairs (EEA) and Governor's Office on potential legislative needs, and ensure that the SMR planning aligns with the State's Clean Energy and Climate Plan.
- ⇨ **CT DEEP** - Coordinate with Mass DOER; participate in regional infrastructure planning, transmission upgrades, and community engagement
- ⇨ **Nuclear Regulatory Commission (NRC)** - Serve as the sole licensing authority for the siting, construction, and operation of nuclear facilities, including SMRs, and conducts safety and environmental reviews, issues licenses and permits, and enforces emergency preparedness standards.
- ⇨ **Municipalities** - After proper siting and regulatory approval, the host municipality of the SMR should review and approve local zoning and land use permissions for SMR siting, coordinate with emergency management agencies such as MEMA and FEMA to develop a nuclear emergency response and evacuation plan and identify public infrastructure or land that can potentially support SMR development.

***Imported Nuclear Energy***

- ⇨ **ISO New England** - Plan and oversee the infrastructure needed to import nuclear power from out-of-region sources and ensure that it is reliably dispatched on the regional grid system.
- ⇨ **Electricity Distribution Companies and Municipal Light Plants** - Negotiate and enter power purchase agreements (PPAs), similar to those of the Taunton Municipal Light Plant and the Hudson Light & Power Department, with out-of-Region nuclear power through the local grid, and integrate nuclear energy procurement into local/municipal decarbonization goals.
- ⇨ **State Energy Offices and Governor's Energy Offices (MA, CT)** - Lead (or co-lead) interstate coordination on shared nuclear procurement strategies, namely Massachusetts's purchasing of a portion of Connecticut's Millstone Nuclear Power Plant.[84]

## Implementation Timelines and Milestones

### Short Term Actions, Years 2026 – 2030

***Development of an in-Region SMR***

- ⇨ Initiate early coordination with the Nuclear Regulatory Commission (NRC) and Massachusetts DOER to clarify regulatory timelines, licensing requirements, public participation opportunities, and potential permitting pathways for an SMR.
- ⇨ Collaborate with workforce development agencies and academic institutions in the Region to begin integrating nuclear energy, radiation safety, and SMR systems into curricula in the Region's high schools, trade schools, colleges, and universities.
- ⇨ Engage host municipalities, local emergency management agencies (such as MEMA), and vulnerable communities to identify potential sites and discuss zoning and emergency planning needs.

***Imported Nuclear Energy***

- ⇨ Assess the current level of imported nuclear power used by the Region by analyzing ISO New England data and consulting with municipal light plants, utilities, and state agencies.
- ⇨ Coordinate with out-of-region stakeholders, which would include the operators of Millstone (CT) and Seabrook (NH) to begin dialogue around new or expanded long-term power purchase agreements.
- ⇨ Distribute educational materials and host regional events

**Medium Term Actions, Years 2030 – 2040**

***Development of an in-Region SMR***

- ⇨ Based on the findings of the feasibility study and community input, select a preferred SMR site and finalize the siting, land acquisition, and permitting processes.
- ⇨ Secure project financing through DOE grants, or utility-backed investments.
- ⇨ Begin construction of an SMR facility. Start with site preparation, energy delivery, and transmission connection infrastructure.
- ⇨ Coordinate with regional emergency response planners (such as MEMA and NRC) to develop and simulate SMR-specific nuclear emergency preparedness and evacuation protocols.

***Imported Nuclear Energy***

- ⇨ Formalize procurement agreements with out-of-Region nuclear providers to target a combined portfolio of contracts to meet 25% of the Region's 2050 electricity demand.
- ⇨ Begin phased integration of imported nuclear power into the Region's grid.
- ⇨ Work with vulnerable communities to ensure equitable access to the benefits of imported nuclear electricity (e.g., lower rates, improved air quality).
- ⇨ Expand technical and policy capacity among the Region's utilities and planning departments to manage nuclear PPAs, integrate zero-carbon baseload power, and support decarbonization targets.
- ⇨ Establish a clean energy policy fellowship or internship program for students and early-career professionals to work on nuclear procurement and integration strategy.

**Long Term Actions, Years 2040 – 2050**

***Development of an in-Region SMR***

- ⇨ Conduct staged component testing of the SMR, including emergency response drills.
- ⇨ Finalize grid readiness coordination with ISO New England to support full SMR integration.
- ⇨ Host a regional energy roundtable to share lessons learned from construction and testing phases with other municipalities and planning agencies across the Northeast.
- ⇨ Complete full commissioning of the SMR and begin commercial operation, supplying 2.77 TWh of energy / 25% of the region's electricity demand.
- ⇨ Conduct evaluation of the SMR's performance, emissions reduction contribution, cost-effectiveness, and social and environmental outcomes.
- ⇨ Use findings to guide future SMR expansion or replication in other parts of the Region or state.

***Imported Nuclear Energy***

- ⇨ Increase the flow of imported nuclear electricity.
- ⇨ Continue grid and regulatory coordination to ensure reliable dispatch of imported nuclear energy without negatively impacting grid flexibility or peak management.
- ⇨ Conduct periodic stakeholder roundtables and technical audits to ensure that import agreements remain cost-effective, environmentally beneficial, and aligned with state energy strategies.
- ⇨ Scale up imported nuclear electricity to meet 100% of the 2050 target (25% of total Region demand) / 2.77 TWh of energy.

- ⇨ Publish a final performance evaluation of imported nuclear energy measures, including GHG reductions, ratepayer impacts, reliability improvements, and lessons learned.
- ⇨ Provide regional guidance for other RPAs or municipalities looking to replicate the procurement model used by the Region.

## Metrics for Tracking Progress

***Development of an in-Region SMR***

- ⇨ Completion of an SMR feasibility and siting study.
- ⇨ Permits issued for SMR siting and construction (local, state, federal)
- ⇨ Construction and operational milestones reached (such as groundbreaking, testing, commissioning)
- ⇨ Emergency preparedness and response plans developed and adopted.
- ⇨ Public outreach and community engagement and education sessions related to SMR development.

***Imported Nuclear Energy***

- ⇨ Percent of the Region's electricity supplied by imported nuclear energy.
- ⇨ Number and capacity (MW) of signed PPAs or contracts for imported nuclear power.
- ⇨ Number of the Region's communities or utilities participating in nuclear energy procurement.
- ⇨ Public outreach and community engagement and education sessions related to imported nuclear energy.

## Case Study

Ontario Power Generation (OPG) announced in 2023 that they are working with the Ontario Government in Canada and North Carolina based GE Hitachi Nuclear Energy to plan for, license and construct the first SMRs in a G7 country – a total of four reactors at the Darlington nuclear site in Ontario. The four SMR units are expected to produce up to 1200 MW altogether, which could power 1.2 million homes in the province. OPG is funding the project through its own assets, including cash on hand, cash flow from generating stations, and debt. The first unit, the BWRX-300, uses commercially available uranium to generate power, and is scheduled to be completed by 2028. The construction of the four units is anticipated to create up to 18,000 jobs and inject $500 million into Ontario's economy annually.[85] The Canadian Nuclear Safety Commission (CNSC)'s environmental protection review concluded that the potential risks from nuclear and hazardous releases into the atmospheric, terrestrial, aquatic, and human environments from the project site to be low to negligible.[86]

*Figure 16. The Construction Site of the Darlington New Nuclear Project in Ontario, Canada*[87]

### Quantified GHG Emission Reduction

The projected greenhouse gas emissions reduction totals from avoided use of fossil fuels as opposed to the business-as-usual scenario for this nuclear energy measure are 105,110 $MTCO_2e$ in 2030 and 459,343 $MTCO_2e$ in 2050.

### Measure Costs

~$225.6 Million

### Intersection with Other Funding Availability

- ⇨ Advanced Reactor Demonstration Program (ARDP), US DOE
- ⇨ Transmission Facilitation Program, US DOE
- ⇨ Generation III+ Small Modular Reactor Program, US DOE
- ⇨ Incentives for Transmission Projects, Federal Energy Regulatory Commission (FERC)
- ⇨ Title XVII Clean Energy Financing, US DOE
- ⇨ InnovateMass Grant, MassCEC

## EGU4: Energy Storage Systems

Diversion of power generation away from fossil fuels should be supported by installing energy storage systems and importing energy from existing energy storage systems, including battery and pumped hydro systems, that store power produced by intermittent renewable energy sources such as solar and wind. The goal is to store 5% of the region's power needs by 2050, reducing the reliance on external power.

Energy storage should continue to play a crucial role in the transition to net-zero greenhouse gas emissions in the Region, as the intermittent nature of solar and wind energy makes it vital to store energy from times of peak production to use during times of lower production.[88] As of February 15, 2025, 644 MWh of energy storage has been installed in Massachusetts, with almost 13,000 more MWh of energy storage planned to be installed in the state.[89]

Several different types of energy storage technologies have been developed. Energy storage technologies which have been implemented at a large-scale include pumped hydro, compressed air, and batteries using lithium-ion technologies and technologies using other chemistries. Other energy storage technologies at an earlier stage of technological development include flow batteries, thermal energy storage, flywheel technologies, hydrogen storage, and gravity energy storage.[90]

### Key Objectives

- ⇨ Plan for, design, permit, construct, operate, and maintain new and expanded energy storage facilities in the Region. Connect the electricity stored at these facilities with the broader regional electricity grid.
- ⇨ Coordinate with regional partners outside the Region to connect the regional energy grid with pumped hydro energy storage systems in western Massachusetts so that the Region can utilize power stored at these facilities. Support the continued operation and maintenance of these facilities.
- ⇨ Educate regional stakeholders and the public about the climate pollution reduction and co-pollutant emission reduction benefits of energy storage technology. In addition, educate regional stakeholders and the public about strategies for overcoming barriers to energy storage technology development and strategies for preventing potential environmental and societal disbenefits of this technology.
- ⇨ Make upgrades to the regional electricity system to accommodate increased amounts of energy storage in the Region.

### Geographic Scope

Different types of energy storage technologies have different geographic constraints, with pumped hydro and gravity energy storage technologies needing spaces with differences in elevation, compressed air energy storage technologies needing spaces such as caverns or former oil wells, and other energy storage technologies being more flexible in where they can be sited. The Region is not a good candidate to adopt compressed air energy storage due to having few caverns and former oil wells, and there are only a few areas in the Region such as Mount Wachusett where elevation changes are large enough for pumped hydro and gravity energy storage technologies to be viable options.[91]

There are several factors that will be especially important for regional stakeholders to consider when siting energy storage systems. These systems will lead to less energy transmission losses if they are sited near and work with clean energy generation facilities. These systems should not be sited in vulnerable communities when their energy storage, air quality, and resiliency benefits are outweighed by disbenefits.[92] And specifically in the case of battery storage systems, it will be important to site them in open-air spaces with a buffer between them and other critical infrastructure to minimize fire risks.[93]

There are seven currently operating battery storage facilities in the Region.[94] There are also two currently operating large-scale pumped hydro energy storage facilities in western Massachusetts,[95] and there is an opportunity for the Region to tap into these facilities' energy storage capacity.

### Implementation Authority and Responsibilities

- ⇨ **Municipal Light Plants and private landowners** – Provide the land for and, in the case of MLPs and some private landowners, the staff to operate and maintain energy storage facilities.
- ⇨ **FirstLight, Emera Energy, and Brookfield Power** – Provide the construction, operations, and maintenance staffing for the pumped hydro energy storage facilities in western Massachusetts.
- ⇨ **Local governments** – Update zoning and permitting processes to streamline the construction of local energy storage projects.
- ⇨ **Private energy storage companies** – Provide the site planning, design, materials, and construction staff for energy storage facilities and assist with the maintenance of these facilities.
- ⇨ **CMRPC, MRPC, and NECCOG** – Provide broad-scale planning, educational initiatives, coordination, grant-writing, grant management, and/or procurement in support of energy storage development in the Region. Also, provide broad-scale planning, educational initiatives, and coordination with stakeholders both within and outside of the Region in support of tapping the Region into electric power from pumped hydro energy storage facilities in western Massachusetts.
- ⇨ **Municipal Light Plants, Electricity Distribution Companies, and ISO New England** – Connect electricity from energy storage facilities, including in-region energy storage facilities and pumped hydro energy storage facilities in western Massachusetts, with customers through the electricity grid.
- ⇨ **Agencies of the States of Massachusetts and Connecticut and the United States Federal Government** – Provide necessary permitting, grant funding, and contracts for in-Region energy storage projects, for transmission lines to bring electricity from pumped hydro energy storage facilities in western Massachusetts to the Region, and for any needed upgrades to the western Massachusetts pumped hydro facilities to return them to their full capacity.
    - State agencies involved in necessary permitting, grant funding, and contracts for these in-Region energy storage projects as well as these new energy transmission lines for and upgrades to these pumped hydro energy storage facilities include **MassCEC, DOER, DPU, and DEEP**.
    - Federal agencies involved in necessary permitting, grant funding, and contracts for these in-region energy storage projects as well as for these new energy transmission lines for and upgrades to these pumped hydro energy storage facilities include **the**

**United States Department of Energy Office of Energy Efficiency and Renewable Energy**.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Develop additional energy storage projects in the Region and partner with municipal light plants on these projects where applicable. Consider public-private partnerships for battery storage projects which shield MLPs from the risks of new battery storage technologies not working as well as hoped. Prioritize projects that provide benefits to vulnerable populations.[96]
- ⇨ Replace inefficient and technologically obsolete energy storage facilities in the Region.
- ⇨ Begin coordinating with stakeholders both within and outside the Region, including fire departments, to work to reduce social and environmental disbenefits of the supply chains and operations of energy storage infrastructure.
- ⇨ Coordinate with stakeholders from outside the Region to complete a feasibility study for resuming the operations of the pumped hydro energy storage facilities in western Massachusetts at full capacity and tapping into electricity from these facilities, potentially through the construction of new electricity transmission lines.
- ⇨ Collaborate with stakeholders based in western Massachusetts to distribute educational materials in the Region and to the west about strategies for overcoming barriers to the resuming of full capacity operations at these pumped hydro energy storage facilities, tapping the MSA into electricity from these facilities, potentially through the construction of new transmission lines, and preventing potential environmental and societal disbenefits.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Informed by previous projects, develop additional energy storage projects in the Region. Prioritize projects that provide benefits to vulnerable populations.
- ⇨ As the scale of energy storage capacity in the Region continues to grow, increase coordination between energy storage facility operators, municipal light plants, and energy distribution companies to more fully integrate energy storage into the grid. Increase coordination to increase the capacity of the regional grid as it integrates power from pumped hydro energy storage facilities in western Massachusetts.
- ⇨ Informed by the results of the aforementioned feasibility study, coordinate with stakeholders based in western Massachusetts to begin working towards resuming full capacity operations at pumped hydro energy storage facilities and begin tapping into electricity from these facilities, potentially via new transmission lines. Collaborate with stakeholders based in western Massachusetts to ensure that they also benefit from the resuming of full capacity operations at these facilities.
- ⇨ Tap into power from pumped hydro energy storage facilities in western Massachusetts.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Informed by previous projects, develop additional energy storage projects to contribute to the 0.55 TWh of electricity sourced from energy storage used by the Region in 2050. Prioritize projects that provide benefits to vulnerable populations.[97]
- ⇨ Coordinate with stakeholders based in western Massachusetts to complete the resuming of full capacity operations at the pumped hydro energy storage facilities in western Massachusetts.

- ⇨ Tap into power from pumped hydro energy storage facilities in western Massachusetts to contribute to the 0.55 TWh of electricity sourced from energy storage used by the Region in 2050.

## Metrics for Tracking Progress

- ⇨ Number of energy storage projects at the planning, design, and permitting phase that plan to store energy in the Region
- ⇨ Number of energy storage projects installed that store energy in the Region
- ⇨ Percentage of the Region's electricity use / number of TWh of electricity which is stored prior to use
- ⇨ Number of energy storage industry jobs in the Region
- ⇨ Number of energy storage industry jobs in vulnerable communities in the Region
- ⇨ Number of energy storage projects located in vulnerable communities in the Region
- ⇨ Number of transmission line projects for distributing power from pumped hydro energy storage facilities in western Massachusetts to the Region at the planning, design, and permitting phase
- ⇨ Number of transmission lines distributing power from pumped hydro energy storage facilities in western Massachusetts to the Region
- ⇨ Percentage of the Region's electricity use and number of TWh of electricity sourced from pumped hydro energy storage facilities in western Massachusetts
- ⇨ Number of jobs in the Region supporting the transmission and use of power from pumped hydro energy storage facilities in western Massachusetts
- ⇨ Number of jobs in the Region supporting the transmission and use of power from pumped hydro energy storage facilities in western Massachusetts in vulnerable communities
- ⇨ Percentage of energy stored in the Region originally generated by renewable sources

## Case Study

Sterling, Massachusetts' Municipal Light Department installed a 2 MW / 3.9 MWh utility-scale battery storage system in 2016. This system has served as an example of a successful battery storage project that utility professionals from around the world learn from.[98]

*Figure 17. Sterling's battery storage system, which is located at the Sterling MLD's Chocksett Road Substation*[99]

## Quantified GHG Emission Reduction

The projected greenhouse gas emissions reduction totals from avoided use of fossil fuels as opposed to the business-as-usual scenario for this energy storage measure are 13,139 $MTCO_2e$ in 2030 and 91,869 $MTCO_2e$ in 2050.

## Measure Costs

~ $71.5 Million

## Intersection with Other Funding Availability

- ⇨ Energy Storage Demonstration and Pilot Grant Program, US DOE
- ⇨ Peak Demand Management Grant Program, MA DOER
- ⇨ Advancing Commonwealth Energy Storage, MassCEC,
- ⇨ Municipal Vulnerability Preparedness Action Grant, MA EEA
- ⇨ SMART Energy Storage Adder Incentives, MA DOER
- ⇨ Pooled Loan Program, MMWEC
- ⇨ Connecticut Energy Storage Solutions Program, CT Green Bank

## EGU5: Hydro-Power Solutions

Power generation should be diverted away from fossil fuels through the installation of additional hydropower and micro-hydropower systems that generate energy for 3.5% of electricity/power use in the region, using dams along rivers and old mill ponds as well as the flow of water from higher to lower elevations to generate electricity. The Region should also tap into hydropower from the broader region which generates energy for 18.5% of electricity and power use in the Region. Combined, hydropower should account for 22% of all power utilized in the region in 2050.

Hydroelectric power is a reliable source of clean energy that should play an important role in the Region's future net-zero energy mix. In-line hydropower, or hydropower generated by turbines which are in pipes that transfer water from high elevations to low elevations, and hydropower generated at dams should both see expanded utilization in the Region. The conversion of some existing non-powered dams to hydroelectric power dams should coincide with removing other non-powered dams to restore ecosystems. The environmental damages from the conversion of dams to hydroelectric power should be minimized,[100] in part through ensuring that new hydropower is certified by the Low Impact Hydropower Institute. United States Energy Information Administration data shows that, as of 2023, hydroelectric power made up 3.62% of Massachusetts' electric grid mix[101] and 1.15% of Connecticut's electric grid mix.[102]

In the 19th century, many dams were constructed along the Region's streams and rivers to power mills.[103] There is potential for several of these dams that are currently non-powered to be converted to hydropower and micro-hydropower dams that can generate energy to contribute to the net-zero transition.[104] The Region has begun to import energy from hydroelectric resources with more significant capacity in Quebec, Canada, and it will be important for the Region to increasingly tap into this source to meet its greenhouse gas emissions reduction goals.[105]

### Key Objectives

- ⇨ Plan for, design, permit, construct, operate, and maintain new and expanded hydropower and micro-hydropower facilities which receive low impact hydropower certification at existing dams and sites with the potential for in-line hydropower. Avoid building new dams or expanding the geographic impacts of existing dams as part of this strategy. Connect the electricity generated from these facilities with the broader regional electricity grid.
- ⇨ Coordinate with regional partners outside the Region to enhance the connection of hydropower generated outside of the Region, especially in Quebec, Canada, to the regional energy grid so that the Region can utilize this power. Support the continued operation and maintenance of these facilities and the reduction of societal and environmental disbenefits of these facilities.
- ⇨ Educate regional stakeholders and the public about the climate pollution reduction and co-pollutant emission reduction benefits of hydroelectric technology. In addition, educate regional stakeholders and the public about strategies for overcoming barriers to hydroelectric energy development and strategies for preventing potential environmental and societal disbenefits of this technology.
- ⇨ Make upgrades to the regional electricity system to accommodate increased amounts of electricity being sourced from hydropower.

## Geographic Scope

Existing non-powered and powered dams are most suitable for the development of hydropower and micro-hydropower facilities which minimize detrimental environmental impacts. There are two in-line hydropower facilities, two powered dams, and three non-powered dams with over 1 MW of energy production capacity in the Region.[106]

Hydropower facilities in Quebec are located across the northern part of the province, with older facilities being concentrated to the northwest near the James Bay, and several newer facilities having been built further to the east in the Côte-Nord region. Currently, and increasingly under this strategy, electricity generated from Quebec hydropower is distributed to the Region via the Quebec grid, through the grid in northern New England, and to the regional grid.[107] There is also potential for the expanded use of domestic out-of-Region hydropower from areas with higher hydroelectric capacity in the Region; several municipal light plants in the Region currently procure power from hydroelectric plants in other parts of the northeast USA.

## Implementation Authority and Responsibilities

- ⇨ **Dam owners** – Grant approval for hydroelectric development or expansion at their dams and assist with operating and maintaining hydropower and micro-hydropower facilities.
- ⇨ **In-line hydropower facility owners** - Grant approval for hydroelectric development or expansion at their facilities and assist with operating and maintaining hydropower and micro-hydropower facilities.
- ⇨ **Local governments** – Update zoning and permitting processes to streamline the construction of local hydropower and micro-hydropower projects.
- ⇨ **Private hydropower companies** – Provide the site planning, design, materials, and construction staff for in-Region hydroelectric power facilities and assist with the maintenance of these facilities.
- ⇨ **CMRPC, MRPC, and NECCOG** – Provide broad-scale planning, educational initiatives, coordination, grant-writing, grant management, and/or procurement in support of hydropower and micro-hydropower development. Also, provide broad-scale planning, educational initiatives, and coordination with stakeholders both within and outside of the Region in support of tapping into hydroelectric power from Quebec.
- ⇨ **Low Impact Hydropower Institute** – Certify hydropower facilities in the Region as low impact hydropower facilities.
- ⇨ **Municipal Light Plants, Electricity Distribution Companies, ISO New England, and Hydro-Quebec** – Connect electricity generated by in-region hydropower and micro-hydropower facilities and Quebec hydropower facilities with customers through the electricity grid.
- ⇨ **Agencies of the States of Massachusetts, Connecticut, Maine, Vermont, and New Hampshire and the Province of Quebec and the United States and Canadian Federal Governments** – Provide necessary permitting, grant funding, and contracts for in-region hydropower and micro-hydropower projects, provide necessary permitting and contracts for transmission lines to bring hydropower from Quebec to the Region and, in the case of Hydro-Quebec, provide the operations and maintenance staffing for hydropower facilities in Quebec.
    - State agencies involved in necessary permitting, grant funding, and contracts for these hydroelectric power facilities and necessary permitting, grant funding, and contracts for these transmission lines include **MassCEC, DOER, DPU, DEEP,**

**including** (in the case of in-region hydropower facilities) **DEEP's Dam Safety Regulatory Program, the Maine Public Utilities Commission (MPUC), the Maine Department of Energy Resources, the Vermont Public Utility Commission, the Vermont Department of Public Service, the New Hampshire Public Utilities Commission (NHPUC), and the New Hampshire Department of Energy**.

- United States federal agencies involved in necessary permitting, grant funding, and contracts for these hydroelectric power facilities and necessary permitting, grant funding, and contracts for these transmission lines include **the United States Department of Energy Office of Energy Efficiency and Renewable Energy, the Federal Energy Regulatory Commission (FERC), and** (in the case of in-region hydropower facilities) **the Federal Emergency Management Agency's National Dam Safety Program (FEMA NDSP)**.
- Province of Quebec agencies involved in necessary permitting, grant funding, and contracts for these transmission lines include **the Quebec Energy Board and Hydro-Quebec**. Hydro-Quebec will also provide the operations and maintenance staffing for hydropower facilities in Quebec that the Region taps energy from.
- Canadian federal agencies involved in necessary permitting, grant funding, and contracts for these transmission lines include **the Canada Energy Regulator and the Canadian Energy Center**.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Apply for and receive grant funding for the design, permitting, and construction of a pilot hydropower or micro-hydropower facility or an expansion of an existing facility in the Region. Consider siting this facility in a municipal light plant community and providing its power to MLP communities. Incorporate measures to benefit vulnerable populations as part of this project and ensure that this project receives low impact hydropower certification. Complete permitting of and begin construction of this facility.[108]
- ⇨ Coordinate to tap into additional Quebec-sourced and northern New England-sourced hydropower via new transmission lines, such as the planned New England Clean Energy Connect transmission line, which are planned to be completed in this timeframe. Collaborate with stakeholders in northern New England to increase these states' benefits from transmission lines distributing this hydropower and therefore their buy-in for these transmission lines.
- ⇨ Begin collaboration with stakeholders in Quebec and domestically to ensure that First Nations and Native American residents of the areas around dams from which hydroelectric power is sourced are fairly compensated for environmental and social disbenefits of these dams on their communities and are given fair and priority opportunities to benefit economically from hydropower production.
- ⇨ Plan for a power-sharing process under which the Region sends solar and wind power from times of peak production and lower demand to Quebec and northern New England; this process will allow Quebec and northern New England hydropower producers to store water during times of drought, which will be increasingly important with climate change increasing the frequency and severity of drought occurrences in the Province.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Informed by the aforementioned pilot hydropower or micro-hydropower project, develop additional hydropower and micro-hydropower projects in the Region. Prioritize projects that

provide benefits to vulnerable populations and ensure that these projects receive low impact hydropower certification.

- ⇨ As the scale of domestic hydroelectric projects and Quebec-sourced hydropower being imported to the Region continue to grow, increase coordination between hydropower and micro-hydropower facility operators, including Hydro-Quebec, energy distribution companies, and ISO New England to more fully integrate hydroelectricity into the grid.
- ⇨ Through regional collaboration, work to create more sustainable financing models for hydropower and micro-hydropower projects that are not reliant on grant funding.
- ⇨ Tap into additional Quebec-sourced and out-of-Region domestic hydropower.
- ⇨ Implement the power-sharing process between the Region and Quebec which was planned for between 2026-2030.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Informed by previous projects, develop additional hydropower and micro-hydropower projects to contribute to the 2.44 TWh of hydroelectricity used by the Region in 2050. Prioritize projects that provide benefits to vulnerable populations and ensure that these projects receive low impact hydropower certification.
- ⇨ Tap into additional Quebec-sourced and out-of-Region domestic hydropower to contribute to the 2.44 TWh of hydroelectricity used by the Region in 2050.

## Metrics for Tracking Progress

- ⇨ Number of hydropower and micro-hydropower projects at the planning, design, and permitting phase that plan to generate energy in the Region
- ⇨ Number of hydropower and micro-hydropower projects installed that generate energy in the Region
- ⇨ Number and percentage of hydropower and micro-hydropower projects installed that generate energy in the Region and have received low impact hydropower certification
- ⇨ Percentage of the Region's electricity use and the number of TWh of electricity which is sourced from in-Region hydropower and micro-hydropower
- ⇨ Number of non-powered dam conversion to hydroelectric dam projects completed in the Region
- ⇨ Number of hydroelectric industry jobs in the Region
- ⇨ Number of hydroelectric industry jobs in vulnerable communities in the Region
- ⇨ Number of in-Region hydropower and micro-hydropower projects located in vulnerable communities
- ⇨ Number of transmission line projects for distributing hydropower from Quebec and northern New England to the Region at the planning, design, and permitting phase
- ⇨ Number of transmission line projects distributing hydropower from Quebec and northern New England to the Region installed
- ⇨ Percentage of the Region's electricity use and the number of TWh of electricity which is sourced from Quebec and out-of-Region domestic hydropower
- ⇨ Number of jobs in the Region supporting the transmission and use of hydropower sourced from Quebec and domestically from outside the Region
- ⇨ Number of jobs in the Region supporting the transmission and use of hydropower sourced from Quebec and domestically from outside the Region in vulnerable communities

## Quantified GHG Emission Reduction

The projected greenhouse gas emissions reduction totals from avoided use of fossil fuels as opposed to the business-as-usual scenario for this hydroelectric power measure are 65,694 $MTCO_2e$ in 2030 and 404,222 $MTCO_2e$ in 2050.

## Measure Costs

~$132.5 Million

## Intersection with Other Funding Availability

- ⇨ Hydroelectric Production Incentive Program, US DOE
- ⇨ Maintaining and Enhancing Hydroelectricity Incentives, US DOE
- ⇨ Disaster Supplemental Grant Program, US EDA
- ⇨ Commonwealth Hydropower, MassCEC

## Electricity Sector Cross-Cutting Implementation Timeline and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Coordinate with federal, state, and local stakeholders to complete comprehensive feasibility studies which include assessments of siting, suitability, safety protocols, environmental and social impacts, transmission integration potential, and emergency preparedness for the expansion of clean energy technologies (including the powering of non-powered dams) in the Region:
- ⇨ Complete a report or reports and a series of roundtables on the performance of the currently existing clean energy facilities in the Region, highlighting any challenges that they have faced and strategies for overcoming these challenges as well as opportunities for expanding the electricity production at these facilities.
- ⇨ Create and distribute educational materials about strategies for overcoming barriers to clean energy development and strategies for preventing potential environmental and societal disbenefits of clean energy throughout the Region, with focuses on SMRs and imported nuclear energy, reducing fire risks from battery storage facilities, and transmission line development.
    - Include campaigns focused on the climate, safety, reliability, cost, and economic development benefits of clean energy, along with discussion of waste, resource usage, governance, energy transmission, and accident risk, in this outreach.
- ⇨ Establish a regionwide clean energy dashboard.
- ⇨ Establish a regionwide energy savings and efficiency educational and tracking initiative to aid the clean energy transition. This initiative will lead to a reduction in electricity use and therefore a reduction in new electrical system infrastructure which will need to be built.
- ⇨ Launch awareness and training programs for clean energy sector career pathways, including in both generation and transmission, in high schools, trade schools, colleges, and universities in the Region.
- ⇨ Begin discussions with ISO New England, private utilities, MLPs and grid transmission operators and experts for increased energy imports in the region and transmission system readiness.
- ⇨ Begin identifying new long-term clean energy procurement opportunities for the Region.
- ⇨ Begin coordinating with stakeholders, both within and outside of the region, to reduce potential environmental benefits and disbenefits of the supply chains and operations of clean energy technology.
- ⇨ Coordinate with power suppliers in the Region to plan for the replacement of paying for RECs (renewable energy certificates) and EFECs (emission-free energy certificates), by which power suppliers take sole credit for the carbon offsets of specific clean energy production, with the direct procurement of clean energy.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Establish technology-specific training hubs for solar installation, wind energy, hydropower, energy storage & pumped hydro, transmission operation management, and nuclear power.
- ⇨ Formalize long-term clean energy procurement agreements; make substantial progress on the replacement of the utilization of RECs and EFECs by power suppliers in the Region with the direct procurement of clean energy.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Achieve full sector targets and complete final buildout towards 2050 generation goals.
- ⇨ Conduct evaluations of energy reliability, performance, and flexibility.
- ⇨ Achieve full grid integration across all technologies.

- ⇨ Complete the replacement of the utilization of RECs and EFECs by power suppliers in the Region with the direct procurement of clean energy.
- ⇨ Host regional roundtables presenting lessons learned. Publish performance evaluations for each technology.

## Benefits Analysis: Electricity Generation and Use

The measures included in this chapter have many co-benefits for the Region other than direct greenhouse gas emissions reductions that mitigate the Region's impact on global climate change.

All five of this plan's electricity sector measures will have the co-benefits of indirectly improving public health outcomes in the Region. Their implementation will lead to a reduction in emissions of co-pollutants detrimental to people's health which are released into the atmosphere and which spread locally when electricity is generated from fossil fuels. Specifically, the co-pollutants emissions reductions that these measures will lead to include the following.

*Table 11. Electricity Generation and Use Co-Pollutant Reductions*

| Measures | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|
| EGU 1: Solar Power Generation | 122 MT | 290 MT |
| EGU 2: Wind Power Generation | 32 MT | 209 MT |
| EGU 3: Nuclear Power Generation | 65 MT | 290 MT |
| EGU 4: Energy Storage Systems | 8 MT | 58 MT |
| EGU 5: Hydro-Power Solutions | 41 MT | 255 MT |

All five electricity sector measures will also lead to direct job creation co-benefits, as the construction and operation of new electricity generation and transmission infrastructure will require many new jobs for residents of the Region.[109] The Solar Power Generation and Energy Storage Systems measures will lead to direct climate resilience if the infrastructure they lead to is built in ways that they can be tapped into as back-up power in the case of severe weather events.[110] All five measures will lead to indirect climate resilience co-benefits. They will contribute to the mitigation of climate change which can in turn reduce the frequency and severity of severe weather events and therefore the climate resilience investment that will be needed. The Solar Power Generation measure will lead to direct energy cost savings for solar facility owners that are able to sell extra electricity that their facilities produce back to the grid.[111] All five measures may lead to indirect energy cost savings for energy consumers if they are incentivized by governments and/or the cost of the production of clean energy infrastructure technology decreases as this technology is more widely adopted.

There are several potential disbenefits of these measures that regional stakeholders should aim to minimize as the measures are implemented. These potential disbenefits include land clearing for the construction of solar facilities, detrimental impacts on marine environments and industries of offshore wind, radioactive waste and accident risk from nuclear facilities, fires sparked at battery storage facilities, environmental damages caused by hydroelectric power production, and detrimental impacts on vulnerable communities.

*Table 12. Electricity Generation and Use Co-Benefits Summary*

| Measures | Improved public health outcomes | Job creation | Improved climate resilience | Decreased energy costs |
|---|---|---|---|---|
| EGU 1: Solar Power Generation | x | x | x | x |
| EGU 2: Wind Power Generation | x | x | x | x |
| EGU 3: Nuclear Power Generation | x | x | x | x |
| EGU 4: Energy Storage Systems | x | x | x | x |
| EGU 5: Hydro-Power Solutions | x | x | x | x |

# Electricity Generation and Use Endnotes

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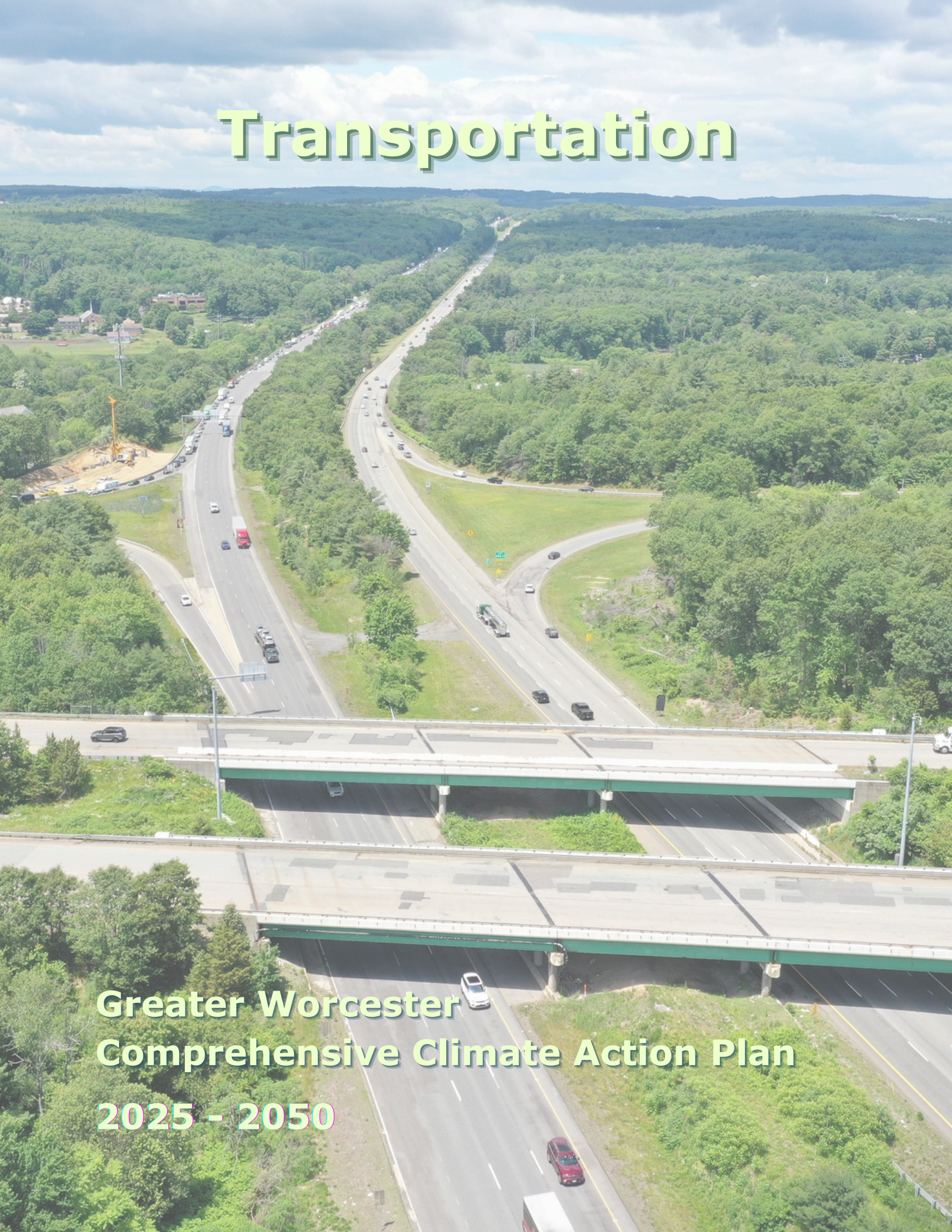
# Transportation



## Greater Worcester Comprehensive Climate Action Plan

2025 - 2050

## 3.3 Transportation

The transportation sector encompasses the movement of people, goods, and services throughout the Greater Worcester Region. The main modes of travel in the region include passenger, commercial, and municipal vehicles, as well as commuter rail, public transit, and active transportation. A complementary network of transportation modes is necessary for residents in the Region to access where they live, work, shop, play, and more.

Transportation is the second largest emitting sector in the Region, accounting for 39% of emissions. More than three quarters of GHG emissions from this sector are a result of internal combustion engine vehicle (ICEV) fuels in passenger vehicles. As a result, the pollutants (i.e., methane and nitrous oxide) emitted contribute to poor air quality and negative health impacts, like asthma. This is particularly true for those in the Region living in LIDAC communities, both rural and urban, who have disproportionally borne the environmental and health burdens associated with historical and present transportation planning. Passenger vehicle emissions are followed by commercial vehicles, rail, and municipal vehicles, respectively.

To reduce emissions in the transportation sector, the measures follow two key themes:

1. Shifting away from personal vehicle trips to alternative, cleaner modes of transportation (i.e., transit and active transportation).
2. Converting ICEV vehicles to alternative fuel vehicles (i.e., electric vehicles) and building out a strong charging infrastructure network.

*Table 13. Transportation Sector Measure Summary Table*

| Measures | GHG Emission Reductions in 2030 Compared to the BAU ($MTCO_2e$) | GHG Emission Reductions in 2050 Compared to the BAU ($MTCO_2e$) | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|---|---|
| T1: Bicycle and Pedestrian Improvements | 133,323 | 266,646 | 15,967 | 19,937 |
| T2: Expand and Improve Public Transit | 3,155 | 15,829 | 3 | 8 |
| T3: Alternative Fuel Charging Infrastructure | 521,092 | 959,370 | 7,956 | 8,283 |
| T4: Adoption of Zero-Emission Light-Duty Vehicles | 3,971 | 22,466 | 33.3 | 112.7 |
| T5: Adoption of Zero-Emission Medium- and Heavy-Duty Vehicles | 2,196 | 11,477 | 8 | 21.8 |

## T1: Bicycle and Pedestrian Improvements

In most of the Region, daily use of a personal vehicle is an essential part of life. Aside from urban areas, most development patterns require cars to get around. Poor multi-modal infrastructure and a lack of holistic planning create an unhealthy environment, turning residents away from walking and biking in their communities. A key component to emissions reduction from the transportation sector is significant improvement to bicycle and pedestrian infrastructure, which achieves reductions in vehicle miles traveled (VMT).[112] The 2018 CMMPO Regional Bicycle Plan highlighted several "problem corridors" for their publicly perceived lack of safety or inability to accommodate non-motorized travel.[113]

Expanding and improving bicycle and pedestrian infrastructure to be safer, more accessible, and well-connected will help reduce car dependency and lead to reduced GHG emissions, increased health benefits, and more economic opportunities. Multi-modal transportation networks should be planned on both a regional and local scale to enable the movement of people within and across the Region and to provide access to residents' needs (i.e., jobs, resources, or services).

### Case Study: MassBike E-Bike Program

Starting as just an experimental program in Worcester, MA in 2022, the MassBike E-Bike Program moved about 100 residents nearly 50,000 miles in one year! Funded by a grant from the Massachusetts Clean Energy Center (MassCEC), the non-profit, MassBike, distributed e-bikes to participants from a variety of backgrounds and income levels, including students, retirees, and working people. All participants were able to keep the e-bikes but would need to share their riding data with MassBike. According to the data, the riders traveled mostly to get to work, followed by recreational and shopping destinations. While the winter months showed a decrease in ridership, it didn't necessarily show a barrier, as the month with the most trips was November. In addition to ridership and mileage, the program also showed how a shift to e-bikes can reduce emissions. During this program, riders saved about 26,000 pounds of carbon dioxide (CO2).[114]

### Key Objectives

- ⇨ Identify gaps and areas for improvement and development in the regional bicycle and pedestrian networks through the use of maps and other tools
- ⇨ Expand and improve regional bicycle and pedestrian networks, including e-bike and bike-share programs; bike parking infrastructure (i.e. bike racks, public bike parking, and transit bike parking); shared-use paths for first- and last-mile trips; and wayfinding signage
- ⇨ Education residents about the basics of riding bicycles, including how to ride, commuting, bike maintenance, and more – encouraging the use of bicycles over cars
- ⇨ Develop maps and other interactive tools for communities to identify areas for improvement and development in their municipality

### Geographic Scope

For this measure, while multi-modal transportation can be developed, expanded, and improved anywhere and everywhere, it is particularly important to focus on denser, urban areas. Specifically, near transit stops, along key corridors, and where safer or upgraded infrastructure is needed.

## Implementation Authority and Responsibilities

- ⇨ **Municipalities** – Apply for grants (i.e. Complete Streets); implement bicycle and pedestrian projects; install bike racks and bike facilities; install and improve wayfinding/signage; implement shared-use path projects; implement provision of policies and ordinances to support the expansion of mobility options; educate residents on positive impacts of bicycle and pedestrian infrastructure and development.
- ⇨ **CMRPC, MRPC, and NECCOG** – Assist communities in grant applications; support the implementation of e-bike and bike-share programs; help identify and plan bicycle and pedestrian improvements; identify locations for new bike racks and bike facilities; identify locations for shared-use paths; implement a region-wide wayfinding signage plan/program; develop interactive maps or applications to complement wayfinding efforts and other planning efforts (i.e. infrastructure locations or projects); complete or update Regional Bicycle and Pedestrian Plans.
- ⇨ **CMMPO and MMPO** – Advance funding mechanisms to complete regionally-based bicycle and pedestrian projects
- ⇨ **State (MassDOT, CTDOT, DCR)** – Support local communities in the implementation of a priority network (bicycle and pedestrian infrastructure).
- ⇨ **WRTA, MART, NECTD, and MBTA** – Install bike racks on buses; install bike facilities at hubs; improve pedestrian/bicycling access to transit routes.
- ⇨ **Private Property Owners** – Install bike racks and bike facilities; implement transportation demand management (TDM) strategies.
- ⇨ **Employers/Large Employers** – Incentivize commuter-reduction programs; provide incentives to promote biking to work or other form of active transportation.
- ⇨ **Community-Based Organizations/Non-Profits** – Implement and fund e-bike and bike-share programs.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Map the existing system of bicycle and pedestrian infrastructure in the Region.
- ⇨ Identify gaps in the bicycle and pedestrian infrastructure in the Region.
- ⇨ Identify opportunities for e-bike and bike-share programs.
- ⇨ Identify locations for bike facility improvements.
- ⇨ Identify opportunities for wayfinding improvements.
- ⇨ Explore opportunities to work with private property owners and employers to implement TDM and incentives.
- ⇨ Install bike facilities for new or existing transit vehicles and transit hubs.
- ⇨ Complete the CMMPO Regional Bicycle and Pedestrian Plans.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Implement local or regional e-bike and bike-share programs.
- ⇨ Install bike facilities across the Region.
- ⇨ Install and update consistent wayfinding across the Region.
- ⇨ Install and update new bicycle and pedestrian infrastructure to the built environment (i.e. separated bike lanes).
- ⇨ Collaborate with private property owners and employers to implement TDM strategies, install bike facilities, incentivize commuter-reduction programs, and incentivize biking to work or other modes of transportation.

- ⇨ Continue installing bike facilities to new or existing transit vehicles and transit hubs.
- ⇨ Update CMMPO Bicycle and Pedestrian Plans, as needed.
- ⇨ Implement shared-use paths projects.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Continue to implement local or regional e-bike and bike-share programs.
- ⇨ Continue to install or update bike facilities across the region.
- ⇨ Continue to install and update new bicycle and pedestrian infrastructure to the built environment (i.e. separated bike lanes).
- ⇨ Continue to collaborate with private property owners and employers to implement TDM strategies, install bike facilities, incentivize commuter-reduction programs, and incentivize biking to work or other modes of transportation.
- ⇨ Continue installing bike facilities to new or existing transit vehicles and transit hubs.
- ⇨ Update CMMPO Bicycle and Pedestrian Plans, as needed.
- ⇨ Continue to implement shared-use paths projects.

## Metrics for Tracking Progress

- ⇨ Miles of sidewalks and bike lanes improved or installed
- ⇨ Number of e-bike and bike-share users
- ⇨ Number of new or continued funding of e-bike and bike-share programs
- ⇨ Number of bike racks and bike facilities installed
- ⇨ Number of Safe Streets and Roads for All (SS4A) or Complete Streets grants approved

## Quantified GHG Emission Reduction

The quantified GHG emission reductions are 133,323 $MTCO_2e$ in 2030 and 266,646 $MTCO_2e$ in 2050. To reach these conclusions, data from the Greater Worcester Regional GHG Inventory for 2022 was used to calculate a reduction in VMT of passenger gasoline vehicles that could be associated with the elements described in the measure. It was assumed that VMT would be reduced by 5% by 2030 and 10% by 2050.

## Measure Costs

~$115.8 Million

## Intersection with Other Funding Availability

- ⇨ SS4A Grant Program, US DOT
- ⇨ Safe Routes to School (SRTS) Program, US DOT
- ⇨ Congestion Mitigation and Air Quality (CMAQ) Improvement Program, US DOT
- ⇨ Better Utilizing Investments to Leverage Development (BUILD) Grant Program, US DOT
- ⇨ Active Transportation Infrastructure Investment Program (ATIIP), US DOT
- ⇨ Complete Streets Program, MA DOT
- ⇨ Shared Streets and Spaces Grant Program, MA DOT
- ⇨ Municipal Vulnerability and Preparedness (MVP) Program, MA EEA
- ⇨ Massachusetts Statewide Electric Bicycle Incentive Program, MA DOT
- ⇨ Complete Streets Program, CT DOT

## T2: Expand and Improve Public Transit

Improving and expanding public transit and passenger rail reduces reliance on personal vehicle usage, which currently accounts for approximately 81% of the transportation sector's emissions, and reduces gasoline consumption.[115][116] Public transit and passenger rail improvements and expansions in underserved areas of the region also help to increase access to services, resources, and economic opportunities. Fare-free public transit improves access to transportation for low-income residents and people without cars, while at the same time increasing overall ridership, as shown by the Worcester Regional Transit Authority (WRTA) fare-free program. Investments to develop and expand passenger rail, like Massachusetts Bay Transportation Authority (MBTA), Compass Rail and Northern Tier, will enhance connectivity for users traveling within and outside of the Region.

### Key Objectives

- ⇨ Expand and electrify the transit network, including transit buses, Council on Aging (COA) transportation services, Micro-Transit (i.e., VIA), and intercity bus services (i.e. Peter Pan and Greyhound)
- ⇨ Begin or continue to fund fare-free public transit system
- ⇨ Implement a Bus Rapid Transit (BRT) system in the City of Worcester
- ⇨ Improve and enhance Union Station
- ⇨ Continuing development of MBTA, Compass Rail, and Northern Tier passenger rail systems in the Region

***Example of Success in the Region***

*WRTA Fare Free Program*

Since March 2020, WRTA has transitioned to a fare-free system. Currently, it is expected to continue through June 2026. Through the funding of fare-free service, WRTA ridership has been higher than it's ever been. This program allows residents to have access to affordable public transit opportunities while helping to lower transportation emissions by reducing VMT.[117]

### Geographic Scope

For this measure, while public transit can be developed, expanded, and improved anywhere and everywhere, it is particularly important and should be focused on denser areas, currently underserved areas, and areas not served by any transit options. More specifically, micro-transit and COA transit should focus on expanding geographic scope. Intercity transit should continue to focus on its service areas and consider expanding its scope to service more customers. Passenger rail service should focus on development while considering the location of ideal stops.

### Implementation Authority and Responsibilities

- ⇨ **Municipalities** – Fund the expansion and electrification of COA vehicles.
- ⇨ **CMRPC, MRPC, and NECCOG** – Support the municipalities, transit authorities, and MBTA in their planning decisions.
- ⇨ **CMMPO and MMPO** – Advance funding mechanisms to complete regionally-based transit projects.
- ⇨ **WRTA, MRTA, and NECTD** – Fund fare-free public transit services; electrify public transit vehicles and micro-transit; expand and electrify COA vehicles; fund improvements and

enhancements of Union Station; and work with MBTA and the state on passenger rail developments.

- ⇨ **MBTA** – Fund and develop MBTA passenger rail systems in the Region.
- ⇨ **MassDOT** – Develop MBTA, Compass Rail, and Northern Tier passenger rail systems in the Region.
- ⇨ **Peter Pan, Greyhound, and other Private Entities** – Electrify and expand transit services in the Region.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Fund fare-free public transit services.
- ⇨ Identify funding to convert to fare-free public transit services.
- ⇨ Identify improvements and enhancements to be made to Union Station.
- ⇨ Replace current or purchase new COA vehicles with EVs.
- ⇨ Purchase electric public transit buses to replace fleet.
- ⇨ Complete a BRT feasibility study for the City of Worcester. This could include four phases:
    - Phase 1 – Existing conditions review
    - Phase 2 – Stakeholder engagement
    - Phase 3 – BRT vision, goals, and objectives
    - Phase 4 – Corridor/network evaluation

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Use the results of the BRT feasibility study to begin development of the BRT system in the City of Worcester.
- ⇨ Continue to replace current COA vehicles with EVs and purchase new vehicles with EVs.
- ⇨ Fund fare-free public transit services.
- ⇨ Implement improvements and enhancements to Union Station.
- ⇨ Continue to purchase electric public transit buses to replace fleet.
- ⇨ Make improvements to the MBTA rail system in the Region.
- ⇨ Make improvements to the Compass Rail and Northern Tier passenger rail system in the Region.
- ⇨ Electrify intercity bus services (i.e. Peter Pan and Greyhound) transit services and look to expand services.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Complete the BRT system in Worcester.
- ⇨ Fully electrify and expand COA services.
- ⇨ Fund fare-free public transit services.
- ⇨ Implement improvements and enhancements to Union Station.
- ⇨ Continue to purchase electric public transit buses to replace fleet.
- ⇨ Continue to make improvements to the MBTA rail system in the Region.
- ⇨ Continue to make improvements to the Compass Rail and Northern Tier passenger rail system in the Region.
- ⇨ Continue to electrify Peter Pan transit services and look to expand services.
- ⇨ Continue to electrify Greyhound transit services and look to expand services.

## Metrics for Tracking Progress

- ⇨ Reduce VMT by 5% by 2030

- ⇨ Reduce VMT by 10% by 2050
- ⇨ Ridership (i.e. rates of ridership, number of additional drivers, and number of riders that take transit instead of passenger vehicles)
- ⇨ Boarding and transit service efficiency, reliability, and variability improvements
- ⇨ Increase in coverage/areas served
- ⇨ Increase in percentage of population with access to services
- ⇨ Implementation of BRT
- ⇨ Replacement of current vehicles with electric/alternative fuel vehicles
- ⇨ Projects to upgrade and improve to Union Station
- ⇨ MBTA/Compass Rail/Northern Tier developments in the Region

### Quantified GHG Emission Reduction

The quantified GHG emission reductions are 3,155 $MTCO_2e$ in 2030 and 15,829 $MTCO_2e$ in 2050. Data for senior van services for municipalities and Regional Transit Authorities (RTAs) was used. For RTA demand response vehicles, the fuel usage, mileage, and fuel efficiency data was obtained from the Federal Transit Administration (FTA) 2022 Fuel and Energy Datasets and from previous coordination with RTAs directly (data collected during PCAP).

### Measure Costs

~$274.9 Million

### Intersection with Other Funding Availability

- ⇨ Grants for Buses and Bus Facilities Programs, US DOT
- ⇨ Community Transit Grant Program, MA DOT
- ⇨ School Bus Program, MassCEC

## T3: Alternative Fuel Charging Infrastructure

A strong network of available, reliable, and accessible electric vehicle (EV) chargers is critical to supporting EV adoption goals, as a well-planned network empowers consumers to feel comfortable when purchasing an EV. Unfortunately, despite the progress of EV charger development, limited availability of the infrastructure remains one of the most prominent barriers to EV adoption.[118] Based on a recent survey by AAA, the top barriers to EV's among consumers are a lack of convenient public charging stations and the perceived unsuitability of EVs for long distance travel.[119] This is called range anxiety and refers to the fear that an EV will not have enough battery charge to reach its destination. This anxiety is particularly prominent when considering long-distance travel, along stretches of road where EV charging points might be few and far between.

Municipalities must not only focus on expanding public EV charging stations near homes, multi-unit dwellings (MUDs), and commercial centers, but also at municipal buildings and facilities to support the transition of a municipal fleet to electric. This will require a heavy effort from municipal and regional staff, including working with state partners. To develop a reliable and accessible EV charging network they will need to research rebates and incentives to offset costs of electrical infrastructure upgrades, charging equipment, and other costs and collaborating with utilities and electric vehicle supply equipment (EVSE) companies.

### Key Objectives

- ⇨ Install public charging stations at municipal buildings, near multi-family buildings, and commercial centers. Identify rebates and incentives to install EV charging infrastructure.
- ⇨ Develop regional and municipal EV charging network plans to identify suitable locations and necessary electrical grid upgrades.
- ⇨ Work with utilities and EVSE companies to install EV charging infrastructure, including necessary electrical grid upgrades.
- ⇨ Implement municipal EV charging building codes, parking ordinances, and/or zoning ordinances.
- ⇨ Develop guidelines and educate residents about EV charging use and the benefits of EV adoption.
- ⇨ Identify potential for other alternative fuel charging infrastructure (i.e. hydrogen)
- ⇨ Be designated as a Green Community and apply for competitive grant awards.

### Geographic Scope

For this measure, public EV charging infrastructure is particularly important at municipal buildings, in areas where off-street parking is limited (i.e., near multi-family housing), and near commercial centers throughout the region.

### Implementation Authority and Responsibilities

- ⇨ **Municipalities** – Apply for rebates and incentives to reduce the cost of installing and maintaining an EV charging infrastructure; develop a municipal plan to identify the most suitable charging locations and necessary electrical grid upgrades; collaborate with EVSE companies and utilities; develop and implement building codes, parking ordinances, and/or zoning ordinances; develop guidelines and educate residents about public EV charging use; create educational materials to present to the public that highlight the benefits of

transitioning to EVs; become designated as a Green Community and apply for competitive grant awards; and identify the potential for other alternative fuel charging infrastructure.

- ⇨ **CMRPC, MRPC, and NECCOG** – Identify potential charging infrastructure locations; apply for funding opportunities to reduce the cost for municipalities to install and maintain charging infrastructure; develop a regional plan to identify suitable charging locations across the region; develop interactive maps and applications; and identify the potential for other alternative fuel charging infrastructure.
- ⇨ **Massachusetts and Connecticut** – Provide state-funded EV charging incentive programs to support the growing charging network (i.e. Green Communities, MassEVIP).
- ⇨ **Utilities (National Grid, Eversource, Unitil, MLPs)** – Collaborate with municipalities early in the process to support municipal and regional EV charging network plans, identify necessary electrical grid upgrades, mitigate grid impacts, and provide rebates and incentives.
- ⇨ **EVSE Companies (i.e. ChargePoint, Blink, Tesla)** – Collaborate with municipalities to install, operate, and maintain EV charging stations over time.
- ⇨ **Private Property Owners** – Collaborate with the municipality to install public charging infrastructure on the property and determine logistics.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Develop a municipal plan to identify the most suitable EV charging locations and necessary electrical grid upgrades.
- ⇨ Identify EV charging locations throughout the region. Develop a regional plan.
- ⇨ Collaborate with utilities and EVSE companies to install, operate, and maintain EV charging stations.
- ⇨ Develop and implement building codes, parking ordinances, and/or zoning ordinances.
- ⇨ Develop guidelines and education materials to share with residents about EV charging use.
- ⇨ Develop educational materials to highlight the benefits of EVs and the transition to EVs.
- ⇨ Become designated as a Green Community and apply for competitive grant awards.
- ⇨ Collaborate with municipalities to install public charging stations at private properties and determine logistics.
- ⇨ Develop EV charging infrastructure interactive maps and applications to share with municipalities.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Install EV chargers and update the electrical grid as necessary.
- ⇨ Continue collaborating with utilities and EVSE companies to install, operate, and maintain EV charging stations.
- ⇨ Continue applying for Green Communities grants and other grant programs to reduce the costs of charging installations.
- ⇨ Maintain interactive maps and applications.
- ⇨ Work with municipalities to install public charging stations at regionally identified locations.
- ⇨ Continue collaborating with municipalities to install public charging stations at private properties and determine logistics.
- ⇨ Explore opportunities for other alternative fuel types and infrastructure.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Continue installing EV chargers and updating the electrical grid as necessary.
- ⇨ Maintain interactive maps and applications.

- ⇨ Update the regional plans that help identify suitable EV charging locations in the region.
- ⇨ Continue collaborating with municipalities to install public charging stations at private properties and determine logistics.
- ⇨ Continue exploring opportunities for other alternative fuel types and infrastructure.

### Metrics for Tracking Progress

- ⇨ Number of chargers purchased
- ⇨ Number of chargers installed
- ⇨ Completion of Regional EV Charging Network Plan
- ⇨ Completion of Municipal EV Charging Network Plans
- ⇨ Updated municipal building codes, parking ordinances, and/or zoning ordinances
- ⇨ Number of municipalities with guidelines developed about public EV charging use

### Quantified GHG Emission Reduction

The quantified GHG emission reductions are 521,092 $MTCO_2e$ in 2030 and 959,370 $MTCO_2e$ in 2050. To reach these conclusions GHG reductions associated with EV charging were quantified by using the Electric Vehicle Infrastructure Coordinating Council Initial Assessment to the General Court report which identifies the charging demand required to meet the MA 2030 statewide EV adoption goal. This report includes the number of charging ports by type which were scaled down to the Massachusetts portion of the MSA by population.

### Measure Costs

~$154.6 Million

### Intersection with Other Funding Availability

- ⇨ CMAQ Improvement Program, US DOT
- ⇨ Charging and Fueling Infrastructure (CFI) Discretionary Grant Program, US DOT
- ⇨ Alternative Fuel Infrastructure Tax Credit (IRS), US DOE
- ⇨ Grants for Buses and Bus Facilities Program, US DOT
- ⇨ MassEVIP Public Charging Incentive, MA DEP
- ⇨ MassEVIP Workplace and Fleets Charging Incentive, MA DEP
- ⇨ MassEVIP Multi-Unit Dwelling and Campus Charging Incentive, MA DEP
- ⇨ MassEVIP Direct Current Fast Charging (DCFC) Incentive, MA DEP
- ⇨ Medium and Heavy Duty Mobile Charging Solutions, MassCEC
- ⇨ V2X Demonstration Projects, MassCEC
- ⇨ ACT4ALL, MassCEC
- ⇨ Fleet Advisor Program, MassCEC
- ⇨ Fleet Programs, National Grid
- ⇨ Green Communities, MA DOER
- ⇨ Connecticut EV Charging Program, Eversource Energy and The United Illuminating Company
- ⇨ Workplace Charging, Eversource
- ⇨ Public/Workplace Programs, National Grid
- ⇨ Multi-Unit Dwelling Programs, National Grid

## T4: Adoption of Zero-Emission Light-Duty Vehicles

Light-duty vehicles (LDVs), like passenger vehicles and small commercial vehicles, are responsible for approximately 32% of the total emissions in the Region and at least 80% of the total transportation sector emissions, mainly due to ICEVs, specifically gasoline and diesel. The transition to EVs in the Region results in significant public health benefits, environmental benefits, economic and workforce development, reduced noise pollution, among others.[120],[121] While municipal fleet vehicles make up a much smaller proportion of LDVs on the roads, they are an important part of the region's efforts to reduce transportation sector emissions through electrification. Furthermore, by transitioning municipal fleet to electric, municipalities can lead by example.

### Key Objectives

- ⇨ Convert LDV municipal fleet to all-electric.
- ⇨ Create purchasing requirements to replace converted municipal fleet vehicles with similar EV or a ZEV at the end of useful life.
- ⇨ Publish annual reports on fuel cost savings, emissions avoided, and other related progress to publicize the success of transitioning to ZEVs.
- ⇨ Install charging infrastructure at key municipal facilities to support charging needs, prioritizing sites with existing electrical grid capacity.
- ⇨ Upgrade municipal fleet facilities to support the development of charging infrastructure.
- ⇨ Implement public education programs or workshops to discuss EVs and the benefits and transitioning to EVs.
- ⇨ Create partnerships with utilities and EVSE companies to build and operate the charging infrastructure.
- ⇨ Become designated as Green Community and apply for competitive grant awards.

### Geographic Scope

This measure should be implemented throughout all the municipal fleet in the Region. Municipalities should target municipal buildings with existing grid capacity to install charging infrastructure to support passenger and light-duty fleet conversion and charging needs.

### Implementation Authority and Responsibilities

- ⇨ **Municipalities** – Procure new ZEVs; create purchasing requirements; publish annual reports; install chargers at municipal facilities; update infrastructure at municipal facilities; implement public education programs or workshops; create partnerships with utilities and EVSE companies.
- ⇨ **CMRPC, MRPC, and NECCOG** – Support the efforts of municipalities to procure new ZEVs, create purchasing requirements, access funding to install charging infrastructure and upgrade facilities, and other needs as required.
- ⇨ **Utilities (National Grid, Eversource, Unitil, MLPs)** – Provide rebates and incentives to install chargers at municipal facilities.
- ⇨ **EVSE Companies (i.e. ChargePoint, Blink, Tesla)** – Install, operate, and maintain charging stations at municipal facilities.
- ⇨ **Massachusetts and Connecticut** – Provide and approve rebates and incentives to purchase municipal EVs (i.e., MOR-EV).

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ RPAs must work with municipalities to determine a plan to begin transitioning their municipal LDV fleet to ZEVs.
- ⇨ Municipalities begin to create partnerships with their utility to identify current electrical grid capacity at their fleet facilities and necessary upgrades for the future.
- ⇨ Municipalities create a partnership with an EVSE company and install at least one charger at each municipal fleet facility.
- ⇨ Green Communities should aim to implement the Fuel-Efficient Vehicles Policies (Green Communities Requirement).
- ⇨ RPAs and municipalities should implement public education programs, develop education materials, or host workshops to review plans, data, and other relevant information for the public.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Create purchasing requirements to replace converted municipal fleet vehicles with similar EV or ZEV at the end of useful life.
- ⇨ Explore the ability to install additional charging infrastructure at municipal fleet facilities. If necessary, begin upgrading facilities to support the electrical grid capacity.
- ⇨ Develop annual reports that summarize fuel cost savings, avoided emissions, and other related progress to help publicize the success of their transition to ZEVs.
- ⇨ Continue to implement public education programs, develop education materials, or host workshops to review plans, data, and other relevant information for the public.
- ⇨ Green Communities in the region should continue to aim to implement the Fuel-Efficient Vehicles Policies (Green Communities Requirement).
- ⇨ Continue expanding adoption of ZEV-First Vehicle Policies (Climate Leaders Requirement).

**Long Term Actions, Years 2040 – 2050**

- ⇨ Continue to transition their municipal LDV fleet to ZEVs.
- ⇨ Continue to support municipal efforts in their full transition to ZEVs.
- ⇨ Continue to install charging infrastructure and make necessary upgrades.
- ⇨ Continue to develop annual reports to publicize the success of transitioning to ZEVs.

## Metrics for Tracking Progress

- ⇨ Convert at least 20% of municipal LDV fleet to all-electric by 2030
- ⇨ Convert 100% of municipal LDV fleet to all-electric or similar ZEV by 2050.
- ⇨ Number of ZEV municipal fleet vehicles purchased
- ⇨ Development of municipal purchasing requirements
- ⇨ Total amount of rebates and incentives received per municipality
- ⇨ Annual reports completed
- ⇨ Educational materials distributed and number of workshops hosted

## Quantified GHG Emission Reduction

The quantified GHG emission reductions are 3,971 $MTCO_2e$ in 2030 and 22,466 $MTCO_2e$ in 2050. The 2022 Greater Worcester Regional GHG Inventory data was used to identify the gasoline usage by municipal vehicles and calculate an emissions reduction associated with electrifying 20% of the fleet vehicles by 2030 and 100% by 2050. Emissions reductions were calculated, assuming a 20% reduction in fuel usage by 2030 and 100% electrification by 2050 for both municipal vehicles and

RTA vehicles.

### Measure Costs

~$217.9 Million

### Intersection with Other Funding Availability

- ⇨ MassEVIP Fleet Vehicles Incentives, MA DEP
- ⇨ MOR-EV Car Rebates, MA DEP
- ⇨ MOR-EV Rebate Offerings for Purchasing or Leasing EVs, MA DEP
- ⇨ Green Communities, MA DOER
- ⇨ Connecticut Hydrogen and Electric Automobile Purchase Rebate (CHEAPR), CT DEEP

## T5: Adoption of Zero-Emission Medium- and Heavy-Duty (MHD) Vehicles

Medium- and heavy-duty vehicles (MHDs) are responsible for approximately 6% of the total emissions in the Region and at least 14% of the total transportation sector's emissions, mainly due to ICEVs, specifically gasoline and diesel. While municipal fleet vehicles make up a much smaller proportion of MHD vehicles on the roads, they are an important part of the Region's efforts to reduce transportation sector emissions through electrification or other alternative fuel sources, like hydrogen. By transitioning municipal fleets to electric or other alternative fuel sources, municipalities can lead by example. The transition of MHD vehicles is a difficult path. MHD vehicles have a very high upfront cost, require longer charging times, and have extremely heavy batteries which bring disadvantages, among others.[122] Therefore, the use of alternative fuel sources with electrification for MHD vehicles in the future will be necessary to reach net-zero emissions.

### Key Objectives

- ⇨ Convert MHD municipal fleet vehicles to all-electric or alternative fuel sources.
- ⇨ Create purchasing requirements to replace converted MHD municipal fleet vehicles with similar alternative fuel vehicles or a ZEV at the end of useful life.
- ⇨ Publish annual reports on fuel cost savings, emissions avoided, and other related progress to publicize the success of transitioning to ZEVs.
- ⇨ Install charging infrastructure at key municipal facilities to support charging needs, prioritizing sites with existing electrical grid capacity.
- ⇨ Upgrade municipal fleet facilities to support the development of charging infrastructure.
- ⇨ Create partnerships with utilities and EVSE companies to build and operate the charging infrastructure.
- ⇨ Become designated as a Green Community and apply for competitive grant awards.

### Geographic Scope

This measure should be implemented throughout all municipalities in the Region. Municipalities should target municipal buildings with existing electrical grid capacity to install charging infrastructure to support the transition of MHD fleet vehicles.

### Implementation Authority and Responsibilities

- ⇨ **Municipalities** – Procure new alternative fuel vehicles, create purchasing requirements, publish annual reports, install chargers at municipal facilities, and create partnerships with utilities and EVSE companies.
- ⇨ **CMRPC, MRPC, and NECCOG** – Support the efforts of municipalities to procure new alternative fuel vehicles, create purchasing requirements, access funding to install charging infrastructure and upgrade facilities.
- ⇨ **Utilities (National Grid, Eversource, Unitil, MLPs)** – Provide rebates and incentives to install chargers at municipal facilities.
- ⇨ **EVSE Companies (i.e. ChargePoint, Blink, Tesla)** – Install, operate, and maintain charging stations at municipal facilities.
- ⇨ **Massachusetts and Connecticut** – Provide and approve rebates and incentives to purchase municipal alternative fuel vehicles (i.e. MOR-EV Trucks Rebates)

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Host a regional roundtable/regional dialogue with municipal staff, DPW, and others to discuss the goals and encourage the transition.
- ⇨ Work with municipalities to determine a plan to begin transitioning MHD fleet vehicles to all-electric or alternative fuel vehicles.
- ⇨ Begin to transition MHD fleet vehicles to all-electric or alternative fuel vehicles.
- ⇨ Sign up for Mass Fleet Advisor.
- ⇨ Create partnerships with utilities to identify current electrical grid capacity at fleet facilities and necessary upgrades for the future.
- ⇨ Create a partnership with an EVSE company and install at least one charger at each municipal fleet facility.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Work together to create purchasing requirements to replace converted MHD municipal fleet vehicles with similar EV or alternative fuel vehicles at the end of useful life.
- ⇨ Explore the ability to install more charging infrastructure at municipal fleet facilities. If necessary, begin upgrading facilities to support the electrical grid capacity.
- ⇨ Develop annual reports that summarize fuel cost savings, avoided emissions, and other related progress to help publicize the success of their transition to EVs or alternative fuel vehicles.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Continue to transition MHD vehicle fleet to all-electric or alternative fuel vehicles.
- ⇨ As needed, continue to install charging infrastructure and make the necessary upgrades.
- ⇨ Continue to develop annual reports to publicize the success of transitioning to electric or alternative fuel vehicles.

## Metrics for Tracking Progress

- ⇨ Convert at least 20% of MHD municipal fleet vehicles to all-electric or alternative fuel by 2030
- ⇨ Convert at least 75% of MHD municipal fleet vehicles to all-electric or alternative fuel by 2050
- ⇨ Number of Electric or Alternate Fuel municipal fleet vehicles purchased
- ⇨ Development of municipal purchasing requirements
- ⇨ Total amount of rebates and incentives received per municipality

## Quantified GHG Emission Reduction

The quantified GHG emission reductions are 2,196 $MTCO_2e$ in 2030 and 11,477 $MTCO_2e$ in 2050. The 2022 Greater Worcester Regional GHG Inventory data was used to identify the diesel usage by municipal vehicles and calculate an emissions reduction associated with electrification of 20% of the fleet vehicles by 2030 and 75% by 2050. The MA DOER Climate Leader Community Program identified 20% by 2030 as a fleet electrification target for Massachusetts municipalities; this was also applied to CT fleet vehicles. The increase in electricity associated with the use of EVs was accounted for in 2030, but in 2050 an electricity emissions factor of zero was used as it was assumed that electricity to charge vehicles will be from renewable sources.

### Measure Costs

~$272.4 Million

### Intersection with Other Funding Availability

- ⇨ MassEVIP Fleet Vehicles Incentives, MA DEP
- ⇨ MOR-EV Truck Rebates, MA DEP
- ⇨ MOR-EV Rebate Offerings for Purchasing or Leading EVs, MA DEP
- ⇨ Medium- and HeavyDuty Mobile Charging Solutions, MassCEC
- ⇨ Mass Fleet Advisor, State - MassCEC
- ⇨ Green Communities, MA DOER
- ⇨ Connecticut Hydrogen and Electric Automobile Purchase Rebate (CHEAPR), CT DEEP

## Benefits Analysis: Transportation

The measures included in this chapter have many co-benefits for the Region other than direct greenhouse gas emissions reductions that mitigate the Region's impact on global climate change.

All five of this plan's transportation sector measures will have the co-benefits of indirectly improving public health outcomes in the Region. Their implementation will lead to a reduction in emissions of co-pollutants detrimental to people's health which are released into the atmosphere and which spread locally when transportation produces emissions from fossil fuels. Specifically, the co-pollutants emissions reductions that these measures will lead to include:

*Table 14. Transportation Co-Pollutant Reductions*

| Measures | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|
| T1: Bicycle and Pedestrian Improvements | 15,967 | 19,937 |
| T2: Expand and Improve Public Transit | 3.0 | 8.0 |
| T3: Alternative Fuel Charging Infrastructure | 7,956 | 8,283 |
| T4: Adoption of Zero-Emission Light-Duty Vehicles | 33.3 | 112.7 |
| T5: Adoption of Zero-Emission Medium- and Heavy-Duty Vehicles | 8 | 21.8 |

All five transportation sector emissions will also lead to direct job creation co-benefits, as the construction, operation, and maintenance of new transportation infrastructure required will lead to many opportunities for residents of the Region. The Bicycle and Pedestrian Improvements and Expand and Improve Public Transit measures will lead to direct improved public health outcomes through improvement of air quality and improved climate resilience by reducing vehicle trips. The Adoption of Zero-Emission Light-Duty Vehicles and the Adoption of Zero-Emission Medium- and Heavy-Duty Vehicles measures will lead to direct decreased energy costs as drivers and fleets will experience immediate fuel and maintenance cost reductions as they transition. The Alternative Fuel Charging Infrastructure, Adoption of Zero-Emission Light-Duty Vehicles, and Adoption of Medium- and Heavy-Duty Vehicles measures will lead to indirect improved public health outcomes through health benefits from cleaner air and improved climate resilience by greater EV adoption. The Bicycle and Pedestrian Improvements, Expand and Improve Public Transit, and Alternative Fuel Charging Infrastructure measures will lead to indirect decreased energy costs due to alternative mode choice incentivization and fuel savings costs because of alternative fuel chargers compared to gasoline/diesel fuel costs.

There are many potential disbenefits for these measures that regional stakeholders should aim to minimize as the measures are implemented. The potential disbenefits include reduced vehicle throughput due to increased multi-modal development; high costs for EV charging installations and necessary grid upgrades; high EV vehicle costs; fare free funding challenges; end of life battery disposal; and the long charging times that will especially impact MHD fleet transition.

*Table 15. Transportation Co-Benefits Summary*

| Measures | Improved Public Health Outcomes | Job Creation | Improved Climate Resilience | Decreased Energy Costs |
|---|---|---|---|---|
| T1: Bicycle and Pedestrian Improvements | X | X | X | X |
| T2: Expand and Improve Public Transit | X | X | X | X |
| T3: Alternative Fuel Charging Infrastructure | X | X | X | X |
| T4: Adoption of Zero-Emission Light-Duty Vehicles | X | X | X | X |
| T5: Adoption of Zero-Emission Medium- and Heavy-Duty Vehicles | X | X | X | X |

# Transportation Endnotes

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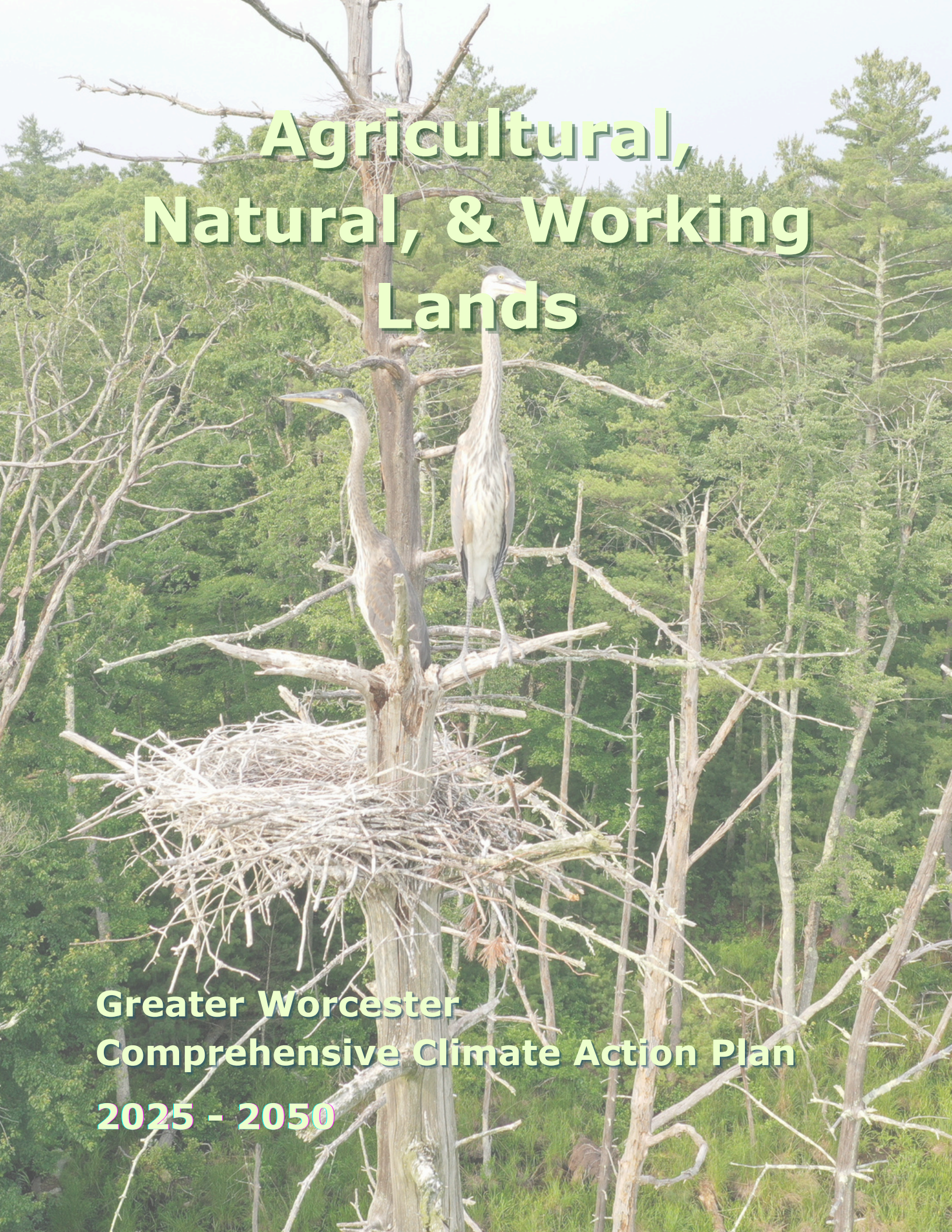

# Agricultural, Natural, & Working Lands

Greater Worcester
Comprehensive Climate Action Plan

2025 - 2050

## 3.4 Agricultural, Natural, and Working Lands

The Agricultural, Natural, and Working Lands sector for the Region comprises lands that are actively used for agriculture or forestry, such as working farms, managed forests, grasslands, wetlands, riparian zones, watersheds, and open green spaces. With all of these critical landscapes, this sector plays a critical role in the region's ambitious climate reduction goals. When these lands are well managed, they act as carbon sequestration sponges, absorbing $CO_2$ through photosynthesis and storing carbon as glucose in plant and soil biomass. In the Region, these lands account for 2.83 $MMTCO_2e$ of sequestered carbon in the region. These lands can also act as natural buffers to climate impacts. They can mitigate urban heat islands, absorb floodwater, protect watersheds, and stabilize soils. Beyond this, the lands in this sector support biodiversity, improve soil health, and can provide recreational, cultural, and health benefits to the communities. It is critical that the Region prioritizes maintaining the lands and resources in this sector as a resource to combat climate change causes and impacts.

*Table 16. Agricultural, Natural, and Working Lands Sector Measure Summary*

| Measures | GHG Emission Reductions in 2030 Compared to the BAU ($MTCO_2e$) | GHG Emission Reductions in 2050 Compared to the BAU ($MTCO_2e$) | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|---|---|
| ANWL 1: Expand Network of Urban Tree and Shrub Coverage | 3,186 | 23,897 | 32 | 243 |
| ANWL 2: Increase Permanently Protected Acres of Forestland | 16,545 | 66,180 | 195 | 779 |
| ANWL 3: Convert Manicured Lawn into Climate-Smart Resiliency Gardens | 1,113 | 5,565 | 0.98 | 4.89 |
| ANWL 4: Transform Underutilized Municipal Lands into Resiliency Pockets | 176,763 | 530,290 | 195 | 584 |
| ANWL 5: Reduce Synthetic Pesticide and Fertilizer Usage | 3,557 | 12,891 | 225 | 817 |

## ANWL1: Expand Network of Urban Tree and Shrub Coverage

The Region's downtown centers and mill-town neighborhoods still carry an industrial legacy with wide expanses of asphalt. While pavement and asphalt may allow for easier travel, they can exacerbate the impacts of climate change. Asphalt is a dark, impermeable surface which causes it to absorb a significant amount of solar radiation. This radiation gets trapped in the asphalt as heat and contributes to an urban heat island effect, a phenomenon where urban areas experience significantly warmer temperatures than their surrounding rural counterparts.[123] As a result, residents in these more urbanized areas experience hotter summers, poorer air quality, and fewer shaded walkways than the outer lying suburbs in the region.[124] Targeted and thoughtful planting of native trees and shrubs in urban communities could create a cooling canopy over these asphalt streetscapes.

Shade trees offer communities a multitude of benefits. First and foremost, they cool the air using shading and evapotranspiration. Trees act like umbrellas, blocking sunlight from reaching the ground, surfaces, and organisms below.[125] This process prevents the surfaces underneath from absorbing that solar heat and radiating it back into the atmosphere, thereby leading to cooler surface and air temperatures. Evapotranspiration cools surrounding air even further by absorbing water from the soil through the tree's roots. This water is transported throughout the tree and released through the stomata or tiny pores on their leaves. Essentially, the tree "sweats" and releases this water vapor into the air.[126] As that water evaporates, heat is absorbed from the surrounding air, causing a cooling effect. If strategically placed, these shade trees can significantly reduce energy consumption for cooling in the summer, reducing the need for air conditioning and lowering utility bills.[127]

Even more critical, trees sequester carbon through photosynthesis. Through this process, trees absorb carbon dioxide from the air through stomata. Using sunlight, they then combine the carbon dioxide with water molecules to create glucose, a type of sugar.[128] Oxygen is released back into the atmosphere, and the created glucose fuels the tree's growth and other functions, becoming part of its roots, trunk, branches, and leaves – its biomass. And as the tree grows, it continues to accumulate biomass through photosynthesis, storing more carbon.[129]

The Region should aim to establish and expand programs that support native tree and shrub planting in its communities. These programs should utilize native species only, as they require little maintenance and are better suited for the local environment. The Region should prioritize planting 15% additional tree cover in public areas that have little coverage.

### Key Objectives

- ⇨ Boost native urban canopy for carbon and energy gains by planting an additional 15% native tree cover in the Region.
- ⇨ Tackle urban heat and energy poverty by using strategic street tree plantings so that vulnerable areas realize temperature reductions in the summertime.
- ⇨ Leverage and combine existing funding programs, such as Greening the Gateway Cities or Urban and Community Forestry Program, that allow for tree planting at no cost to community members.
- ⇨ Advance public education and engagement by establishing a "Tree Stewards" program to reinforce messages on cooling, health, and cost benefits provided by trees.

- ⇨ Protect and maintain shade trees as a critical resource through stronger municipal ordinances.

## Geographic Scope

While this measure should be widely implemented across the Region, native tree and shrub plantings should be prioritized in communities with little public tree and shrub coverage, such as Fitchburg, Gardner, Leominster, Southbridge, Webster, and Worcester in Massachusetts, as well as Windham in Connecticut.

## Implementation Authority and Responsibilities

- ⇨ **Departments of Public Works** – Set planting priorities, secure funding, and plant, monitor, and maintain shade/street tree inventory.
- ⇨ **Tree Wardens** – Monitor health of trees on public property.
- ⇨ **Conservation Commissions** – Monitor the health of and plant additional trees on property managed by the Conservation Commission.
- ⇨ **CMRPC, MRPC, and NECCOG** – Convene multi-town canopy working groups, author or assist joint grant applications to fund plantings, align planting goals and tree works with climate action plans.
- ⇨ **MA Department of Conservation & Recreation** – Administer the Urban and Community Forestry Program, providing technical assistance and pass-through funding to support communities and non-profit groups in protecting, growing, and managing community trees and forest ecosystems.
- ⇨ **CT Department of Energy & Environmental Protection, Division of Forestry** – Administer the Urban and Community Forestry Program, providing technical assistance and pass-through funding to support communities and non-profit groups in protecting, growing, and managing community trees and forest ecosystems.
- ⇨ **New England Botanic Garden at Tower Hill** – Assist in operating nursery and providing outreach opportunities.
- ⇨ **Utility Companies (National Grid, Eversource, Unitil, Municipal Light Plants)** – Sponsor free shade-tree giveaways and conduct maintenance for shade trees near powerlines.
- ⇨ **Local Non-Profits** – Coordinate volunteer Tree Stewards and community outreach.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Begin tree inventory assessment, establishing a baseline for canopies and shade trees, utilizing non-proprietary inventory software if feasible.
- ⇨ Establish municipal tree boards and adopt uniform planting and maintenance specifications.
- ⇨ Amend public shade-tree ordinances to require a "replace-plus-one" for any shade tree removals.
- ⇨ Secure grant funding to support and/or supplement existing regional native tree and shrub nurseries.
- ⇨ Plant 5,000 trees in priority urbanized areas.
- ⇨ Launch a Tree Steward outreach initiative to educate the public on the importance of trees.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Complete the remaining tree inventory assessments
- ⇨ Secure regular funding to maintain the regional nursery stock.

- ⇨ Plant an additional 20,000 native trees and shrubs in the region.
- ⇨ Expand the Tree Steward initiative into a training program that establishes a set of local volunteers to support tree care and maintenance.
- ⇨ Pilot canopy audits to recalibrate high priority planting zones.
- ⇨ Implement a three-year establishment care cycle.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Require canopy audits on a five-year cycle recalibrate high priority planting zones
- ⇨ Train community members on native tree stewardship and explore the possibility of transferring mature stewardship duties to municipal budgets where feasible.
- ⇨ Update planting lists and nursery stocks for mid-century climate scenarios and emerging pests.
- ⇨ Plant the remaining 15,000 native trees and shrubs.

## Metrics for Tracking Progress

- ⇨ Percent increase in native canopy cover
- ⇨ Number of native trees and shrubs planted
- ⇨ kWh and peak demand avoided on hot-weather days
- ⇨ Delta of surface temperatures in shaded versus non-shaded areas
- ⇨ Number of volunteers trained through the Tree Steward Program
- ⇨ Survival rate of plantings
- ⇨ Funding secured and spent on installation of plantings
- ⇨ Money spent on long-term maintenance of plantings

## Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 3,186 $MTCO_2e$, and by 2050 it will reduce emissions by 23,897 $MTCO_2e$. The estimated emissions reductions reflect a 2% increase in urban tree plantings by 2030 and a 15% increase by 2050.

## Measure Costs

$19 – $43 Million

## Intersection with Other Funding Availability

- ⇨ Urban & Community Forestry Program, USDA
- ⇨ Community Change Grants, EPA
- ⇨ Community Development Block Grant, HUD
- ⇨ Land & Water Conservation Fund
- ⇨ Urban & Community Forestry Challenge Grants, MA DCR
- ⇨ Greening the Gateway Cities Implementation & Partnership Grants, MA DCR
- ⇨ Municipal Vulnerability Preparedness Action Grants, MA EEA
- ⇨ Cooling Corridors Grants, EEA
- ⇨ Urban and Forest Equity Grants, CT DEEP
- ⇨ Sustainable CT Community Match Fund
- ⇨ Community Preservation Act Funds
- ⇨ Municipal Capital/Bonds
- ⇨ Energy Saving Trees Program, Eversource Arbor Day Foundation

## ANWL2: Increase Permanently Protected Acres of Forestland

Protecting and maintaining the region's forestland is crucial for achieving net-zero GHG emissions targets by 2050. Forests play a critical role in mitigating climate change through acting as a carbon sink. Like shade trees, the trees in forests also absorb carbon dioxide from the atmosphere during photosynthesis and store the converted sugars in their network of roots, limbs, and leaves as biomass. Forests can also store carbon in dead wood, soil, and leaf litter, and can store it for much longer periods of time than individual trees.[130]

Across the entire state, forests sequester roughly 14% of the state's gross annual carbon emissions.[131] In the Region, the carbon storage impact of forests is more than double. There are approximately 430,913 acres of deciduous forest, 113,825 acres of evergreen forest, and 311,049 acres of mixed forest in the region.[132] In total, there are about 855,787 acres of carbon sequestering forest, and this helps account for 2.83 $MMTCO_2e$ of carbon being sequestered annually, or about 29.7% of the region's gross annual carbon emissions. However, not all of these forested areas are permanently protected and could be at risk for deforestation.

Residential, commercial, and solar development are drivers of forest loss in both Worcester County and Eastern Connecticut. With increasing populations, limited housing, and lack of desire to redevelop existing facilities, forests are even more at risk of being cleared to make way for housing and commercial buildings.[133] While solar energy is another crucial component for fighting climate change, current solar development practices can undermine this progress by clearing large tracts of forested land and destroying ecosystems. As forests are cleared, their stored carbon is released back into the atmosphere and that land's capacity to sequester more carbon is reduced.[134] Increasing protection for the vast amount of forested land will be vital to maintain a stable climate. The Region should seek to utilize existing land protection tools, like Conservation Restrictions and Conservation Easements, to ensure that these carbon sinks are here to stay.

### Key Objectives

- ⇨ Accelerate the use of and diversify land protection tools, aiming to permanently protect and/or enhance 20,000 acres of land.
- ⇨ Embed nature-based climate solutions in local land-use policies, such as adopting forest-friendly zoning and setting preserved acreage targets.
- ⇨ Advance public education and stewardship through volunteer opportunities, workshops on legacy planning and climate-smart forestry practices, and school programming.
- ⇨ Target preservation of climate-critical parcels like headwater riparian zones, steep ridgetops, and connectors between existing reserves.
- ⇨ Establish long-term monitoring and adaptive management practices to track the health of the forests and reduce wildfire risk.
- ⇨ Explore the creation of carbon markets to generate revenue for climate-smart forestry implementation.

### Geographic Scope

Forestland preservation should be expanded across the entire Region, however, land conservation of climate-critical parcels on the eastern half of the Region should be prioritized.

## Implementation Authority and Responsibilities

- ⇨ **Local Land Trusts** – Identify willing sellers/donors, raise matching funds, acquire, hold Conservation Restrictions and/or Easements, and convene landowner outreach.
- ⇨ **Municipal Conservation Commissions** – Acquire and hold Conservation Restrictions and/or Easements and update local plans to steer growth away from core forestlands.
- ⇨ **MA Division of Conservation Services** – Administers LAND grant program.
- ⇨ **MA Department of Conservation & Recreation** – Manages state parks and oversees more than 450,000 acres throughout Massachusetts.
- ⇨ **MA Executive Office of Energy and Environmental Affairs** – Set statewide land protection policies and certify the Commonwealth Conservation Land Tax Credit.
- ⇨ **CT Department of Energy & Environmental Protection** – Administers the Open Space & Watershed Land Acquisition and Urban Green & Community Garden grant programs, and co-signs or holds conservation easements.
- ⇨ **USDA Forest Service** – Provides financial assistance via the Forest Legacy Act.
- ⇨ **Natural Resources Conservation Service** – Implement the Agricultural Conservation Easement Program via the Farm Bill.
- ⇨ **CMRPC, MRPC, and NECCOG** – Convene multi-town climate-smart forestry working groups, author or assist joint grant applications to fund acquisitions, align preservation goals with climate action plans throughout the Region, provide model bylaws, and assist with land conservation roadshow.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Convene land trusts, municipal officials, private landowners, and non-profit groups to identify climate-critical parcels
- ⇨ Establish a regional climate-smart forestry group and develop regional outreach and engagement strategy
- ⇨ Map/prioritize climate-critical parcels for protection or further enhancement
- ⇨ Launch a land protection tools roadshow and estate planning workshop
- ⇨ Preserve 5,000 acres of climate-critical forestland

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Continue land protection tools roadshow and estate planning workshop
- ⇨ Secure funding to pilot a stewardship fund for small-parcel landowners to complete climate-smart forestry projects that improve forest health and reduce wildfire risk
- ⇨ Host series of climate-smart forestry workshops
- ⇨ Preserve 10,000 additional acres of forestland, prioritizing remaining climate-critical parcels

**Long Term Actions, Years 2040 – 2050**

- ⇨ Preserve remaining 15,000 acres of forestland
- ⇨ Integrate climate-smart forestry into K-12 curriculum

## Metrics for Tracking Progress

- ⇨ Acres of permanently protected forestland
- ⇨ Acres of forestland with limited protections
- ⇨ Average transaction time and cost for restriction recording
- ⇨ Value of tax credits claimed
- ⇨ Amount of funding secured to preserve forestlands

- ⇨ Amount of money per acre of forestland protected
- ⇨ Number of municipalities adopting forest-friendly zoning tools
- ⇨ Number of municipalities referencing climate-smart forestry in relevant plans
- ⇨ Number of residents reached through volunteer opportunities, workshops, and webinars

### Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 16,545 $MTCO_2e$, and by 2050 it will reduce emissions by 66,180 $MTCO_2e$. The estimated emissions reductions reflect protection of an additional 20,000 acres of forestland calculated using a rate of 2.23 MT C per hectare per year from the EPA Local Greenhouse Gas Inventory Tool.

### Measure Costs

$90 – $180 Million

### Intersection with Other Funding Availability

- ⇨ Foresty Legacy Program, USFS
- ⇨ Community Forest & Open Space Program, USFS
- ⇨ Agricultural Conservation Easement Program, USDA & NRCS
- ⇨ Land & Water Conservation Fund – State and Local Assistance, NPS
- ⇨ Local Acquisitions for Natural Diversity Grant, MA DCS
- ⇨ Conservation Partnership Grant, MA EEA
- ⇨ Commonwealth Conservation Land Tax Credit, MA EEA
- ⇨ Municipal Vulnerability Preparedness Action Grants, MA EEA
- ⇨ Drinking Water Supply Protection Grant, MA DCR
- ⇨ Open Space & Watershed Land Acquisition, CT DEEP
- ⇨ Urban Green & Community Garden, CT DEEP
- ⇨ CT Forest Legacy (State Share), CT DEEP/USFS

## ANWL3: Convert Manicured Lawn into Climate-Smart Resiliency Gardens

Suburban settlement and the invention of the lawnmower led to the rise of the well-manicured lawn. While manicured lawns have become a symbol of status and a sense of connection to nature, they actually do more harm than good to the local ecosystem.[135] Lawns require significant amounts of water, especially in times of drought, to maintain a lush appearance, and this associated increased demand can strain local water resources. Landowners often utilize fertilizer to aid in growth and appearance of lawns as well, and the fertilizers used often contain nitrogen and phosphorous which runoff lawns and into waterways during times of rain. The decomposition of these excess nutrients can release nitrous oxide, emitting GHG emissions into the atmosphere.[136]

Though grass does absorb some carbon dioxide, frequent mowing can hinder these natural carbon sequestration processes reducing the amount of carbon stored in the soils and biomass of lawns.[137] And when coupled with the use of gas-powered lawncare equipment, such as lawn mowers and leaf blowers, the negative climate impacts are worsened as these pieces of equipment emit carbon dioxide, methane, nitrous oxide, and other particulate matter into the atmosphere.[138]

Rather than continue to invest in labor-intensive and ecologically degraded lawns, the Region should convert portions of lawn into climate-smart resiliency gardens. These climate-smart gardens could include: Food Gardens, promoting local food production to reduce emissions from food transportation, packaging, and storage; Rain Gardens, which manage stormwater on-site, reduce runoff and flooding, and limit energy-intensive water treatment; and Pollinator Gardens, which support biodiversity and sequester carbon in soil and perennial plants.[139]

### Key Objectives

- ⇨ Shrink the irrigated/monoculture lawn footprint by replacing 10,000 acres with native meadows, food gardens, and pollinator species.
- ⇨ Establish a Resiliency Garden Program that enables homeowners to convert portions of their yard into climate-smart gardens, offering rebates and technical guidance to residents who install and maintain qualifying gardens.
- ⇨ Increase landscape-level carbon sequestration through perennial root systems.
- ⇨ Promote existing outdoor water use reduction strategies and enhance strategies for communities without them.
- ⇨ Enroll 40% of the Region in “Climate-Smart Yard” campaigns, promoting low or no mowing and no pesticide usage.
- ⇨ Embed lawn-conversion criteria into municipal landscape ordinances.
- ⇨ Develop guides and educational materials on maintaining climate-smart yards and gardens.

### Geographic Scope

This measure should be implemented on single and multi-family home lawns across the entire Region. Yards with limited shade trees or nearby open spaces should be prioritized.

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, and NECCOG** – Convene multi-town Climate-Smart Yard garden working groups, author or assist joint grant applications to fund installations and education, align lawn conversion goals with climate action plans.
- ⇨ **Municipalities/Conservation Commissions** – Participate in pilot program, encouraging residents to sign up to convert portions of their lawn.
- ⇨ **MA Department of Conservation & Recreation** – Administer challenge grants, technical standards, and resource mapping tools.
- ⇨ **CT Department of Energy & Environmental Protection** – Provide guidance on native plants and integrate lawn conversion into updated certification programs.
- ⇨ **CT Department of Agriculture** – Administer Climate-Smart Agriculture & Forestry Grants for design, plant material, and stipends.
- ⇨ **UMass Extension** – Land grant university extension, provide professional workshop and maintenance crews.
- ⇨ **UConn Extension** – Land grant university extension, provide volunteer training and demonstrations.
- ⇨ **Mass Audubon** – Offer demonstration sites, biodiversity monitoring, and support outreach.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Establish multi-town climate-smart yard working group.
- ⇨ Secure grant funding to pilot climate-smart yard installation rebates.
- ⇨ Develop branding, design templates, and rebate schedule
- ⇨ Partner with existing nurseries to stock native plantings in bulk.
- ⇨ Host climate-smart yard demonstrations at libraries, schools, and other heavily utilized facilities.
- ⇨ Convert first 2,000 acres of manicured lawn into climate-smart yards.
- ⇨ Identify communities with bylaws preventing climate-smart yards and host conversations with Boards of Health in those communities.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Launch climate-smart yard tools, such as a technical assistance hotline or tracking dashboard.
- ⇨ Establish peer-to-peer seed saving networks.
- ⇨ Secure additional grant funding for climate-smart lawn installations.
- ⇨ Convert an additional 4,000 acres of manicured lawn to climate-smart yards.
- ⇨ Integrate rain garden retrofits into storm-water utility fee credits.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Convert the final 8,000 acres of manicured lawn to climate-smart yards.
- ⇨ Continue outreach to homeowners
- ⇨ Secure program funding to support maintenance of installed climate-smart yards and succession plantings.

## Metrics for Tracking Progress

- ⇨ Acres of lawn converted to climate-smart gardens
- ⇨ Gallons of fuel use from mowing avoided
- ⇨ Outdoor water usage savings

- ⇨ Number of residents/households enrolled in climate-smart yard program
- ⇨ Amount of grants provided
- ⇨ Number of municipalities adopting sustainable landscape ordinances

### Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 1,113 $MTCO_2e$, and by 2050 it will reduce emissions by 5,565 $MTCO_2e$. The emissions reductions were estimated for avoided truck and transportation of food which is instead produced locally. It was assumed the average trucking distance is 1,400 miles for long distance, based on the Food Carbon Calculator, and the local food is 48 miles.

### Measure Costs

$3 Billion - $11 Billion

### Intersection with Other Funding Availability

- ⇨ Environmental Quality Incentives Program, USDA/NRCS
- ⇨ Urban & Community Forestry Grants, USFS
- ⇨ National Coastal Resilience Fund, NFWS
- ⇨ Partnerships for Climate-Smart Commodities, USDA
- ⇨ Drought Resiliency & Water-Efficiency Grant, MA EEA
- ⇨ Municipal Vulnerability Preparedness Action Grant, MA EEA
- ⇨ DCR-National Grid Partnership Challenge Grants, DCR/National Grid
- ⇨ Climate-Smart Agriculture & Forestry Grant, CT DOAG

## ANWL4: Transform Underutilized Municipal Lands into Resiliency Pockets

Vacant, degraded, or underutilized municipal lots are not only eyesores to communities but can also exacerbate climate risks. Dark, bare asphalt and compacted soil store solar heat during the day and radiate this heat at night, raising neighborhood air temperatures by up to 4–8°F. This creates the need for residents to run their air conditioning units longer, which in turn drives up electricity-sector GHG emissions.[140] Beyond just emissions impacts, these impermeable lots can increase flash flooding risks and intense rainstorms can flush heavy metals and pollutants into storm drains, degrading water quality downstream.[141] Vacant and degraded lot can also pose social costs as well. Studies have shown that these blighted parcels can lead to higher crime, respiratory stress, and heat-related illness.[142] They also negatively impact biodiversity with research showing that each 10% rise in impervious cover can eliminate 7.5% of the local pollinator species.[143]

Transforming these grey and degraded lots into resiliency pockets flips this risk into an opportunity. Miyawaki micro-forests are tiny, densely planted native woodlands grown on small parcels of land. They can reach maturity in about 20 years and can absorb $CO_2$ at rates higher than monoculture plantations.[144] Alternatively, these lots could be transformed into food forest with edible perennial landscapes accessible to the public to promote carbon-smart local food, rain gardens to reduce runoff and urban flooding, or parks with native grasses and flowers that require minimal maintenance and promote high ecological value.[145] Threading together once vacant lots with these ecologically focused resources can create a porous green network that intercepts stormwater, shades and cools pavements, and restores habitat for birds and pollinators.

### Key Objectives

- ⇨ Repurpose 15,000 acres of vacant, degraded, and underutilized lands into Resiliency Pockets.
- ⇨ Embed green infrastructure in Capital Improvement Plans.
- ⇨ Align Resiliency Pocket creation with pavement-management and storm-sewer upgrades.
- ⇨ Establish a youth green corps for installation and care.
- ⇨ Increase tree canopy coverage and decrease acreage of impervious surfaces.
- ⇨ Promote hands-on workshops and create neighborhood Resiliency Steward programs.

### Geographic Scope

Resiliency pockets should be installed throughout the Region with early pilots prioritized on neighborhoods with high heat-vulnerability index scores.

### Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, and NECCOG** – Convene multi-town Resiliency Pocket working groups, author or assist joint grant applications to fund installations, align pocket goals with climate action plans throughout the region.
- ⇨ **Department of Public Works** – Oversee design, procurement, and long-term operations and maintenance of municipal Resiliency Pockets.
- ⇨ **Planning Boards** – Amend zoning and stormwater bylaws to facilitate the installation of Resiliency Pockets.

- ⇨ **Select Boards/Chief Executive Office** – Acquire or lease surplus degraded or vacant lots to repurpose into Resiliency Pockets.
- ⇨ **MA Executive Office of Energy and Environmental Affairs** – Provide financial and technical assistance to municipalities installing Resiliency Pockets.
- ⇨ **CT Department of Energy and Environmental Protection** – Provide financial and technical assistance to municipalities installing Resiliency Pockets.
- ⇨ **Local Land Trusts** – Accept conservation restrictions and coordinate volunteer ecological stewardship of Resiliency Pockets.
- ⇨ **Sustainable CT** – Provide no-cost technical coaches, model ordinances, seed grants to assist with implementation of Resiliency Pockets.
- ⇨ **Local Nurseries** – House a collection of native plantings to be utilized for the Resiliency Pocket installations.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Convene a regional Resiliency Pocket working group.
- ⇨ Develop criteria for site prioritization and inventory underutilized parcels.
- ⇨ Secure grant funding to pilot the installation of a resiliency pocket parks or forests in areas with high heat vulnerability scores.
- ⇨ Train DPW crews in meadow management and bioswale maintenance.
- ⇨ Convert the first 5,000 acres of vacant or degraded land into Resiliency Pockets.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Secure additional grant funding and convert the next 5,000 acres of vacant or degraded land into Resiliency Pockets

**Long Term Actions, Years 2040 – 2050**

- ⇨ Secure additional grant funding and convert the last 5,000 acres of vacant or degraded land into Resiliency Pockets
- ⇨ Publish publicly available atlas of all municipal Resiliency Pockets in the Region.
- ⇨ Incorporate resilient-pocket standards into zoning codes and site-plan review checklists

## Metrics for Tracking Progress

- ⇨ Number of municipal lots inventoried
- ⇨ Acres of impervious surface converted to resilient lands
- ⇨ Acres of impervious surface removed
- ⇨ Number of trees planted
- ⇨ Number of native pollinator friendly species planted
- ⇨ Number of parks created
- ⇨ Number and type of workshops delivered
- ⇨ Number of attendees at workshops
- ⇨ Number of Municipalities that have revised zoning codes or embedded green infrastructure into their plans
- ⇨ Water quality downstream
- ⇨ Crime rate

### Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 176,763 $MTCO_2e$, and by 2050 it will reduce emissions by 530,290 $MTCO_2e$. The estimated emissions reductions were quantified using a carbon sequestration rate for Miyawaki forests. It was assumed that by 2030 and 2050, 5,000 acres and 15,000 acres of Miyawaki forests could be established, respectively.

### Measure Costs

$2 - $11 Billion

### Intersection with Other Funding Availability

- ⇨ Brownfields Multipurpose Assessment & Cleanup Grants, US EPA
- ⇨ Urban & Community Forestry, USFS
- ⇨ Community Development Block Grant, US HUD
- ⇨ Outdoor Recreation Legacy Partnership, NPS Land & Water Conservation Fund
- ⇨ Five-Star & Urban Waters, National Fish and Wildlife Foundation
- ⇨ Municipal Vulnerability Preparedness Action Grants, MA EEA
- ⇨ Urban & Community Forestry Challenge/Cool Corridors, MA DCR
- ⇨ Section 319 Non-point Source Grant, MA DEP
- ⇨ Community Forest Grant Program, MA EEA
- ⇨ Urban Green & Community Garden Grants, CT DEEP
- ⇨ Community Match Fund, Sustainable CT
- ⇨ Environmental & Community Grants, Greater Worcester Community Foundation
- ⇨ Climate Resilience Strategy Grant, Barr Foundation

## ANWL5: Reduce Pesticide and Synthetic Fertilizer Usage

Pesticide and fertilizer usage are the largest drivers of GHG emissions in the Agricultural, Natural, and Working Lands sector. In the Region, approximately 15,127 $MTCO_2e$ is emitted from agricultural activities. This includes emissions from liming (adding limestone to soil to reduce acidity), urea (fertilizer and animal feed additive), and soil disturbance.[146]

The manufacturing of synthetic fertilizer is an energy-intensive, fossil-gas process that releases approximately 1.6 tons of $CO_2e$ for every ton of ammonia produced. When fertilizer is spread on lawns, gardens, or agricultural lands, microbes convert the excess nitrogen into nitrous oxide.[147] Pesticides carry a similar hidden GHG emission load. Studies show that a kilogram of common herbicides emits 18-27 kg $CO_2e$, while insecticides average 15-19 kg $CO_2e$.[148] Both pesticides and fertilizer contribute to particulate pollution, increase GHG emissions, and intensify heat stress on crops.

In contrast, regenerative agriculture practices, like cover cropping, no-till, agroforestry, and biological-based pest controls, can have significant gains in soil organic carbon storage.[149] In fact, modeling suggests that widescale adoption of robust cover-crop rotations could double the nation's soil carbon sink by 2050.[150] The Region should aim to transition away from synthetic-input dependent agriculture and instead should promote the adoption of Integrated Pest Management strategies and other sustainable land management practices to help reduce reliance on pesticides and synthetic fertilizers and their associated environmental impacts.

### Key Objectives

- ⇨ Reduce the usage of pesticides and synthetic fertilizers on 9,000 acres of municipal, commercial, and residential land by 2050.
- ⇨ Encourage farms to adopt regenerative practices.
- ⇨ Provide or enhance technical and financial assistance for regenerative farming practices.

### Geographic Scope

Reduced pesticide and fertilizer use should be implemented across the entire Region with special emphasis on land in or adjacent to environmentally sensitive areas.

### Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, and NECCOG** – Convene multi-town canopy working groups, author or assist joint grant applications to fund plantings, align reduction of fertilizer or pesticide usage with climate action plans throughout the region.
- ⇨ **Select Boards/Chief Executive Office** – Adopt local fertilizer and pesticide use policies on town-owned lands.
- ⇨ **Conservation Commission** – Host community workshops and demonstration on integrated pest management and enroll public parks as demonstration sites.
- ⇨ **Massachusetts Department of Agricultural Resources** – Provide regenerative farming financial and technical assistance to local farmers.
- ⇨ **Connecticut Department of Agriculture** – Provide regenerative farming financial and technical assistance to local farmers.

- ⇨ **UMass Extension** – Conduct public education, host field days, and provide technical assistance on integrated pest management and regenerative agriculture.
- ⇨ **UConn Extension** – Conduct public education, host field days, and provide technical assistance on integrated pest management and regenerative agriculture.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Establish an inter-state working group on pesticide use and reduction.
- ⇨ Identify, map, and prioritize environmentally sensitive areas
- ⇨ Adopt local policies to ban pesticide and synthetic fertilizer use on school grounds.
- ⇨ Adopt local policies to ban pesticide and synthetic fertilizer use on municipally-owned properties.
- ⇨ Adopt local polices on utilizing Integrated Pest Management strategies.
- ⇨ Establish training and technical support programs to encourage municipalities, schools, and public landowners to adopt Integrated Pest Management policies.
- ⇨ Host workshops and outreach materials to educate the public of pesticide and fertilizer impacts and sustainable alternatives.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Continue hosting workshops and distributing outreach materials to increase pesticide impact and alternatives awareness.
- ⇨ Draft and pilot model ordinances phasing out the use of synthetic chemicals on cosmetic lawns
- ⇨ Begin outreach to pass statewide ban on pesticide usage for non-agricultural areas.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Continue outreach and advocacy for a statewide ban of pesticides for non-agricultural lands.
- ⇨ Create a dashboard of pesticide-free communities.
- ⇨ Create a dashboard of local farms utilizing regenerative farming practices across the region.

## Metrics for Tracking Progress

- ⇨ Number of municipal lots inventoried
- ⇨ Priority rankings of municipal lots inventoried.
- ⇨ Number of attendees at educational workshops and events.
- ⇨ Number of municipalities that adopt pesticide-free policies on municipally-owned lands.
- ⇨ Percentage support for statewide ban on pesticides
- ⇨ Amount of costs savings from reduced pesticide usage.

## Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 3,557 $MTCO_2e$, and by 2050 it will reduce emissions by 12,891 $MTCO_2e$. The estimated emissions reductions reflect a reduction of fertilizer use on 9,000 acres.

## Measure Costs

$8 - $14 Million

### Intersection with Other Funding Availability

- ⇨ Environmental Quality Incentives Program (EQIP), USDA NRCS
- ⇨ Conservation Stewardship Program, USDA NRCS
- ⇨ Regional Conservation Partnership Program, USDA NRCS
- ⇨ Conservation Innovation Grants, USDA NRCS
- ⇨ Urban Agriculture & Innovative Production, USDA
- ⇨ Pesticide Stewardship Program, US EPA
- ⇨ Northeast SARE Farmer & Partnership Grants, USDA NIFA
- ⇨ Partnerships for Climate-Smart Commodities, USDA
- ⇨ Climate Smart Agriculture Program, MDAR
- ⇨ Agricultural Food & Safety Improvement, MDAR
- ⇨ Composting Improvement, MDAR
- ⇨ Healthy Soils Program, MA EEA
- ⇨ Farm Transition Grant, CT DoAg
- ⇨ Climate Smart Agriculture & Forestry Grant, CT DoAg
- ⇨ Farmland Restoration, Climate Resiliency, & Preparedness, CT DoAg
- ⇨ Agricultural Enhancement, CT DoAg
- ⇨ Farmland Access Grant, CT DoAg
- ⇨ CT Land Conservation Council Climate Smart Land Stewardship Grants, CLCC

## Benefits Analysis: Agricultural, Natural, and Working Lands

In addition to a reduction in GHG emissions, these five measures are intended to improve air quality and reduce co-pollutants. Protecting existing trees and planting more trees in urban areas can boost air quality. Trees can remove particulate matter and gaseous pollutants from the surrounding air through interception and stomatal uptake.[151] Converting lawn to gardens and meadows helps lessen the need for frequent mowing, reducing smog-forming emissions from fossil-fuel powered landscaping equipment. If successfully implemented, these measures should help the Region realize the following co-pollutant reductions:

*Table 17. Agricultural, Natural, and Working Lands Co-Pollutant Reductions*

| Measures | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|
| ANWL1: Expand Network of Urban Tree and Shrub Coverage | **32** | **243** |
| ANWL2: Increase Permanently Protected Acres of Forestland | **195** | **779** |
| ANWL3: Convert Manicured Lawn into Climate-Smart Resiliency Gardens | **0.98** | **4.89** |
| ANWL4: Transform Underutilized Municipal Lands into Resiliency Pockets | **195** | **548** |
| ANWL5: Reduce Synthetic Pesticide and Fertilizer Usage | **225** | **817** |

Beyond GHG emissions and co-pollutant reductions, these measures can also impact the health and well-being, economics, ecology, and resilience of the region. Increasing nearby access to nature is linked with stress reductions, improved cardiovascular health, and higher overall well-being.[152] Expanding the native tree canopy can cool nearby building and streets through shading and evapotranspiration, lowering heat exposure and heat-related illness.[153] And utilizing integrated pest management practices and cutting the use of cosmetic pesticide use on public lands and school grounds reduces the exposure risk for children who are vulnerable to both acute and chronic pesticide effects.[154]

Economically, co-benefits can be achieved through avoided costs and asset value. As noted above, trees and strategic landscaping can cool nearby buildings, reducing building energy demand. Research also suggests that well-maintained street trees and landscaping can increase surrounding property values.[155] Ecologically, replacing monoculture turf and hardscape with native plantings, pollinator gardens, and mini-forests increases vegetation, providing food and habitat for native species. Research shows that even small-scale urban plantings can deliver measurable benefits for pollinators and beneficial insects.[156] Finally, rain gardens, native meadows, and tree plantings slow, infiltrate, and filter runoff, cutting pollutant loads and flood peaks while easing strain on stormwater systems.[157] Reducing synthetic fertilizer and pesticide usage, paired with these diversified native plantings also improves soil structure, organic matter, and nutrient cycling, enhancing drought tolerance and reducing erosion.[158]

*Table 18. Agricultural, Natural, and Working Lands Co-Benefits Summary*

| Measures | Improved Public Health Outcomes | Improved Economic Outcomes | Improved Ecological Systems | Improved Climate Resilience |
|---|---|---|---|---|
| ANWL1: Expand Network of Urban Tree and Shrub Coverage | X | X | X | X |
| ANWL2: Increase Permanently Protected Acres of Forestland | X | X | X | X |
| ANWL3: Convert Manicured Lawn into Climate-Smart Resiliency Gardens | X | X | X | X |
| ANWL4: Transform Underutilized Municipal Lands into Resiliency Pockets | X | X | X | X |
| ANWL5: Reduce Synthetic Pesticide and Fertilizer Usage | X | X | X | X |

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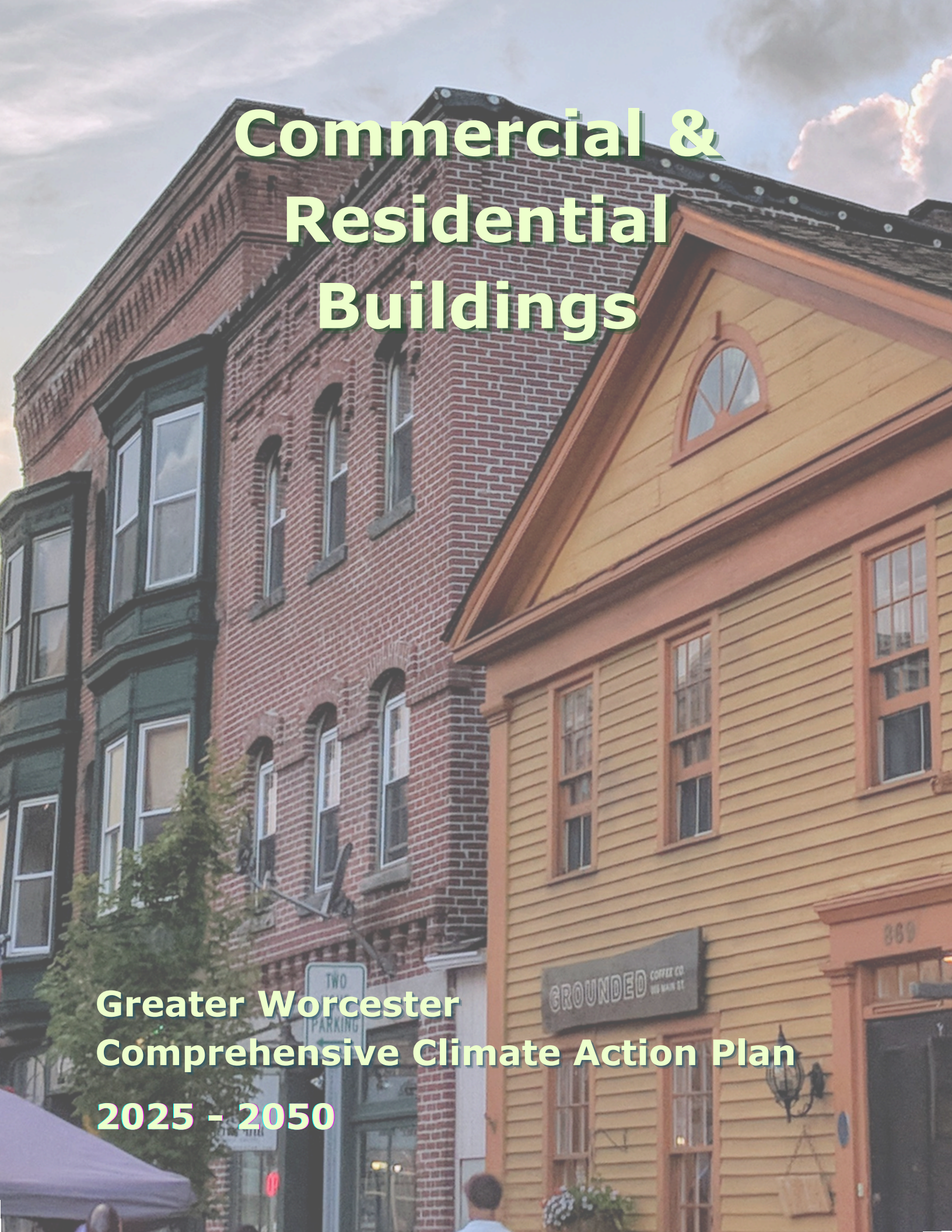
# Commercial & Residential Buildings




## Greater Worcester Comprehensive Climate Action Plan

## 2025 – 2050

## 3.5 Commercial and Residential Buildings

Buildings are a leading source of greenhouse gas emissions in the Region, representing a substantial share of the area's operational carbon footprint. Residential buildings alone contribute over 2.6 million metric tons of $CO_2$ equivalent ($MTCO_2e$) annually, largely from the direct combustion of fuel oil (1.07 million $MTCO_2e$), propane (385,000 $MTCO_2e$), and natural gas (515,000 $MTCO_2e$) for space and water heating. Electricity use adds another 507,000 $MTCO_2e$, with 25,000 $MTCO_2e$ from transmission and distribution losses. Altogether, operational emissions from residential buildings account for nearly 29% of total regional emissions, making this sector a key target for decarbonization through strategies such as electrification, deep energy retrofits, and weatherization.

Business-as-usual (BAU) projections further emphasize the importance of addressing building-related emissions. In 2021, combined emissions from residential, commercial, and electric power sources totaled approximately 41.5 million $MTCO_2e$, and while electric power emissions are expected to decline with grid decarbonization, emissions from residential and commercial fuel use are projected to remain flat or increase slightly through mid-century without further action. These trends suggest that without substantial policy shifts and investment, the building sector will continue to pose a persistent barrier to achieving regional climate goals. Tackling this challenge will require not only reducing operational emissions but also addressing upstream impacts such as embodied carbon in construction materials and supply chains. This underscores the need for integrated, lifecycle-based climate strategies for both existing buildings and new development.

These figures capture only part of the story. The inventory accounts for operational emissions produced from energy use during a building's life, but does not include embodied carbon, which refers to the emissions generated throughout the building lifecycle, including the extraction, manufacturing, and transportation of materials (like cement, steel, and insulation), as well as construction processes and eventual demolition. These upstream and downstream emissions, also known as supply chain or Scope 3 emissions, can account for 20–50% of a building's total carbon footprint, particularly in new construction or renovations involving carbon-intensive materials. Addressing building sector emissions, therefore, requires a dual strategy: reducing operational emissions through retrofits and electrification, and minimizing embodied carbon by reusing existing buildings, sourcing low-carbon or recycled materials, and implementing lifecycle-based design and procurement standards. A holistic approach that encompasses both operational and embodied emissions is crucial for achieving long-term carbon-neutrality goals and fostering a more energy-efficient, and resilient built environment.

*Table 19. Commercial and Residential Buildings Sector Measure Summary*

| Measures | GHG Emission Reductions in 2030 Compared to the BAU ($MTCO_2e$) | GHG Emission Reductions in 2050 Compared to the BAU ($MTCO_2e$) | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|---|---|
| CRB1: Shift Settlement Patterns through Land Use, Zoning, and Transit Integration to Promote Walkable, Mixed-Use Communities. | 16,607 | 32,168 | 3,921 | 4,732 |
| CRB2: Weatherize, deep retrofit, and electrify the existing building stock for optimum use of energy. | 22,497 | 64,275 | 19 | 53 |
| CRB3: Promote Circular Construction, Emphasizing Deconstruction and Material Reuse. | 588 | 2,939 | 13 | 63 |
| CRB4: Mainstream Sustainable Materials and Green Construction Practices. | 2,322 | 9,288 | 47 | 114 |
| CRB5: Strengthen Codes, Incentives, and Community Engagement to Support the Net-Zero Built Environment | 512,032 | 1,354,800 | 355 | 943 |

## CRB1: Shift Settlement Patterns through Land Use, Zoning, and Transit Integration to Promote Walkable, Mixed-Use Communities

This measure proposes a transformative shift in regional development patterns by encouraging compact, transit-connected, and walkable communities across the Region. The goal is to reduce vehicle miles traveled (VMT) by 30–40% and limit greenfield development by 70–80% through coordinated land use and transportation planning.[159] Worcester County, where over 75% of land remains undeveloped, faces a critical decision point: continue with carbon-intensive sprawl or strategically direct growth toward areas with existing infrastructure.[160] This measure promotes the latter by advancing mixed-use zoning, Transit-Oriented Development (TOD), and smart growth approaches that protect forests, farmlands, and natural carbon sinks.

The measure prioritizes rail-served communities such as Worcester, Grafton, Fitchburg, Westborough, Leominster, Shirley, and Ayer, where existing infrastructure and transit access can support higher-density, mixed-income housing. Strategic zoning reform and development incentives will concentrate new growth in town and village centers, reducing reliance on personal vehicles and curbing emissions from both transportation and building operations.[161] Infill and brownfield redevelopment will be paired with protections for open space through tools like cluster development, growth boundaries, and Transfer of Development Rights (TDR) programs. This approach directly addresses local air pollution concerns, especially in marginalized communities disproportionately impacted by vehicle and construction-related emissions.[162]

By integrating land conservation, housing equity, and low-emission transportation, this strategy supports a holistic vision of regional sustainability. Reducing sprawl lessens the need for new roads, utilities, and energy infrastructure, resulting in long-term cost savings and environmental benefits. Cleaner air, lower per capita emissions, and reduced habitat fragmentation strengthen both public health and ecological resilience.[163] With clear adoption targets—25% of municipalities by 2035, 50% by 2040, and full implementation by 2050—this measure builds a sustainable foundation for climate action and regional livability.

### Key Objectives

- ⇨ Encourage adoption of mixed-use zoning and Transit-Oriented Development (TOD) in at least 25% of municipalities by 2035 and 50% by 2040, with full adoption in priority centers by 2050.
- ⇨ Facilitate the implementation of cluster development, growth boundaries, and Transfer of Development Rights (TDR) programs in 50% of municipalities by 2040 to reduce greenfield development by 70–80%.
- ⇨ Encourage municipalities to prioritize infill and brownfield redevelopment, aiming to reuse or redevelop at least 30% of vacant or underutilized parcels in designated growth areas by 2040.
- ⇨ Facilitate local zoning and policy reforms by providing technical assistance, model bylaws, and funding support to at least 50 municipalities across the Region by 2030.
- ⇨ Encourage cross-sector regional coordination to align land use, housing, and transportation plans, aiming to reduce regional vehicle miles traveled (VMT) by 30–40% by 2050.

## Geographic Scope

This measure applies across the Region. Two focus areas are:

- Town and village centers with transit access (e.g., Worcester, Grafton, Fitchburg, Leominster, Westborough, Leominster, Shirley and Ayer), high-growth towns facing development pressure (e.g., Shrewsbury, Westborough, Auburn, Southbridge), designated development districts and Priority Development Areas (CMRPC, MRPC, NECCOG), and brownfield or underused parcels in core communities for cleanup and compact redevelopment.
- Greenfield areas at risk of sprawl, especially rural and semi-rural towns.

## Implementation Authority and Responsibilities

- ⇨ **MA Executive Office of Energy and Environmental Affairs (EEA)** – Provide funding, regulatory guidance, and program oversight for land conservation, smart growth, and building energy use to advance GHG reduction goals
- ⇨ **CT Department of Energy and Environmental Protection (CT DEEP)** – Provide funding, regulatory oversight, and technical support for energy efficiency, land conservation, and climate resilience planning in Connecticut communities
- ⇨ **MA Department of Environmental Protection (MassDEP)** – Oversee brownfield cleanup, enforce environmental regulations, and guide stormwater and emissions management to support sustainable redevelopment
- ⇨ **CT Department of Economic and Community Development (CT DECD)** – Support brownfield redevelopment, smart growth, and infrastructure investments to align development with climate and economic goals
- ⇨ **Municipal Planning Boards, Conservation Commissions, Selectboards** – Adopt zoning reforms, manage permitting and comprehensive planning, and integrate climate resilience and emissions reduction into local codes and plans.
- ⇨ **CMRPC, MRPC, NECCOG** – Facilitate implementation of climate-aligned bylaws, support transit-oriented development, and provide technical assistance on policies such as TDR, cluster zoning, and stormwater management.

## Implementation Timelines and Milestones

### Short Term Actions, Years 2026 - 2030

- ⇨ Support community outreach and education efforts across the region to build awareness of the climate, pollution, and affordability benefits of compact, mixed-use development and land conservation.
- ⇨ Assist 3–5 municipalities, focusing on rail-served communities, in launching TOD zoning and village center revitalization pilots, offering technical guidance on zoning overlays, visualization tools, and stakeholder engagement.
- ⇨ Partner with local academic institutions to co-create a "Reimagining Village Centers" studio program, engaging residents and local leaders in visioning, tactical urbanism, and design of infill redevelopment strategies.
- ⇨ Work with municipalities and MassDEP to identify and initiate 2–3 brownfield-to-housing or mixed-use redevelopment pilot sites, focusing on walkable parcels in towns such as Webster, Gardner, and Fitchburg, which have underutilized industrial sites, strong transit connections, and downtown areas suited for compact, mixed-use growth.

- ⇨ Facilitate early conversations with local officials and state partners to explore enabling authority for inter-municipal Transfer of Development Rights (TDR) frameworks and regional growth boundaries.
- ⇨ Develop and disseminate planning tools, including model bylaws, public engagement toolkits, best practices guide, and priority site maps to assist municipalities in exploring zoning updates and conservation strategies.
- ⇨ Expand multilingual and inclusive engagement practices to ensure participation from underserved communities, renters, and small business owners.
- ⇨ Provide technical assistance to evaluate outcomes, measure cumulative impacts on VMT, emissions, and land conservation, and develop regional success stories. Continue this throughout the next 25 years.
- ⇨ Start quantifying additional benefits from this measure as a short-term implementation action, in addition to measuring impacts on GHG and co-pollutant emissions reductions from this measure. This tracking and holistic systems analysis would help build a case for long-term implementation.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Support 20-25 municipalities in adopting compact zoning strategies—such as cluster development, growth boundaries, or TOD overlays—using insights from early pilots and tailored technical assistance.
- ⇨ Assist municipalities in applying for state and federal funding (e.g., MassWorks, brownfield remediation grants) to scale up successful brownfield reuse projects in designated village centers and commercial corridors.
- ⇨ Guide 3-5 municipalities in piloting regional TDR frameworks, simulating transfer mechanisms and conservation credits in collaboration with local land trusts and planning boards.
- ⇨ Coordinate a Compact Growth Peer Cohort, providing workshops, data-sharing, and peer learning for municipalities navigating similar land use challenges.
- ⇨ Provide staff support and training to local boards and departments to ensure capacity for zoning implementation, infrastructure planning, and code reform.

**Long Term Actions, Years 2040–2050**

- ⇨ Facilitate broader regional adoption of growth boundaries, cluster zoning, and coordinated infill strategies, with the goal of reaching 50% of municipalities in the Region.
- ⇨ Provide technical and legal support for the implementation of regional or inter-municipal TDR banks (pending enabling legislation).
- ⇨ Support municipalities in updating local master plans and zoning codes, institutionalizing compact growth and land conservation practices.
- ⇨ Assist municipalities in integrating brownfield reuse and infill development into broader housing and climate strategies, ensuring alignment with GHG reduction targets.
- ⇨ Guide municipalities through the final phase of adoption, ensuring region-wide implementation of compact growth, TOD, and open space protection strategies.
- ⇨ Support the creation of long-term guidance tools, including shared permitting templates, regional growth boundary maps, and a regional compact development best practices report.

## Metrics for Tracking Progress

- ⇨ Number of municipalities adopting TOD, smart growth overlays, compact zoning ordinances, or similar local policies

- ⇨ Acres of greenfield land conserved through zoning, TDR programs, or conservation easements
- ⇨ Number of brownfield sites redeveloped for housing, mixed-use, or community-serving purposes
- ⇨ Vehicle miles traveled (VMT) per capita by municipality or subregion
- ⇨ Number of municipalities with established growth boundaries, cluster development bylaws, or TDR programs
- ⇨ Change in share of new development occurring in designated village centers, TOD zones, or infill areas
- ⇨ Public participation and stakeholder engagement activities

## Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 16,607 $MTCO_2e$, and by 2050 it will reduce emissions by 32,168 $MTCO_2e$. These estimates are based on decreased Vehicle Miles Traveled (VMT) resulting from compact, transit-oriented, and mixed-use development that encourages walking, biking, and public transit use while limiting greenfield sprawl and preserving natural carbon sinks. Additional co-benefits include improved air quality, reduced traffic congestion, enhanced walkability, and long-term protection of forests, wetlands, and farmland.

## Measure Costs

$49 - $61 Million

## Intersection with Other Funding Availability

- ⇨ EPA Brownfields Grants, US EPA
- ⇨ Massachusetts Community One Stop for Growth, MA EOHLC
- ⇨ MassDevelopment Brownfields Redevelopment Fund, MassDevelopment
- ⇨ District Local Technical Assistance (DLTA), MA DHCD/RPAs
- ⇨ Planning Assistance Grants, MA EEA
- ⇨ Complete Streets Funding Program, MA DOT
- ⇨ Connecticut Brownfield Remediation & Revitalization Program, CT DECD
- ⇨ Connecticut Regional Planning Incentive Account (RPIA), CT OPM
- ⇨ Local Capital Improvement Plans (CIPs), Individual Municipalities
- ⇨ Municipal Brownfield Revolving Funds, Select Municipalities
- ⇨ Design Studio for Social Intervention, Barr Foundation
  Examples: Greater Worcester Community Foundation, Enterprise Community Partners
- ⇨ The 11th Hour Project, The Schmidt Family Foundation

## Case Study: Devens, MA Redevelopment

Devens, Massachusetts, a former military base repurposed for civilian use, exemplifies how semi-rural communities can embrace compact, low-emissions development. Guided by the 1994 Reuse Plan and overseen by MassDevelopment, Devens has concentrated residential, commercial, and civic uses in walkable, village-scale nodes while permanently protecting over 1,400 acres of open space through conservation easements and clustering requirements.[164] This strategy minimized greenfield development, reduced infrastructure costs, and preserved critical natural systems.

The Unified Development Bylaw encourages infill, adaptive reuse, and energy-efficient construction while streamlining permitting for projects aligned with sustainability goals.[165] Devens includes a connected street network, sidewalks, bikeways, and employer-supported shuttles linking to the Fitchburg MBTA station.[166] These features have helped lower per capita Vehicle Miles Traveled (VMT) and supported emissions reductions through green building practices, large-scale solar installations, and LEED-certified campuses.[167] However, gaps remain: limited transit frequency, auto-oriented employment sites, and the lack of full municipal governance constrain long-term social equity and regional integration.[168]

Despite these challenges, Devens now houses more than 1,800 residents and 100 businesses employing over 5,000 people, offering a replicable model for post-industrial municipalities seeking climate-aligned growth. Its approach demonstrates how state partnerships, brownfield reuse, and compact land use strategies can advance rural economic development while reducing environmental impacts.

## CRB2: Weatherize, deep retrofit, and electrify the existing building stock for optimum use of energy

Upgrading existing buildings across the Region is one of the most cost-effective and impactful strategies to reduce emissions, lower public energy costs, and improve resilience. Buildings account for over 30% of greenhouse gas emissions in Massachusetts, with space heating — still dominated by oil, gas, and propane, making up nearly 60% of building energy use.[169] In Worcester County, over half of residential buildings were built before 1980, predating modern energy codes, while several of the public K–12 schools were constructed before 1970, and many of them need extensive retrofitting to meet contemporary heating and cooling challenges.[170] Many town halls, libraries, and fire stations across the Region are still heated by outdated systems, resulting in high operating costs and avoidable emissions.[171]

Retrofitting these buildings, through envelope improvements, high-efficiency electric HVAC and hot water systems, energy management tools, and solar + storage, reduces energy use by 30–60% in many cases[172] while enhancing comfort and usability. Upgrades to public facilities pay off in operational savings and ensure that essential buildings, such as schools, emergency shelters, and town offices, are climate-ready and resilient. Moreover, retrofitting existing buildings is generally faster and less resource-intensive than new construction and helps preserve embodied carbon, historic character, and community continuity.[173] It also avoids sprawl-related emissions by concentrating investment in already-developed areas.

This measure proposes a regional, phased approach: prioritize high-energy-use public buildings first, use joint procurement and bundled energy performance contracts to lower costs, and coordinate through Regional Planning Agencies (RPAs) to provide support, especially for smaller towns. Capital improvement plans should align with energy goals, and public building renovations should be required to meet updated performance standards.

Ultimately, investing in existing buildings is a smart policy. It leverages what communities already own, avoids the carbon and costs of demolition and new construction, strengthens local trades and supply chains, and delivers energy equity by reducing burdens in under-resourced areas. The Region can lead by example—modernizing its civic infrastructure while laying the groundwork for a more resilient and inclusive energy future.

### Key Objectives

- ⇨ Facilitate energy benchmarking and building assessments across all 79 municipalities through RPA-led data collection, analysis, and technical guidance to help municipalities identify priority public buildings, and adopt a streamlined process for retro-commissioning, weatherization, and electrification in alignment with state decarbonization and resilience goals.
- ⇨ Support joint planning, procurement, and implementation by having RPAs or Councils of Government assist municipalities, particularly those with limited staff capacity, access shared energy services, contractor pools, and project delivery tools to streamline and scale local actions.
- ⇨ Align local building upgrades with state programs and capital planning through RPA consultation, helping municipalities integrate energy and electrification goals into Capital

Improvement Plans and facilitating access to Mass Save, Green Communities, and other state-administered funding.

- ⇨ Promote retrofit incentives and technical support for private-sector buildings, with RPAs assisting municipalities in engaging property owners and connecting them to available programs such as PACE, IRA tax credits, and Connecticut Green Bank resources in eligible municipalities.
- ⇨ Strengthen regional workforce capacity and municipal readiness by having RPAs coordinate with state workforce agencies, technical schools, and unions to expand training in building decarbonization, while assisting municipalities, especially small towns, with permitting, funding access, and contractor engagement.
- ⇨ Streamline procedures to encourage adaptive reuse and building retention, with RPAs supporting municipalities in reviewing and updating local permitting, zoning, and code enforcement to facilitate cost-effective building upgrades and reduce regulatory barriers to reuse.
- ⇨ Prevent unnecessary demolition and preserve embodied carbon by promoting the reuse of existing structures, with RPAs providing municipalities with technical guidance, model policies, and case studies that support life-cycle assessments and prioritize retrofit over new construction where feasible.
- ⇨ Advance regionwide adoption and equitable implementation by having RPAs facilitate shared planning frameworks, track progress, and replicate successful models (e.g., Green Communities), ensuring consistent support, resources, and funding across all municipalities.

## Geographic Scope

This measure will be implemented across the Region.. Primary areas of focus include the service regions of the Central Massachusetts Regional Planning Commission (CMRPC), Montachusett Regional Planning Commission (MRPC), and Northeastern Connecticut Council of Governments (NECCOG).

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, NECCOG** – Facilitate implementation of climate-aligned bylaws and local capacity building, coordinate joint procurement, contractor engagement, GHG tracking, and funding access; provide permitting and technical assistance to municipalities with limited staff capacity.
- ⇨ **MA Department of Energy Resources (DOER), Massachusetts School Building Authority (MSBA), Division of Capital Asset Management and Maintenance (DCAMM)** – Align funding criteria, technical guidance, and procurement standards to prioritize adaptive reuse, weatherization, and electrification of public buildings.
- ⇨ **Board of Building Regulations and Standards (BBRS), Massachusetts Historical Commission (MHC)** – Streamline code compliance and permitting for retrofit and historic reuse projects.
- ⇨ **Massachusetts Clean Energy Center (MassCEC)** – Expand workforce training, provide grants for demonstration projects, and coordinate retrofit-first pilot programs.
- ⇨ **CT Department of Energy and Environmental Protection (CT DEEP)** – Integrate building reuse and retrofits into state climate goals, provide guidance, and align funding for municipal upgrades.
- ⇨ **Connecticut Green Bank and C-PACE** – Expand financing and grant programs to include public-sector reuse and electrification projects.

- ⇨ **Regional Vocational Schools, Community Colleges, Labor Unions** – Deliver training in weatherization, HVAC electrification, and energy auditing; support apprenticeship standards tied to federal funding.
- ⇨ **Worcester Community Housing Resources, NeighborWorks, Worcester Green Jobs Coalition** – Conduct outreach and tenant education in EJ communities, administer demonstration retrofits, and leverage foundation funding for equitable implementation.
- ⇨ **National Grid - Massachusetts, Eversource - Connecticut, ESCOs, and PACE Providers** – Deliver energy efficiency incentives, technical assistance, grid planning for electrification, and performance-based retrofit financing to scale upgrades without large upfront municipal costs.
- ⇨ **CT Office of Policy and Management (OPM), State Historic Preservation Office (SHPO)** – Embed reuse priorities in capital planning and streamline permitting for energy-efficient upgrades of historic buildings.
- ⇨ **Massachusetts and Connecticut State Legislatures** – Enact "reuse and retrofit first" mandates, create or expand incentives (Green Communities, Mass Save, municipal retrofit grants), authorize regional procurement, and require life-cycle carbon assessments for public buildings.
- ⇨ **Municipal Governments (Select Boards, Planning Boards, Conservation Commissions, City Councils)** – Integrate reuse and electrification into Capital Improvement Plans, adopt demolition delay ordinances or reuse incentives, streamline permitting, and engage RPAs for technical support.
- ⇨ **U.S. Department of Energy (DOE), Environmental Protection Agency (EPA), Department of Housing and Urban Development (HUD)** – Provide grants (EECBG, CDBG), tools (ENERGY STAR Portfolio Manager, emissions calculators), and technical guidance to support retrofits and equitable building decarbonization.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 - 2030**

- ⇨ Assist 30 – 40 municipalities in expanding participation in Mass Save and C-PACE programs to access technical support and incentives for energy assessments, weatherization, retro-commissioning, and electrification in public buildings.
- ⇨ Support early reuse and retrofit efforts through programs such as the Green Communities Program and Connecticut Green Bank financing, helping municipalities undertake initial projects in high-priority buildings like schools, libraries, and town halls.
- ⇨ Facilitate a comprehensive regional assessment of public building stock to help municipalities identify suitable candidates for reuse and deep energy upgrades, using available tools and resources from Mass Save, Green Communities, and regional partners.
- ⇨ Enable Regional Planning Agencies (RPAs) to provide shared services, including procurement support, contractor coordination, and funding navigation, to assist smaller towns in accessing existing incentive programs and federal resources (e.g., IRA).
- ⇨ Encourage municipalities to integrate reuse and electrification goals into Capital Improvement Plans (CIPs) and local policy updates, while supporting pilot projects that demonstrate practical pathways to building reuse and energy efficiency.
- ⇨ Initiate workforce readiness efforts through partnerships with technical schools, RPAs, and MassCEC, or equivalent entities in CT, to ensure local contractor availability for retrofit projects.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Facilitate expansion of reuse and electrification projects across at least 70% of municipal buildings, using outcomes from early projects to assist municipalities in streamlining permitting, planning, and procurement.
- ⇨ Encourage state program administrators (e.g., DOER, Green Bank) to consider enhancing program flexibility and incentivizing reuse-focused retrofits, particularly for older and historically significant buildings.
- ⇨ Assist RPAs in establishing regional coordination frameworks to help municipalities scale retrofits, share contractor resources, and access tailored technical assistance for complex reuse scenarios.
- ⇨ Support municipalities in applying life-cycle carbon assessments to public building projects, with guidance from state agencies and RPAs, to promote reuse and reduce emissions.
- ⇨ Facilitate outreach to 60-70% private-sector building owners, particularly in downtowns and village centers, to promote voluntary participation in retrofit and reuse programs, with support from PACE, Green Bank, and IRA-based incentives.

**Long Term Actions, Years 2040–2050**

- ⇨ Help municipalities complete reuse, weatherization, and electrification upgrades for remaining eligible public buildings, including auxiliary and structurally complex facilities.
- ⇨ Ensure continued access to funding from Mass Save, Green Communities, Connecticut Green Bank, and other programs, and apply lessons learned to improve ongoing retrofit projects.
- ⇨ Assess regional outcomes such as emissions reductions, cost savings, and workforce impacts to refine policies and guide future building decarbonization programs.
- ⇨ Support municipalities in maintaining net-zero operations for public buildings by integrating reuse and electrification into planning, procurement, and facility management.
- ⇨ Assist local and regional partners in embedding reuse-focused planning frameworks to secure long-term access to resources, technical guidance, and support beyond 2050.
- ⇨ Coordinate building reuse initiatives with resilience planning so upgraded buildings can serve multiple community roles, including emergency preparedness.

## Metrics for Tracking Progress

- ⇨ Number of municipal buildings assessed for reuse and energy upgrades
- ⇨ Number of public buildings weatherized, retro-commissioned, or electrified
- ⇨ Square footage of building stock reused or upgraded (versus demolished)
- ⇨ Estimated GHG emissions avoided through reuse, weatherization, and electrification ($MTCO_2e$)
- ⇨ Number of municipalities participating in incentive programs (Mass Save, Green Communities, C-PACE, CT Green Bank)
- ⇨ Number of local policies adopted to support reuse and retrofitting

## Quantified GHG Emission Reduction

By 2030, this measure will reduce emissions by 22,497 $MTCO_2e$, and by 2050 it will reduce emissions by 64,275 $MTCO_2e$, representing roughly 4 to 5% of BAU building-sector emissions. These reductions are based on decreased municipal natural gas and heating oil use (35% by 2030, 60% by 2040, and 100% by 2050) in line with Climate Leader Community Roadmap guidance, with increased electricity demand met by renewable sources. Additional co-benefits include reduced $NO_x$ and $SO_2$ emissions from lower fuel combustion, preserved embodied carbon through building reuse, and long-term cost and climate benefits for municipalities.

### Measure Costs

$5.4 - $7.9 Billion

### Intersection with Other Funding Availability

- ⇨ PACE Financing (Private Capital), MassDevelopment
- ⇨ Energy Performance Contracts, Energy Service Companies (ESCOs)
- ⇨ Mass Save Municipal Pathway Program, MA Energy Efficiency Service Providers
- ⇨ Green Communities Competitive Grants, MA DOER
- ⇨ Accelerated Repair Program, MA MSBA
- ⇨ PACE Financing, MassDevelopment
- ⇨ C-PACE Program, CT Green Bank
- ⇨ Energy Efficiency Fund, CT DEEP
- ⇨ School Construction Grants, CT DAS
- ⇨ Utility Incentive Programs, Eversource / United Illuminating (UI)
- ⇨ Climate & Energy Grants, Barr Foundation
- ⇨ Climate Resilience & Urban Opportunity, Kresge Foundation
- ⇨ Buildings & Clean Energy, Energy Foundation
- ⇨ Community Project/Planning Grants, Greater Worcester Community Foundation / Hartford Foundation for Public Giving

### Case Study: Ithaca, NY Electrification

Ithaca, New York (population: 32,000), committed to electrifying 100% of its building stock—including all public, residential, and commercial buildings—by 2030. Under its Green New Deal, Ithaca launched an ambitious building decarbonization strategy focused on deep energy retrofits, weatherization, and full electrification using air-source heat pumps, alongside solar PV and battery storage for resilience and cost control.[174] The city began with municipal buildings to lead by example and create a scalable model for the entire community.

*The Financing and Implementation Model:* To implement this citywide initiative, Ithaca adopted a public-private partnership model that leverages private capital, aggregated demand, and third-party expertise. The city partnered with BlocPower, a climate tech company specializing in building electrification, to manage assessment, project delivery, and financing. Together, they created a $100 million fund using private investment and federal incentives to finance retrofits with no upfront costs for property owners, including municipal entities.[175] Retrofit projects are aggregated into a portfolio, which allows for bulk procurement of materials and labor, reducing per-building costs by up to 30%.[176] Property owners, including the city, repay costs over time via performance-based contracts or energy savings agreements. This structure allows Ithaca to scale retrofits quickly, ensure quality control, and focus city resources on coordination and equity, rather than technical project delivery.

*Key Lessons for the Region:* Some key lessons that could translate from this model are:

- ⇨ *Initiate with public buildings to lead by example:* Municipal facilities—such as schools, libraries, and town halls—can serve as early demonstration sites for energy retrofits and electrification, building momentum for broader adoption across the region.
- ⇨ *Facilitate regional aggregation of retrofits*: Coordinating building upgrades across multiple municipalities can reduce costs, streamline procurement, and enable access to larger-scale

financing. Regional Planning Agencies can support this aggregation and project management.

- ⇨ *Enable public-private implementation partnerships: Municipalities* can partner with energy service companies, green banks, or nonprofit intermediaries to secure funding, technical expertise, and scalable project delivery for building decarbonization.
- ⇨ *Promote performance-based financing tools:* No-upfront-cost models, such as energy savings agreements or on-bill repayment, can increase access to retrofit funding for municipalities and private property owners, particularly in resource-constrained communities.
- ⇨ *Support equitable workforce development:* Retrofit initiatives should integrate local job training and prioritize vulnerable communities, ensuring that building decarbonization efforts deliver broad economic and social benefits across the region.

Ithaca's integrated, finance-driven model offers a credible pathway for how small cities can decarbonize public buildings quickly while setting the stage for widespread private-sector retrofits. By using public-private partnerships, aggregated project delivery, and performance-based financing, the Region can adapt this model to accelerate net-zero buildings at scale.

## CRB3: Promoting Circular Construction in the Region, Emphasizing Deconstruction and Material Reuse

Greater Worcester can significantly reduce construction-related emissions and waste by adopting a circular construction model that prioritizes deconstruction, material reuse, and low-carbon building practices. Traditional demolition sends vast amounts of usable materials to landfills, wasting embodied carbon and contributing to pollution. Deconstruction, or the careful dismantling of buildings to preserve materials, offers a practical alternative, supporting climate goals, local economic development, and historic preservation. Municipalities across the region can lead by example, implementing policies such as reuse mandates for public projects, differential permit fees (lower for deconstruction), and material diversion targets. A phased approach beginning with pilot projects in larger municipalities such as Worcester, Fitchburg, and Leominster can help build local capacity, while regional reuse hubs, established through public-private partnerships, can centralize materials and create green jobs. These initiatives align with successful models in Ithaca, NY, and support emerging guidance from CR0WD's (Circularity, Reuse, Zero Waste Development) Local Government Policy Guide, which recommends combining regulatory tools with community engagement and market development.[177]

To scale circular construction, municipalities in the Region should also update procurement policies to prioritize reclaimed materials and adopt model deconstruction ordinances, as outlined in recent national and state-level toolkits.[178] Municipal support for pre-demolition materials audits, salvage assessment protocols, and training programs for contractors can further embed reuse practices. Integrating these efforts into zoning and permitting processes—such as requiring deconstruction plans or reuse feasibility studies—can ensure long-term compliance and cultural shift in the construction industry. Given that material reuse reduces project costs and environmental impacts, promoting circular construction is both an economic and climate-resilient strategy.[179] A regional working group can help coordinate best practices, standardize reporting metrics, and track diversion rates. Ultimately, promoting deconstruction and material reuse positions the Region as a leader in sustainable development while meeting state climate mandates and building a resilient local economy.[180]

### Key Objectives

- ⇨ Support municipalities in adopting deconstruction ordinances that integrate material audits, reuse plans, and permit incentives, building the regulatory foundation for a circular construction system.
- ⇨ Co-create a region-wide system for material reuse—including safe storage, processing, distribution, and marketplace access—through public-private partnerships and coordinated infrastructure planning.
- ⇨ Establish standardized procurement, safety, and delivery protocols to ensure the reliable use of reclaimed and low-carbon materials in public projects across the region.
- ⇨ Build a regional workforce development system that offers training, certification, and job placement in deconstruction, material handling, and reuse logistics.
- ⇨ Develop and maintain a coordinated regional tracking and reporting system through RPAs to monitor material flows, measure reuse outcomes, and support continuous improvement and system-wide learning.

## Geographic Scope

The circular construction and material reuse measure will prioritize regional coordination, shared infrastructure, and local leadership across the Region.

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, NECCOG** – Lead regional coordination by drafting deconstruction ordinances, facilitating intermunicipal agreements for reuse hubs, standardizing procurement and material tracking, and supporting smaller towns with shared resources, technical assistance, and funding opportunities.
- ⇨ **Municipal Governments** – Adopt and enforce deconstruction policies, embed reuse targets in procurement, pilot showcase projects, revise permitting to incentivize deconstruction, and partner with contractors and reuse organizations to engage communities.
- ⇨ **MassDEP and EEA** – Provide regulatory guidance, funding, and policy integration; issue best practices for material diversion, offer grants, incorporate reuse into statewide decarbonization goals, and coordinate funding from federal and state sources.
- ⇨ **Massachusetts Legislature** – Strengthen circular construction through mandates and incentives, require deconstruction for state-funded projects, create tax credits for reclaimed materials, and fund reuse infrastructure and workforce programs.
- ⇨ **Private Sector Partners** – Operate reuse infrastructure, manage logistics, invest in reuse hubs and markets for salvaged materials, and provide deconstruction services to expand regional capacity.
- ⇨ **Nonprofit Organizations** – Run reuse warehouses and resale programs, lead local reuse initiatives, offer community workshops, and ensure equitable access to reclaimed materials.
- ⇨ **Vocational Schools and Unions** – Provide certification programs in deconstruction, material safety, and reuse logistics; partner with colleges and unions to prepare a skilled local workforce.
- ⇨ **Community-Based Organizations (CBOs)** – Engage residents and underrepresented groups, lead neighborhood-scale reuse projects, and foster equity, resilience, and community ownership within the reuse economy.

## Implementation Timelines and Milestones

### Short Term Actions, Years 2026 - 2030

- ⇨ Assess construction and demolition waste flows, existing reuse markets, and workforce capacity to guide system design.
- ⇨ Develop a model deconstruction ordinance and host regional workshops to prepare municipalities for adoption.
- ⇨ Identify and evaluate potential reuse hub sites through feasibility studies and partnership development with private and nonprofit organizations.
- ⇨ Pilot small-scale deconstruction projects in 2–3 municipalities to refine processes, gather data, and assess training needs.
- ⇨ Launch initial workforce training pilots with vocational schools and unions on deconstruction basics and material handling.
- ⇨ Collaborate with state agencies to define safety standards and reporting requirements for material tracking.
- ⇨ Begin legislative engagement to explore funding, incentives, and policy mandates.

- ⇨ Initiate public education campaigns and community engagement to build awareness and participation.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Support the adoption of deconstruction ordinances in at least 50% of municipalities and provide technical assistance with shared tools.
- ⇨ Establish and operate 1–2 regional reuse hubs for the collection, processing, and distribution of salvaged materials.
- ⇨ Standardize regional procurement policies to prioritize reclaimed and low-carbon materials in public projects.
- ⇨ Expand workforce development programs to a regional scale, ensuring inclusive access for underrepresented groups.
- ⇨ Deploy regional data systems to track material diversion, emissions reductions, and economic benefits.
- ⇨ Integrate circular construction targets into municipal climate action plans and zoning updates.
- ⇨ Explore and pilot financial incentives such as tax credits or procurement preferences to stimulate private reuse markets.

**Long Term Actions, Years 2040–2050**

- ⇨ Achieve adoption of deconstruction ordinances in all municipalities and update policies using performance data and feedback.
- ⇨ Expand reuse hub capacity, adding mobile or satellite units to serve smaller and rural communities.
- ⇨ Advance digital material exchange platforms to widen market access for builders, contractors, and residents.
- ⇨ Fully integrate circular construction practices into municipal permitting, procurement, and planning systems.
- ⇨ Achieve 90–100% material diversion in public projects and set targets for private-sector demolition.
- ⇨ Renew intermunicipal agreements and partnerships to sustain infrastructure and workforce pipelines.
- ⇨ Share outcomes and best practices at state and national levels; pursue innovation and new policy opportunities.
- ⇨ Continue community engagement, education, and collaboration on safety, quality, and performance standards.

## Metrics for Tracking Progress

- ⇨ Number of municipalities adopting deconstruction ordinances
- ⇨ Volume (tons) of construction and demolition (C&D) materials diverted from landfill to reuse
- ⇨ Number and capacity of operational reuse hubs and storage facilities
- ⇨ Participation rates in workforce training programs including number of trainees and certifications issued
- ⇨ Percentage of public construction projects using reclaimed or low-carbon materials
- ⇨ Estimated greenhouse gas (GHG) emissions avoided from material reuse (tons $CO_2e$)
- ⇨ Stakeholder engagement activities including number of public workshops, participants, and outreach campaigns
- ⇨ Reuse market activities including number of material transactions and value of reclaimed materials sold

## Quantified GHG Emission Reduction

By 2030, this measure will reduce 588 $MTCO_2e$, rising to 2,939 $MTCO_2e$ by 2050—less than 1% of BAU emissions but supporting waste and materials goals. Reductions are based on sustaining a 50% diversion rate of construction and demolition waste, with avoided methane and co-pollutant emissions ($NO_x$, $SO_2$) estimated at 13 MT in 2030 and 63 MT in 2050.

## Measure Costs

$200 - $225 Million

## Intersection with Other Funding Availability

- ⇨ Sustainable Materials Recovery Program (SMRP) Grants, MA DEP
- ⇨ Waste Reduction Innovation Grants (WRIG), MA DEP
- ⇨ CT Materials Management Infrastructure (MMI) Grant Program, CT DEEP
- ⇨ Environmental Grants, The Kresge Foundation

## Case Study: Stockholm's Circular Construction Pilot

Sweden's Scale Stockholm initiative demonstrates how cities can advance circular construction through localized pilot projects, multi-stakeholder collaboration, and strategic policy integration. The city established five district-level "transition arenas" to test circular practices such as deconstruction, reuse logistics, and sustainable procurement in partnership with residents, civil society, and businesses.[181] These arenas serve as innovation hubs where municipal leaders can pilot material recovery strategies and track environmental and social impacts before scaling region-wide. Stockholm embeds circular construction into its broader climate governance. Under its Climate Action Plan 2030 and Environment Programme 2030, the city aims to be climate-positive by 2040, with key measures including pre-demolition materials audits, lifecycle carbon assessments, and the prioritized use of reclaimed and low-carbon materials in public construction.[182] Stockholm's approach is informed by global and regional best practices, including the Nordic Network for Circular Construction, which highlights the importance of standardizing reuse protocols and coordinating infrastructure, policy, and market development.[183]

To support system-wide transformation, Stockholm's pilot initiatives are accompanied by stakeholder partnerships with academia, industry, and nonprofits. Institutions such as the IVL Swedish Environmental Research Institute and the city's urban development agencies collaborate on material tracking, reuse hub planning, and workforce readiness.[184] The city's Wood City project, a large-scale mass timber district, exemplifies its commitment to circularity by combining renewable and salvaged materials to reduce carbon and support livability.[185] These efforts align with global recommendations from the Stockholm+50 Global Roadmap for an Inclusive Circular Economy, which emphasize local action, multi-sector governance, and material flow tracking as critical levers for success.[186]

Four key lessons can be drawn from Stockholm's experience. First, begin with pilot projects in selected municipalities to test deconstruction protocols, develop reuse logistics, and generate implementation data. Second, integrate circular construction into existing climate action plans and public procurement systems to ensure consistency, scalability, and funding alignment. Third,

establish a regional circular construction council, similar to Stockholm's collaborative transition arenas, to convene municipalities, RPAs, nonprofits, and the private sector in a shared governance structure. Fourth, develop and standardize material tracking systems and reuse standards early in implementation, drawing from Nordic and global guidance to ensure safety, quality, and accountability.

## CRB4: Mainstreaming Sustainable Materials and Green Construction Practices

This strategy focuses on advancing sustainable materials and green construction practices, emphasizing passive design and energy modeling to reduce energy consumption. Key actions include revising procurement policies, prioritizing green design practices, implementing pilot programs for innovative materials, and creating municipal capacity to monitor and track progress toward reducing energy usage and net carbon emissions by 40% by 2045.

**Mainstreaming Sustainable Materials and Construction Practices**: This component focuses on incorporating sustainable materials and low-carbon construction methods in both public and private sector projects. Key actions include revising procurement policies to prioritize carbon-smart, locally sourced, and circular materials, along with encouraging the use of innovative solutions such as recycled steel, reclaimed wood, bamboo, and recycled plastics. Collaboration with state agencies will help incentivize the adoption of these materials through updated construction specifications and guidelines. The aim is to integrate sustainable materials into 30% of municipally and state-owned projects by 2035, scaling to 100% by 2050. This effort seeks to reduce embodied carbon emissions by 40% by 2045, supporting the global transition to a low-carbon economy.

**Mainstreaming Green Design and Energy Modeling Considerations:** This component focuses on embedding energy-efficient design principles and energy modeling into the planning and approval processes of all new constructions. Municipalities will be encouraged to incentivize green design by offering technical support for energy modeling during the design phase, ensuring the integration of passive design strategies such as natural ventilation, shading, and thermal mass. By promoting green building certifications, such as LEED, municipalities can recognize projects that meet high environmental performance standards. These actions will ensure that energy-efficient practices are incorporated from the outset, leading to long-term reductions in energy use and carbon emissions across both public and private sector developments.

Together, these components provide a comprehensive framework to significantly reduce the environmental impact of construction and foster a sustainable, low-carbon future.

### Key Objectives

- ⇨ Update procurement and design policies to prioritize low-carbon materials and green building practices so municipalities can directly reduce embodied and operational emissions in all new projects.
- ⇨ Integrate sustainable materials, passive design, and energy modeling into planning, permitting, and construction processes to ensure long-term reductions in energy use and lifecycle carbon impacts.
- ⇨ Implement targeted pilot projects to test and refine innovative materials and design approaches, helping communities reduce risk and accelerate broader adoption.
- ⇨ Build technical capacity among municipal staff, developers, and contractors so the region has the expertise needed to consistently implement sustainable construction practices.
- ⇨ Develop monitoring and reporting systems to track material use, energy performance, and emissions, ensuring accountability and guiding future policy improvements.
- ⇨ Expand municipal staffing and coordination capacity to support implementation, maintain consistent standards, and drive progress toward 2035, 2045, and 2050 climate targets.

## Geographic Scope

The geographic scope of this strategy includes all seventy-nine municipalities within the Region, served by CMRPC, MRPC, NECCOG.

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, NECCOG –** Facilitate implementation of climate-aligned bylaws, support transit-oriented development, and provide technical assistance on policies such as TDR, cluster zoning, and stormwater management.
- ⇨ **MA Executive Office of Energy and Environmental Affairs (EEA)** – Provide funding, regulatory guidance, and program oversight for land conservation, smart growth, and building energy use to advance GHG reduction goals
- ⇨ **CT Department of Energy and Environmental Protection (CT DEEP**) – Provide funding, regulatory oversight, and technical support for energy efficiency, land conservation, and climate resilience planning in Connecticut communities
- ⇨ **MA Department of Environmental Protection (MassDEP)** – Oversee brownfield cleanup, enforce environmental regulations, and guide stormwater and emissions management to support sustainable redevelopment
- ⇨ **CT Department of Economic and Community Development (CT DECD)** – Support brownfield redevelopment, smart growth, and infrastructure investments to align development with climate and economic goals
- ⇨ **Municipal Planning Boards, Conservation Commissions, Selectboards**– Adopt zoning reforms, manage permitting and comprehensive planning, and integrate climate resilience and emissions reduction into local codes and plans

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 - 2030**

- ⇨ Collaborate with MassDEP, RPCs, and municipalities to study sustainable materials, green building standards, and energy-efficient practices, informing procurement updates by 2030.
- ⇨ Revise state and municipal procurement policies by 2033 to prioritize low-carbon materials and green design in line with Massachusetts Stretch Energy Code and Connecticut energy policies.
- ⇨ Launch Pilot Programs, testing sustainable materials and green design methods in 2–3 municipalities by 2034.
- ⇨ Secure legislative or regulatory authority for implementation by 2034 for municipalities to adopt low-carbon materials and design standards.
- ⇨ Begin training municipal staff, contractors, and architects by 2030 to develop expertise in sustainable construction and green design.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Incorporate green building standards and energy modeling into municipal permitting by 2038 to ensure energy-efficient, low-carbon construction.
- ⇨ Establish three Regional Collaborative Hubs by 2039 to support municipalities with sustainable construction practices and energy-efficient technologies.
- ⇨ Develop integrated systems by 2042 to track GHG reductions, efficiency, and adoption of green design principles.

- ⇨ Scale successful pilot programs to 50% of municipalities by 2043, including renewable energy and advanced water management features.
- ⇨ Partner with local governments and state agencies to build public support for GHG reduction measures.
- ⇨ Develop grants, tax credits, and other funding strategies to support sustainable construction, complementing programs like Massachusetts' Mass Save and Connecticut's Energy Efficiency Fund.

**Long Term Actions, Years 2040–2050**

- ⇨ Ensure all new construction projects use green materials, sustainable design, and energy-efficient strategies by 2048, aligned with state and regional climate goals.
- ⇨ integrate monitoring by 2050 to track GHG reductions, energy efficiency, and adoption of green design practices.

## Metrics for Tracking Progress

- ⇨ Tracking GHG Emissions Reductions from Sustainable Construction Practices
- ⇨ Percentage of Public Sector Construction Projects Using Low-Carbon or Recycled Materials
- ⇨ Energy Efficiency Performance in New Construction Projects
- ⇨ Adoption of Green Design Standards by Municipalities
- ⇨ Integration of Green Design Principles in New Construction
- ⇨ Training and Capacity Building for Municipal Staff and Contractors in Sustainable Practices
- ⇨ Adoption Rate of Sustainable Building Practices from Pilot Programs
- ⇨ Implementation and Use of Monitoring Systems to Track GHG Reductions and Energy Efficiency

## Quantified GHG Emission Reduction

This measure is projected to reduce GHG emissions by approximately 2,322 $MTCO_2e$ in 2030 and 9,288 $MTCO_2e$ in 2050, compared to a business-as-usual (BAU) scenario. These reductions result from the use of low-carbon building materials and improved design practices that reduce embodied carbon in new construction. The model accounts for a very small number of new constructions across the region, and its impact is scalable with wider adoption.

## Measure Costs

$16 - $36 Million

## Intersection with Other Funding Availability

- ⇨ Green Communities Program, MA EEA
- ⇨ Energize Connecticut, CT DEEP
- ⇨ Regional Greenhouse Gas Initiative (RGGI), Multi-state collaborative
- ⇨ Massachusetts Clean Energy Center, MassCEC
- ⇨ Green Building Certification Programs (LEED, Passive House), USGBC

## CRB5: Strengthen Codes, Incentives, and Community Engagement to Support the Net-Zero Built Environment

Municipalities in Massachusetts and Connecticut will prioritize community engagement and education to normalize sustainable practices in new construction and major renovations, creating a culture of sustainability through collaboration, shared goals, and transparent communication. In Massachusetts, communities will adopt the Stretch Energy Code by 2035 or a specialized version by 2050 to align with net-zero goals, with flexible alternatives available where immediate adoption is not feasible. Connecticut municipalities will adopt energy-efficient standards aligned with best practices in the Connecticut State Building Code and programs like EnergizeCT, supported by incentives and the Connecticut Green Building Standard.

A key strategy will require energy and building energy modeling (BEM) for all large developments over 10,000 sq. ft., with public disclosure of performance metrics and projected carbon emissions, ensuring transparency and accountability. Flexible permitting systems with point-based bonuses will incentivize green, passive, and net-zero designs. Smart technologies, such as energy management systems, smart thermostats, and IoT (Internet of Things) devices, will optimize energy use, while municipalities will ensure 100% adoption of high-efficiency lighting by 2030 through LEDs and retrofits across all building types.

By 2035, all new residential appliances will be electric, expanding to all commercial appliances by 2045, transitioning away from fossil fuels. Buildings will increasingly use high-efficiency electric HVAC and geothermal systems to reduce emissions and improve resilience. Together, these measures will create an energy-efficient, net-zero built environment where sustainability is the standard, supported by engaged communities, informed developers, and coordinated municipal leadership.

### Key Objectives

- ⇨ Assist municipalities in Massachusetts and Connecticut with adopting the Stretch Energy Code by 2035 or a specialized version by 2050, providing flexible pathways to integrate sustainable design practices and materials that align with net-zero energy goals.
- ⇨ Guide municipalities in requiring energy and building energy modeling (BEM) for large developments (over 10,000 sq. ft.), ensuring that energy performance and carbon emissions projections are publicly disclosed to enhance transparency and accountability.
- ⇨ Help municipalities implement flexible permitting systems and point-based development bonuses that incentivize the adoption of green, passive, and net-zero building designs, promoting sustainable development practices.
- ⇨ Support the adoption of smart technologies, such as energy management systems and IoT devices, to help buildings optimize resource usage and reduce energy consumption.
- ⇨ Assist municipalities in ensuring the adoption of 100% high-efficiency lighting by 2030 and facilitate the transition to electric residential appliances by 2035 and commercial appliances by 2045.
- ⇨ Help municipalities transition buildings away from non-renewable energy sources by integrating high-efficiency electrical HVAC systems and geothermal solutions to reduce carbon emissions.

- ⇨ Support community education efforts to create widespread awareness and acceptance of sustainable practices, making energy-efficient, net-zero development the norm across municipalities through workshops, resources, and collaboration with local stakeholders.

## Geographic Scope

The geographic scope of this strategy includes all seventy-nine municipalities within the Region, served by CMRPC, MRPC, NECCOG.

## Implementation Authority and Responsibilities

- ⇨ **CMRPC, MRPC, NECCOG** – Facilitate energy code implementation, provide technical assistance to municipalities, support renewable energy integration and green building incentives, and coordinate data collection and progress tracking.
- ⇨ **Massachusetts Executive Office of Energy and Environmental Affairs (EEA)** and **Connecticut Department of Energy and Environmental Protection (DEEP)** – Set energy policies, enforce building codes, administer funding programs such as Green Communities and MassCEC, provide technical support, and ensure compliance with energy goals.
- ⇨ **Massachusetts Department of Environmental Protection (MassDEP)** – Provide funding for energy efficiency projects, support municipalities in adopting and tracking building energy codes, and ensure sustainable practices are integrated into local governance.
- ⇨ **Connecticut Green Bank** – Finance energy efficiency projects through programs like C-PACE and support local integration of renewable energy solutions.
- ⇨ **Municipal Governments** – Adopt energy codes, oversee efficiency projects, integrate sustainable practices into new developments, and use local energy managers to coordinate programs and meet sustainability targets.
- ⇨ **Utilities and Energy Providers (Eversource, National Grid, others)** – Deliver efficiency programs, rebates, incentives, and technical support for renewable energy and energy-saving technologies, while maintaining clean energy infrastructure.
- ⇨ **Contractors, Developers, and Builders** – Implement energy-efficient designs and retrofits, adopt high-efficiency lighting, HVAC, renewables, and smart technologies, and collaborate with municipalities to comply with codes and standards.
- ⇨ **Community Stakeholders and Advocacy Groups** – Lead outreach and education, engage residents and businesses, raise awareness of sustainability goals, and encourage participation in energy efficiency initiatives in partnership with municipalities.

## Implementation Timelines and Milestones

### Short Term Actions, Years 2026 - 2030

- ⇨ Assist municipalities in Massachusetts and Connecticut as they begin adopting the Stretch Energy Code or similar pathways, offering guidance on integrating sustainable design and materials.
- ⇨ Support energy code advocacy in Connecticut and help Massachusetts communities adopt the Stretch Energy Code by 2030 while preparing for specialized opt-in adoption by 2035.
- ⇨ Pilot energy modeling and public disclosure requirements for large developments (>10,000 sq. ft.) to ensure transparent energy performance and emissions reporting.
- ⇨ Initiate flexible permitting systems and development bonuses to encourage green, passive, and net-zero building designs.

- ⇨ Begin workforce and stakeholder training programs to build capacity for sustainable construction and energy-efficient practices.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Facilitate wider adoption of the Stretch Energy Code and specialized opt-in version across Massachusetts and transition Connecticut municipalities to comparable energy-efficient standards.
- ⇨ Expand and standardize energy modeling and public disclosure for all large developments to ensure accountability and transparency.
- ⇨ Refine and scale green building incentives and flexible permitting programs based on pilot results to improve effectiveness.
- ⇨ Promote integration of smart technologies (e.g., energy management systems, IoT devices) in new developments to optimize energy use.
- ⇨ Support the transition to 100% high-efficiency lighting in public and private buildings by 2035.
- ⇨ Establish regional collaborative hubs to provide ongoing technical support, data tracking, and knowledge sharing for municipalities.

**Long Term Actions, Years 2040–2050**

- ⇨ Help municipalities complete full adoption of the specialized Stretch Energy Code in Massachusetts and comparable standards in Connecticut by 2050.
- ⇨ Work with municipalities and various state and private agencies to advocate for the electrification of residential and commercial appliances, ensuring 100% adoption by 2045.
- ⇨ Continue expanding renewable energy integration through geothermal and high-efficiency HVAC systems in new construction and retrofits.
- ⇨ Expand community education and engagement initiatives to reinforce energy-efficient, net-zero development as the standard.
- ⇨ Evaluate and adjust energy modeling and disclosure requirements to address emerging technologies and regional needs.
- ⇨ Confirm all new and existing buildings meet energy-efficient, net-zero standards, and reset or assign new goals as needed to maintain climate targets.

## Metrics for Tracking Progress

- ⇨ Adoption of Energy Codes
- ⇨ Energy Modeling and Public Disclosure
- ⇨ Green Building Incentives and Flexible Permitting
- ⇨ Smart Technology Integration
- ⇨ High-Efficiency Lighting Adoption
- ⇨ Electrification of Appliances
- ⇨ Renewable and High-Efficiency HVAC Integration
- ⇨ Community Education and Engagement
- ⇨ Progress Toward Net-Zero Energy Buildings

## Quantified GHG Emission Reduction

By 2030, this measure is projected to cut 512,032 $MTCO_2e$, increasing to 1,354,800 $MTCO_2e$ by 2050—representing about 80–85% of BAU building-sector emissions. These reductions result from improved building codes, mandatory energy modeling, efficiency gains, electrification, and the addition of 19,628 fossil-free homes by 2030 and 47,107 by 2050.

### Measure Costs

$255 Million - $270 Million

### Intersection with Other Funding Availability

- ⇨ Green Communities Designation & Grant Program, MA DOER
- ⇨ Building Energy Efficiency Program, MassCEC
- ⇨ Energize Connecticut (EnergizeCT), CT DEEP
- ⇨ Municipal Energy Manager Grant, Mass Save
- ⇨ Regional Greenhouse Gas Initiative (RGGI), Multi-state collaborative

## Benefits Analysis: Commercial and Residential Buildings

The Commercial and Residential Buildings measures provide many co-benefits for the Greater Worcester Region beyond direct reductions in greenhouse gas emissions. Collectively, they strengthen regional health, economic resilience, equity, and long-term sustainability. All five measures will indirectly improve public health outcomes in the Region. Their implementation will reduce emissions of co-pollutants released from fossil fuel combustion for space heating, water heating, and general building operations. These co-pollutants, including nitrogen oxides ($NO_x$), sulfur dioxide ($SO_2$), and particulate matter, have direct local impacts on air quality and human health. The shift toward electrification, weatherization, sustainable materials, and compact development will significantly lower these harmful emissions. Specifically, the co-pollutant reductions associated with this sector's measure include:

*Table 20. Commercial and Residential Buildings Co-Pollutant Reductions*

| Measures | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|
| CRB1: Shift Settlement Patterns through Land Use, Zoning, and Transit Integration to Promote Walkable, Mixed-Use Communities. | 3,921 | 4,732 |
| CRB2: Weatherize, deep retrofit, and electrify the existing building stock for optimum use of energy. | 19 | 53 |
| CRB3: Promote Circular Construction, Emphasizing Deconstruction and Material Reuse. | 13 | 63 |
| CRB4: Mainstream Sustainable Materials and Green Construction Practices. | 47 | 114 |
| CRB5: Strengthen Codes, Incentives, and Community Engagement to Support the Net-Zero Built Environment | 355 | 943 |

All five building-sector measures will also lead to direct job creation co-benefits. Weatherization, deep retrofits, electrification, deconstruction, adaptive reuse, sustainable materials manufacturing, and energy code implementation will contribute to workforce expansion across skilled trades, green construction, energy auditing, deconstruction, and municipal planning.

Three of the measures (Weatherization and Electrification, Circular Construction, and Sustainable Materials) will lead to direct resilience co-benefits by improving building durability, enhancing passive survivability, reducing exposure to extreme temperatures, and preserving existing

structures. All five measures will deliver indirect climate resilience co-benefits by reducing climate hazards over time, lowering infrastructure strain, and expanding access to safer and healthier buildings.

Two measures (Weatherization and Electrification, and Strengthened Codes and Incentives) will also directly reduce energy costs for building owners and occupants. Efficiency upgrades, passive design, and thermal improvements decrease energy demand, while electrification reduces reliance on volatile fossil fuel markets. All five measures may yield indirect energy cost savings across the Region by minimizing peak demand, reducing long-term operating costs, and increasing access to clean energy technologies.

Potential disbenefits should be minimized through careful implementation. These include upfront retrofit costs, permitting delays for adaptive reuse, potential displacement during renovations, limited contractor availability, embodied carbon impacts of new construction if not controlled, and disproportionate implementation burdens on vulnerable communities. Targeted incentives, tenant protections, and equitable engagement strategies can help reduce these risks.

*Table 21. Commercial and Residential Buildings Co-Benefits Summary*

| Measures | Improved Public Health Outcomes | Job Creation | Improved Climate Resilience | Decreased Energy Costs |
|---|---|---|---|---|
| CRB1: Shift Settlement Patterns through Land Use, Zoning, and Transit Integration to Promote Walkable, Mixed-Use Communities. | X | X | X | X |
| CRB2: Weatherize, deep retrofit, and electrify the existing building stock for optimum use of energy. | X | X | X | X |
| CRB3: Promote Circular Construction, Emphasizing Deconstruction and Material Reuse. | X | X | X | X |
| CRB4: Mainstream Sustainable Materials and Green Construction Practices. | X | X | X | X |
| CRB5: Strengthen Codes, Incentives, and Community Engagement to Support the Net-Zero Built Environment | X | X | X | X |

# Commercial and Residential Buildings Endnotes

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# Industry

## Greater Worcester Comprehensive Climate Action Plan

## 2025 – 2050

## 3.6 Industry

The industrial sector contributes 24% of global GHG emissions, with Massachusetts industries emitting approximately 2.9 million metric tons of $CO_2e$ annually, about 8% of the state's total emissions In Worcester, legacy manufacturers such as Saint-Gobain and Norton Abrasives operate alongside rapidly growing biomanufacturers, including WuXi Biologics (189,500 sq ft facility, 250+ jobs) and Galaxy Life Sciences (246,000 sq ft, 300 jobs), reflecting the region's evolving industrial landscape.[187] As industrial growth accelerates, the Region intends to achieve net-zero industrial emissions by 2050, while also cultivating its identity as a regional hub for emerging green and blue industries, including clean energy, sustainable biomanufacturing, and Blue Economy.

To support this transition, the Region plans to expand Large Building Energy Reporting (LBER) to include industrial buildings over 18,000 sq ft by 2030 and 15,000 sq ft by 2035 in Massachusetts, with comparable thresholds phased in for Connecticut. Starting in 2040, the Region will pilot a voluntary decarbonization program for industrial buildings over 15,000 sq ft, with the intent to make such plans mandatory by 2050.[188] These steps are designed to increase transparency, foster energy efficiency, and provide businesses with clear, predictable pathways for emissions reduction. Additionally, a regional circularity accelerator is anticipated to launch by 2030, fostering partnerships between industry leaders, chambers of commerce, and institutions. This initiative will promote material efficiency, conduct waste flow audits, and support the creation of shared infrastructure for reuse, recycling, and sustainable procurement. By 2040, the Region aims to have comprehensive systems in place to enable industries to divert 60% of solid waste from landfills or incineration by 2050, supported by tax incentives and grant programs.[189] The Region also plans to explore overlay zoning for industrial corridors, encouraging the development of net-zero industrial zones that integrate clean energy systems like microgrids, water reuse, and circular resource flows. These zones are expected to serve as models for industrial sustainability, contributing to an additional 5% reduction in GHG emissions while promoting best practices and innovation.[190]

Several of the measures described in the energy, building, waste, and building sectors have definite co-benefits for the industry sector. The state-level and regional push towards electrification, the implementation of EV infrastructure, an emphasis on a circular economy, and green building mandates will likely have co-benefits in this sector. By taking a facilitative and collaborative approach, centered on technical assistance, financial incentives, and stakeholder engagement, the Region aims to support industry partners in designing tailored decarbonization pathways. These efforts align with the Massachusetts Clean Energy and Climate Plan, ensuring that industrial decarbonization strengthens, rather than hinders, regional economic development and innovation.

*Table 22. Industry Sector Measure Summary*

| Measures | GHG Emission Reductions in 2030 Compared to the BAU ($MTCO_2e$) | GHG Emission Reductions in 2050 Compared to the BAU ($MTCO_2e$) | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|---|---|
| I1: Mandate GHG Emissions Reporting and Decarbonization Planning for Large Buildings | 1,209 | 3,225 | 1 | 3 |
| I2: Establish an Industrial Material Efficiency and Waste Circularity Network | 469 | 2,812 | 10 | 60 |
| I3: Improve Electrification and Energy Efficiency of Industrial Operations and Systems | 12,095 | 32,252 | 10 | 26 |

## I1: Mandate GHG Emissions Reporting and Decarbonization Planning for Large Buildings

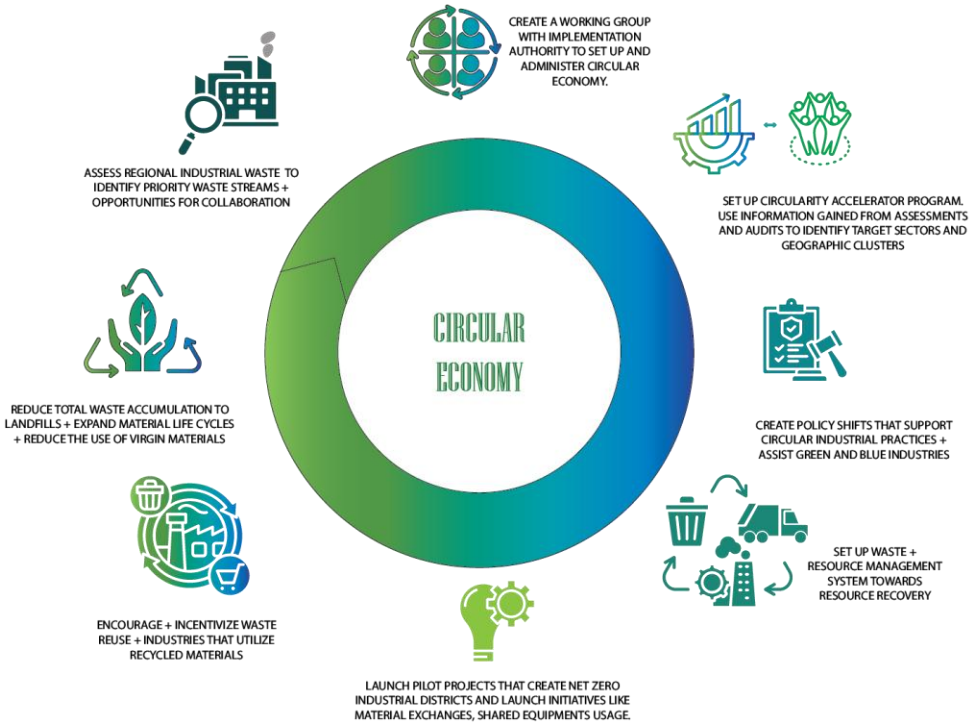


*Figure 18: Kick-starting a Regional Circular Economy towards encouraging Waste-Reuse, Industrial Collaboration, and the rise of new Green + Blue Industries*

This strategy seeks to accelerate industrial decarbonization in the Greater Worcester Region and northeastern CT by mandating greenhouse gas (GHG) emissions reporting and long-term planning for reduction in large industrial buildings. Massachusetts' state-level Large Building Energy Reporting (LBER) law requires disclosure of energy usage for buildings 20,000 sq ft and larger, beginning in 2025, with utilities reporting most data and building owners supplementing with additional sources as needed.[191] Under the proposed framework, LBER would be expanded in Massachusetts to include industrial buildings over 18,000 sq ft by 2030, and over 15,000 sq ft by 2035. In Connecticut, a parallel program would be implemented, with thresholds of 20,000 sq ft by 2030, reducing to 18,000 sq ft by 2035, and 15,000 sq ft by 2040, aligning with the state's broader decarbonization momentum.[192]

To complement the reporting requirements, a voluntary decarbonization planning program would be introduced for industrial buildings over 15,000 sq ft, beginning by 2040, which would become mandatory by 2050. This plan would outline energy-efficiency upgrades, electrification pathways, renewable energy integration, and emissions mitigation steps. The public disclosure of these sustainability plans and periodic progress reports would enhance transparency and industrial accountability, providing clarity and encouraging investment in sustainable strategies.

Together, this phased framework establishes both the foundation for consistent emissions data tracking and a pathway for strategic decarbonization. It also enables regulatory and incentive-based support, such as technical assistance, workforce training, and financial mechanisms, to foster adoption and innovation. Over time, the mandate will cultivate a culture of environmental responsibility within the industrial sector and support alignment with 2050 net-zero emissions objectives and climate justice goals in the Region.

## Key Objectives

- ⇨ Ensure consistent, high-quality emissions data across Massachusetts and Connecticut to inform future climate policies and industrial innovation.
- ⇨ Use pilot programs and phased targets to test and refine decarbonization strategies before making them mandatory, reducing implementation risks.
- ⇨ Link industrial participation in reporting and planning to financial incentives and technical resources, encouraging proactive investment in clean technologies.
- ⇨ Build public trust and private-sector accountability by making energy performance and emissions data visible and easy to understand for communities and investors.
- ⇨ Develop a pipeline of skilled workers through partnerships with vocational schools and unions, ensuring industries can meet new reporting and efficiency requirements.
- ⇨ Analyze reported data to identify emission hotspots and direct resources toward the sectors and technologies with the greatest potential for reductions.

## Geographic Scope

This measure targets industrial facilities across the Region, including urban centers such as Worcester, Fitchburg, and Leominster, as well as smaller towns in central Massachusetts and northeastern Connecticut. Although the initial focus is regional, the plan is to expand statewide in Massachusetts and Connecticut and ultimately serve as a model for New England.

## Implementation Authority and Responsibilities

- ⇨ **MA Department of Environmental Protection (MassDEP) –** Regulate greenhouse gas emissions; establish reporting requirements and sector-specific emissions limits; enforce compliance, collect emissions data, and issue rules to support large-building reporting aligned with statewide reduction goals. Expanding LBER to smaller or industrial buildings or Scope 1/2 emissions would require legislative amendments or administrative rulemaking; MassDEP or CT DEEP could broaden scope using existing authority through public processes and stakeholder engagement.
- ⇨ **MA Department of Energy Resources (DOER) –** Oversee Large Building Energy Reporting (LBER) under the 2022 Clean Energy Act; define covered buildings, develop compliance tools, enforces reporting, and may expand thresholds to include industrial buildings.
- ⇨ **CT Department of Energy & Environmental Protection (CT DEEP) –** Set building decarbonization goals, manage efficiency standards, develops emissions reporting frameworks, and authorize voluntary or mandatory programs and adopt high-performance building codes.
- ⇨ **Regional Planning Agencies (CMRPC, MRPC, NECCOG) –** Coordinate municipal efforts, provide technical assistance, data aggregation, GIS, and planning support.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Initiate stakeholder engagement and regional coordination by working with industrial stakeholders, municipal leaders, utilities, and trade associations through CMRPC, MRPC, and NECCOG, using interviews, expert focus groups, and workshops to build awareness, assess needs, and secure early buy-in.
- ⇨ Expand LBER coverage in Massachusetts to industrial buildings by collaborating with DOER and MassDEP on regulatory expansion of the Large Building Energy Reporting policy to include industrial buildings over 20,000 sq ft, drafting amendments by 2028 and targeting adoption for 2030.
- ⇨ Begin policy development in Connecticut by partnering with CT DEEP, legislators, and industry groups to explore legislative pathways for establishing building energy and GHG reporting requirements, conducting research and consultations with the goal of introducing legislation by 2030.
- ⇨ Launch a voluntary reporting pilot in the Region by recruiting industrial facilities over 25,000 sq ft in select municipalities, providing technical assistance, and documenting case studies to inform future policy.
- ⇨ Develop reporting tools, templates, and regional data infrastructure by creating standardized emissions reporting protocols and user-friendly tools, and begin building a regional digital platform for data collection and visualization hosted by CMRPC with MRPC and NECCOG support.
- ⇨ Integrate reporting with incentives and workforce training by partnering with MassCEC and EnergizeCT to link voluntary reporting to funding and technical assistance, and begin developing training programs for emissions auditing and reporting in collaboration with vocational schools and community colleges.

**Medium Term Actions, Years 2030 - 2040**

- ⇨ Implement mandatory reporting in Massachusetts starting in 2032, requiring energy use and emissions reporting from industrial facilities over 20,000 sq ft, and expanding to facilities over 15,000 sq ft by 2035 under the expanded LBER policy.

- ⇨ Secure pertinent legislation in Connecticut between 2032 and 2035 to require energy and emissions reporting from large industrial buildings, with implementation beginning by 2035 for facilities over 20,000 sq ft.
- ⇨ Expand the voluntary decarbonization planning program between 2032 and 2035 by introducing incentives and technical support for industrial facilities to create decarbonization plans, encouraging early adoption through recognition and financial assistance.
- ⇨ Scale up workforce training and industry support programs by expanding emissions monitoring and reduction training to build a regional workforce and establishing a Manufacturers Resource Network for peer learning and resource sharing.
- ⇨ Launch the regional emissions dashboard and public data access by operationalizing the regional platform, providing public access to aggregated emissions trends and progress toward targets, and using data insights to guide targeted support and policy refinement.

**Long Term Actions, Years 2040 - 2050**

- ⇨ Mandate public decarbonization plans by 2042, requiring all industrial buildings over 15,000 sq ft to submit plans outlining emissions reduction targets, strategies, and timelines.
- ⇨ Expand reporting scope to include a full GHG inventory by standardizing Scope 1 and 2 emissions in all industrial reporting and providing ongoing technical assistance and monitoring support.
- ⇨ Strengthen compliance, monitoring, and adaptive management by implementing compliance checks and performance benchmarking, and adjusting policies as needed based on emerging technologies, sector needs, and program evaluations.
- ⇨ Achieve full compliance by ensuring all eligible industrial buildings report and implement decarbonization plans, tracking emissions reductions and progress toward net-zero goals.
- ⇨ Integrate data and policy with statewide and regional climate goals by aligning industrial decarbonization efforts with Massachusetts, Connecticut, and New England emissions reduction strategies.
- ⇨ Publish regional progress reports and impact assessments to document outcomes, highlight innovations, and identify ongoing needs for continuous improvement and climate leadership.

## Metrics for Tracking Progress

- ⇨ Industrial buildings reporting energy use and GHG Emissions
- ⇨ Total reported Industrial GHG Emissions ($MTCO_2e$)
- ⇨ Number of Decarbonization Plans submitted by facilities
- ⇨ Emissions reductions achieved (relative to baseline)
- ⇨ Number of participants in incentive and support programs
- ⇨ Number of people trained in Emissions Reporting and Reduction

## Quantified GHG Emission Reduction

This measure promotes industrial decarbonization by requiring large facilities to publicly report energy use and GHG emissions and develop long-term decarbonization plans. Although it does not directly cut emissions, transparent reporting incentivizes efficiency improvements, cost-saving upgrades, and proactive emissions reduction strategies, driving measurable downstream impacts. An estimated 10% of total sector reductions are attributed to these reporting effects, with projected reductions of 1,209 $MTCO_2e$ (8.8%) by 2030 and 3,225 $MTCO_2e$ (8.4%) by 2050, along with small co-pollutant reductions ($NO_x$, $SO_2$).

### Measure Costs

$63 - 65 Million

### Intersection with Other Funding Availability

- ⇨ Catalyst & DICES Grants, MassCEC
- ⇨ InnovateMass, MassCEC
- ⇨ CriticalMass, MassCEC
- ⇨ Equity Workforce Training Implementation Grants, MassCEC
- ⇨ Leading by Example Solar-Decarbonization Grant Program, MA DOER
- ⇨ State Energy Program, CT DEEP
- ⇨ Small Business Energy Advantage (SBEA), CT Green Bank
- ⇨ Commercial Property Assessed Clean Energy (C-PACE), CT Green Bank

## I2: Establish an Industrial Material Efficiency and Waste Circularity Network

The Region stands at a critical crossroads in its climate and economic future. Like many industrialized areas, its manufacturing, food processing, and logistics sectors rely heavily on a linear "take–make–dispose" model. This approach, extracting virgin materials, producing goods, and discarding waste, has driven economic growth for decades but now threatens the Region's ability to meet 2050 net-zero emissions targets. Landfill methane, energy-intensive production, and emissions from transporting raw inputs and discarded materials are significant contributors to greenhouse gas (GHG) pollution. At the same time, global supply chain disruptions and resource scarcity are highlighting the fragility of an economy that relies on constant material throughput.

Addressing these challenges demands more than incremental efficiency upgrades. Even as many firms adopt recycling programs or energy audits, these isolated measures cannot overcome the structural waste embedded in the current system. Industrial processes remain siloed, duplicating energy use and disposal efforts, while opportunities for industrial symbiosis, where one company's by-product becomes another's resource, go untapped. Without a coordinated shift, the Region risks missing economic opportunities, persistent emissions, and higher long-term costs for waste management and energy.

A cradle-to-cradle industrial ecosystem offers a transformative alternative. By designing products, processes, and regional systems to reuse materials indefinitely, the Region can dramatically reduce lifecycle emissions, conserve natural resources, and spark innovation in green technologies. Circular systems shorten supply chains, reduce hauling distances, and significantly reduce the methane released by landfilled organics. They also create resilient local markets for recovered materials and by-products, shielding industries from global price volatility and resource shortages.

The proposed Industrial Circularity Accelerator Program, slated for launch by 2030, is a pivotal first step toward realizing this vision. Developed through collaboration among regional planning agencies, municipalities, chambers of commerce, academic institutions, and industry leaders, the program will map material flows, identify priority sectors, and design coordinated strategies to reduce waste. By 2040, investments in shared infrastructure, tax incentives, and overlay zoning for circular industrial districts will enable net-zero industrial neighborhoods that serve as demonstration models for the nation.

Through coordinated planning and innovative partnerships, the Greater Worcester region can position itself as a leader in industrial circularity, advancing climate goals, strengthening its economy, and enhancing environmental quality for its communities. By shifting from a wasteful linear model to a regenerative cradle-to-cradle system, the Region can meet its 2050 decarbonization commitments while creating long-term social and economic benefits.

### Key Objectives

- ⇨ Coordinate and complete regional industrial waste and material flow assessments to identify priority waste streams, circularity opportunities, and baseline conditions for program development and tracking.

- ⇨ Launch and manage an Industrial Circularity Accelerator Program that provides technical assistance, fosters collaboration among industrial stakeholders, and connects businesses to resources, funding, and training for implementing circular practices.
- ⇨ Develop and implement enabling infrastructure and policy tools, including regional reuse hubs, digital material exchange platforms, tax incentives, and supportive zoning, to facilitate material efficiency, reuse, and circular systems across the region.
- ⇨ Support municipal adoption of circularity-oriented planning and zoning policies, particularly in industrial corridors and clusters, by offering model bylaws, technical guidance, and planning assistance through RPAs and state agencies.
- ⇨ Complete at least three net-zero industrial districts, integrating circular energy, water, and material systems.
- ⇨ Provide capacity-building, outreach, and engagement opportunities to ensure that municipalities, industrial operators, and local institutions can effectively participate in and benefit from circular economy programs.
- ⇨ Monitor, evaluate, and report progress toward waste diversion and emissions reduction goals using regionally coordinated systems, with RPAs responsible for data collection, analysis, and dissemination of outcomes to stakeholders.
- ⇨ Leverage partnerships and funding opportunities at the local, state, and private levels to support implementation, including joint procurement initiatives, infrastructure financing, and innovation pilots in green manufacturing and material reuse.

## Geographic Scope

To advance decarbonization and resource efficiency, the Region will serve as a launch hub for a circular economy system. As these systems mature, the Region's model will guide statewide adoption, leveraging economies of scale, shared innovation investment, and regulatory alignment to position Massachusetts as a leader in sustainable material management and green economic development.

## Implementation Authority and Responsibilities

- ⇨ **Massachusetts Department of Energy Resources (DOER)** – Administer the Green Communities Program, oversee adoption/enforcement of advanced energy codes, provide technical guidance and grants to municipalities, and expand efficiency standards and reporting requirements.
- ⇨ **Massachusetts Department of Environmental Protection (MassDEP)** – Enforce emissions reporting and waste diversion standards, manage the Sustainable Materials Recovery Program (SMRP), track state-level emissions under the GWSA, and support regional infrastructure for material recovery and circular economy initiatives.
- ⇨ **Municipal Governments –** Adopt advanced energy codes, zoning reforms, and green procurement; implement building retrofits, clean fleets, deconstruction, and material reuse ordinances; engage communities and align local policies with regional/state climate goals.
- ⇨ **CMRPC, MRPC, NECCOG** – Integrate GHG reduction strategies into land use, transportation, housing, and sustainability plans; provide technical assistance, data coordination, stakeholder engagement, and regional infrastructure planning; facilitate inter-municipal collaboration and funding alignment.

- ⇨ **State Legislature & Inter-Municipal Agreements** – Expand authority for industrial emissions reporting and regional circular economy infrastructure through new legislation, inter-municipal agreements, or regulatory updates by DOER and MassDEP.

## Implementation Timelines and Milestones

**Short Term Actions, Years 2026 – 2030**

- ⇨ Form an Implementation Authority and Regional Circular Industry Working Group including municipalities, RPAs, chambers of commerce, industrial leaders, academic institutions, and community organizations.
- ⇨ Draft the Industrial Circularity Accelerator Program framework with governance, funding, and outreach strategies.
- ⇨ Secure seed funding through state programs, regional economic development agencies, and private-sector sponsors.
- ⇨ Conduct comprehensive industrial waste and material flow audits for manufacturing, logistics, and food processing sectors.
- ⇨ Prioritize target sectors and geographic clusters based on audit findings for early implementation.
- ⇨ Launch pilot projects such as material exchanges, shared equipment use, or waste valorization in selected industrial clusters.
- ⇨ Develop initial outreach campaigns to engage local industries and communities in circular economy concepts.

**Medium Term Actions, Years 2030 - 2040**

- ⇨ Officially launch the Industrial Circularity Accelerator Program to provide technical assistance, funding incentives, and networking opportunities.
- ⇨ Build and maintain a regional digital materials exchange platform to connect businesses, track flows, and coordinate shared use of infrastructure.
- ⇨ Establish two to three regional hubs for material recovery, reuse marketplaces, and shared access to waste processing or green technologies.
- ⇨ Adopt overlay zoning guidelines in industrial corridors to support green infrastructure, microgrids, and water reuse systems.
- ⇨ Introduce tax credits and grants to reward material diversion and fund cradle-to-cradle industrial practices.
- ⇨ Facilitate joint procurement agreements among municipalities and industries for sustainable or recycled materials.
- ⇨ Conduct capacity-building workshops, peer learning events, and targeted outreach to expand industrial participation.
- ⇨ Foster public–private partnerships to finance and expand circular economy infrastructure and innovation.
- ⇨ Perform mid-term evaluations to measure waste diversion, greenhouse gas reductions, and economic impacts. Refine strategies and adjust implementation based on evaluation findings and emerging technologies.

**Long Term Actions, Years 2040 - 2050**

- ⇨ Expand or replicate circular hubs and reuse networks based on regional demand and performance. Embed circular economy objectives in comprehensive plans, zoning ordinances, and capital investment strategies. Coordinate shared logistics, data management, and financing systems among municipalities and RPAs.

- ⇨ Plan, design, and implement at least three net-zero industrial districts that integrate circular energy, water, and material systems.
- ⇨ Maintain ongoing stakeholder engagement to ensure alignment with evolving industrial and community needs.
- ⇨ Verify diversion of 60% of industrial solid waste from landfills or incineration across the region. Confirm significant GHG reductions in line with 2050 climate targets. Document and share best practices statewide to enable replication and position Massachusetts as a leader in sustainable industrial development.
- ⇨ Ensure Program Continuity and Innovation. Institutionalize circularity within permitting processes, public procurement policies, and regional economic development strategies. Continue supporting innovation in green manufacturing technologies, materials, and logistics to maintain long-term competitiveness and resilience.

## Metrics for Tracking Progress

- ⇨ Industrial Waste Diversion Rate (%)
- ⇨ Number of Participating Industrial Facilities
- ⇨ Quantity of Materials Exchanged or Reused (tons/year)
- ⇨ Greenhouse Gas Emissions Reductions (MT $CO_2e$/year)
- ⇨ Number of Circularity Hubs Established
- ⇨ Participation in Incentive Programs
- ⇨ Adoption of Circularity Zoning or Policies

## Quantified GHG Emission Reduction

This measure will cut industrial emissions by minimizing waste, promoting material reuse, and advancing circular economic practices. Using waste audits, reuse infrastructure, and tax and grant incentives, the Region targets 60% diversion of industrial solid waste by 2050, avoiding both landfill and incineration emissions and upstream emissions from raw material extraction and production. Overlay zoning and green systems on large industrial campuses will add further reductions. Quantification is based on diversion targets and emissions factors for landfill avoidance and material production (see Appendix). Projected reductions compared to BAU include 469 $MTCO_2e$ by 2030 (~10–15% diversion, 3.4% of sector reduction) and 2,812 $MTCO_2e$ by 2050 (60% diversion, 7.4% of sector reduction). Co-pollutant reductions for $NO_x$ and $SO_2$ are estimated using standard emissions factors tied to reduced fossil fuel use.

## Measure Costs

$142 – $195 Million

## Intersection with Other Funding Availability

- ⇨ Solid Waste Infrastructure for Recycling (SWIFR) Grants, US EPA
- ⇨ InnovateMass Program, MassCEC
- ⇨ Sustainable Materials Recovery Program (SMRP), MA DEP
- ⇨ Recycling & Reuse Business Development Grants, MA DEP
- ⇨ Waste Reduction Innovation Grants, MA DEP
- ⇨ Reduce, Reuse, Repair Micro-Grants, MA DEP
- ⇨ MassWorks Infrastructure Program, MA EOED

- ⇨ Green Communities Competitive Grants Program, MA DOER
- ⇨ Materials Management Infrastructure (MMI) Grant Program, CT DEEP
- ⇨ Sustainable Materials Management Grant Program, CT DEEP
- ⇨ Municipal Recycling Resources Center – Recycling Incentive Grants & Technical Assistance, CT DEEP
- ⇨ Municipal and Regional Economic Development Funds, Individual Municipalities

### Case Study: Kalundborg Eco-Industrial Park, Denmark

Kalundborg is home to the world's first fully developed eco-industrial park,[193] where multiple companies and municipal services engage in industrial symbiosis—the exchange of energy, water, and materials to minimize waste and environmental impact. Since the 1970s, Kalundborg's key partners, including the Asnæs Power Station, Novo Nordisk, and Statoil refinery, have developed a closed-loop system. For example, waste heat from the power plant provides district heating to over 20,000 households, while surplus steam is used by nearby industrial processes. By-products like fly ash and gypsum are repurposed for cement and construction, and treated wastewater is reused in cooling systems.[194]

*Key Lessons:* The Kalundborg experience demonstrates that industrial collaboration often develops organically from shared economic and environmental benefits, rather than being imposed solely through top-down mandates. This suggests that fostering mutual incentives among industrial actors, utilities, and municipalities can be more effective than regulation alone. Trust and open communication are critical to sustaining long-term resource-sharing agreements, whether in energy, water, or materials. Additionally, strategic investment in enabling infrastructure, such as pipeline networks, storage facilities, and waste treatment systems, is essential to support these exchanges and ensure resilience. Kalundborg's success also underscores that geographic proximity of industries, combined with supportive governance frameworks, can create the ideal conditions for scalable industrial symbiosis in the Region.[195]

## I3: Improve Electrification and Energy Efficiency of Industrial Operations and Systems

To drive industrial-sector decarbonization, the Region will accelerate the shift to low-carbon energy systems through electrification, efficiency upgrades, and zero-emission mobility. Current industrial systems often rely on fossil-fuel boilers, inefficient HVAC, and outdated lighting, which lock in high greenhouse gas (GHG) emissions, generate waste heat, and expose businesses to volatile fuel prices. In contrast, electric heat pumps are two to three times more efficient than combustion-based heating, reduce operating costs over time, and eliminate on-site fossil fuel combustion. Smart controls and occupancy-based systems minimize wasted energy by adjusting heating, cooling, and lighting only when and where needed—cutting costs and peak demand while extending equipment life.

Similarly, EV charging infrastructure and fleet electrification reduce dependence on diesel and gasoline, avoiding harmful tailpipe emissions ($NO_x$, $SO_2$, and particulates) that degrade local air quality and harm worker health. However, adoption has lagged due to high upfront costs, limited grid capacity, and uncertainty about return on investment, barriers this plan addresses through rebates, incentives, and pre-permitted low-carbon industrial zones.

By 2040, the Region will electrify 60% of large industrial facilities (>15,000 sq ft) and cut sector energy use by 35%, while requiring EV charging in all new industrial facilities larger than20,000 sq ft by 2030 (lowered to 15,000 sq ft by 2035). Supporting fleet electrification (50% of light-duty and 15% of medium-duty vehicles by 2040, reaching 100% and 30% by 2050) further reduces emissions and operational costs. Where full electrification isn't yet feasible, idle-reduction retrofits and low-carbon fuels provide interim solutions. Finally, low-carbon industrial zones, pre-permitted areas equipped with grid capacity, EV networks, and shared efficiency resources, will streamline permitting, reduce infrastructure duplication, and lower participation costs. These zones will act as demonstration sites, attract green investment, support workforce development, and foster collaboration among industries, utilities, and municipalities, positioning the Region as a leader in industrial decarbonization and sustainable economic growth.

### Key Objectives

- ⇨ Facilitate widespread electrification and energy efficiency upgrades in industrial facilities through targeted rebates, technical assistance, and building code alignment.
- ⇨ Develop and implement EV infrastructure requirements for new industrial developments, ensuring timely compliance with phased square footage thresholds.
- ⇨ Support industrial fleet transition by providing resources for electrification, idle-reduction retrofits, and adoption of low-carbon fuels.
- ⇨ Plan and establish low-carbon industrial zones equipped with clean energy infrastructure, streamlined permitting, and shared decarbonization resources.
- ⇨ Coordinate regional efforts across municipalities and RPAs to align policies, share best practices, and leverage funding for infrastructure, training, and implementation.

### Geographic Scope

This measure will be implemented across the Region. Key focus areas for expanded and synergistic decarbonization planning include industrial zones and corridors within major urban centers such as

Worcester, Fitchburg, Leominster, and Southbridge, as well as other municipalities with significant industrial activity. Implementation will prioritize sites with existing or planned industrial development, access to transportation infrastructure, and capacity for clean energy upgrades and fleet electrification.

## Implementation Authority and Responsibilities

- ⇨ **Massachusetts Department of Energy Resources (DOER)** – Oversee energy code adoption, Green Communities Program, and clean energy policies.
- ⇨ **Massachusetts Department of Environmental Protection (MassDEP)** – Enforce emissions tracking, waste reduction, and recycling standards.
- ⇨ **Massachusetts Clean Energy Center (MassCEC)** – Provide funding, workforce development, and technical assistance for clean energy, industrial efficiency, and transportation electrification.
- ⇨ **Connecticut Department of Energy and Environmental Protection (CT DEEP)** – Manage energy efficiency programs, emissions reduction mandates, and climate initiatives under state law.
- ⇨ **Energize Connecticut (Energize CT)** – Offer incentives and technical support for building decarbonization, industrial upgrades, and fleet electrification.
- ⇨ **State Legislatures** – Authorize new mandates, funding mechanisms, and regulatory changes to scale GHG reduction measures.
- ⇨ **Utilities & Regional Transit Agencies** – Upgrade grid capacity, expand EV charging networks, and support fleet electrification and shared mobility.
- ⇨ **Municipal Governments** – Adopt zoning reforms, enforce energy codes, require EV infrastructure in developments, decarbonize public buildings and fleets, engage communities, and integrate low-carbon standards into procurement and capital planning.
- ⇨ **Regional Planning Agencies (CMRPC, MRPC, NECCOG)** – Provide technical assistance, conduct GHG inventories, coordinate inter-municipal efforts, guide zoning reforms, and facilitate access to state and federal funding for decarbonization and circular economy projects.
- ⇨ **Industrial Actors (Manufacturers, Logistics Operators, Large Facility Owners)** – Electrify operations, adopt low-carbon fuels, improve efficiency, participate in reuse networks, and invest in eco-industrial zones.
- ⇨ **Local and Capacity-Building Organizations (e.g., Chambers of Commerce, Workforce Boards, Academic Institutions)** – Support outreach, workforce training, community engagement, and industry collaboration to ensure equitable and effective implementation.

## Implementation Timelines and Milestones

### Short Term Actions, Years 2026 – 2030

- ⇨ Establish regional coordination teams across RPAs (CMRPC, MRPC, NECCOG) and municipalities for planning, outreach, and baseline data collection.
- ⇨ Secure implementation authority through local bylaw adoption (e.g., EV infrastructure requirements, reuse mandates) and interagency agreements.
- ⇨ Launch pilot programs for industrial fleet electrification, material reuse hubs, and energy efficiency upgrades with early adopter municipalities and industries.
- ⇨ Develop a funding strategy and pursue grants (state clean energy funds, CPRG implementation grants, utility incentives) to support immediate and mid-term actions.

- ⇨ Initiate stakeholder engagement with industrial actors to assess technical needs, capacity gaps, and opportunities for resource sharing.

**Medium Term Actions, Years 2030 – 2040**

- ⇨ Expand EV infrastructure and fleet electrification mandates to all municipalities, paired with financial and technical implementation support.
- ⇨ Scale up industrial retrofit programs to improve energy efficiency and electrify operations, prioritizing large facilities (>15,000 sq ft).
- ⇨ Formalize regional reuse hubs and circular economy partnerships among industries, waste management entities, and municipal governments.
- ⇨ Integrate climate measures into municipal capital planning, procurement policies, and zoning updates to align with state GHG reduction targets.
- ⇨ Continue securing and deploying funding to expand infrastructure upgrades and incentives for industry adoption.

**Long Term Actions, Years 2040 – 2050**

- ⇨ Work with state and private actors to electrify or transition 50 percent of industrial light-duty fleets and 15 percent of medium-duty fleets to low-carbon fuels by 2045 and drive these transitions to 100 percent and 30 percent by 2050.
- ⇨ Work with state and private actors to implement energy-efficiency and electrification measures in 60 percent of large industrial facilities by 2045 and reduce overall industrial energy use by 35 percent by 2050, enabled by grid upgrades, charging networks, and reuse systems.
- ⇨ Evaluate and adjust policies, building codes, fleet standards, and emissions tracking systems to ensure continued progress.
- ⇨ Conduct community and industry workshops to share outcomes, challenges, and best practices, and finalize long-term monitoring and reporting systems for ongoing emissions and equity tracking.
- ⇨ Integrate lessons learned into updated regional climate action plans, positioning the Region for continued leadership and innovation.

## Metrics for Tracking Progress

- ⇨ **Electrification of Industrial Facilities:** Measures the share or number of industrial facilities that have transitioned from fossil-fuel technologies to electric systems (e.g., process heat, machinery, building systems).
- ⇨ **Reduction in Energy Use Intensity (EUI):** Measures how much energy consumption per unit of output, floor area, or production declines over time, indicating improvements in efficiency.
- ⇨ **Deployment of Zero-Emission or Low-Carbon Industrial Vehicles:** Measures how many industrial fleet vehicles have shifted to electric, hydrogen, or other low-carbon technologies.
- ⇨ **Installation of EV Charging Infrastructure in Industrial Zones:** Measures the quantity, capacity, distribution, and usage of EV chargers installed to support industrial fleets and worker vehicles.
- ⇨ **Industrial Material Reuse and Waste Diversion Rates:** Measures the proportion of industrial byproducts, scrap, and waste that are reused, recycled, or diverted from landfills.
- ⇨ **GHG Emissions Reduction from Industrial Measures:** Measures the absolute or relative decline in greenhouse gas emissions attributable specifically to industrial decarbonization strategies.

- ⇨ **Stakeholder Engagement and Participation:** Measures the extent and quality of participation from industry partners, workers, local governments, utilities, and community groups in planning and implementation.

### Quantified GHG Emission Reduction

This measure delivers the sector's largest emissions cuts by electrifying 60% of large industrial facilities and reducing overall energy use by 35% by 2040. Incentives for heat pumps, smart controls, efficiency upgrades, mandatory EV infrastructure, and fleet electrification will curb natural gas and fuel oil use, driving major GHG and co-pollutant reductions, an estimated 12,095 $MTCO_2e$ by 2030 and 32,252 $MTCO_2e$ by 2050. Assumptions include a 15% fossil fuel reduction by 2030 and 40% by 2050, with co-pollutant benefits ($NO_x$, $SO_2$) calculated using standard emissions factors.

### Measure Costs

~$200 Million

### Intersection with Other Funding Availability

- ⇨ Decarbonization Pathways Program, MassCEC
- ⇨ Mass Save Incentive Programs, Massachusetts Utilities
- ⇨ Climate Resilience and Clean Energy Programs, CT DEEP
- ⇨ Energize CT Incentive Programs, Connecticut Utilities / CT DEEP partnership
- ⇨ Municipal Climate Resilience and Infrastructure Funds (e.g., Local Capital Budgets), Individual Municipalities
- ⇨ The Recycling Partnership – Circular Economy Infrastructure Grants, The Recycling Partnership
- ⇨ American Cities Climate Challenge & Circular Economy Projects, Bloomberg Philanthropies
- ⇨ Climate Program Grants, Barr Foundation.

### Case Study: Fleet Electrification at the Port of Los Angeles

Under the Clean Air Action Plan (CAAP), the Port of Los Angeles has committed to achieving 100% zero-emission drayage trucks by 2035. As of 2024, the port had achieved significant air quality gains, reducing diesel particulate matter by 91%, nitrogen oxides by 74%, and sulfur oxides by 98%, compared to 2005 levels.[196]

Through the Clean Truck Fund (CTF), launched in 2022, the port charges fees on loaded containers to fund zero-emission vehicle (ZEV) deployment. By 2025, it had collected $123 million, funding vouchers for over 350 zero-emission drayage trucks and 207 charging stations across Southern California.[197] The program complements state incentives from the California Air Resources Board (CARB) and private investment from companies such as Forum Mobility and Volvo.[198] Fleet operators such as Tradelink Transport have deployed Volvo VNR Electric trucks, while Amazon has partnered with Forum Mobility to operate electric drayage trucks and charging hubs.[199] Additional projects include hydrogen fuel-cell truck demonstrations, with Shell and Toyota establishing fueling stations to support early deployment.[200]

The Port of Los Angeles experience highlights several critical lessons for regions aiming to decarbonize freight and industrial transportation. First, phased regulations combined with financial incentives, such as the Clean Truck Fund (CTF), create market certainty and help small operators overcome high upfront costs. Successful implementation also hinges on public-private collaboration to support infrastructure deployment, vehicle procurement, and pilot demonstrations. However, grid readiness and infrastructure coordination remain major challenges; proactive investment in grid upgrades and power system modernization is essential to support large-scale fleet electrification.[201] By 2025, over 546 zero-emission trucks were in operation at the Los Angeles and Long Beach ports, significantly reducing emissions and health risks. The initiative has become a scalable model for zero-emission freight corridors across the United States, offering valuable insights for industrial zones like those in the Region.

## Benefits Analysis: Industry

The Industry sector measures generate significant co-benefits for the Greater Worcester Region beyond direct reductions in greenhouse gas emissions. Together, they improve air quality, reduce operational risks, expand workforce opportunities, strengthen supply chain stability, and support long-term economic competitiveness. All three industrial measures, which include Industrial Reporting and Decarbonization Planning (I1), Material Efficiency and Circularity (I2), and Electrification and Energy Efficiency (I3), directly reduce combustion-related emissions from industrial heating systems, diesel fleets, and waste management activities. Reductions in nitrogen oxides (NOx), sulfur dioxide ($SO_2$), particulate matter, and landfill-related emissions will provide important public health improvements, especially in vulnerable communities located near industrial corridors. Co-pollutant reductions associated with these three measures include:

*Table 23. Industry Co-Pollutant Reductions*

| Measures | Co-Pollutant Reductions in 2030 Compared to the BAU (MT) | Co-Pollutant Reductions in 2050 Compared to the BAU (MT) |
|---|---|---|
| I1: Mandate GHG Emissions Reporting and Decarbonization Planning for Large Buildings | 1 | 3 |
| I2: Establish an Industrial Material Efficiency and Waste Circularity Network | 10 | 60 |
| I3: Improve Electrification and Energy Efficiency of Industrial Operations and Systems | 10 | 26 |

All three measures also support job creation in fields such as electrification, energy auditing, industrial retrofits, fleet management, materials recovery, logistics, circularity infrastructure, and clean manufacturing. Workforce development partnerships will expand training programs that prepare workers for emerging roles in clean energy and the circular economy.

Two measures, Material Efficiency and Circularity (I2) and Electrification and Efficiency (I3), provide direct climate resilience benefits by reducing exposure to fuel price volatility, increasing process reliability during extreme weather, lowering waste-related hazards, and improving operational continuity. All measures contribute indirect resilience benefits by reducing regional pollution, decreasing strain on local infrastructure, and modernizing industrial facilities.

Electrification and Efficiency (I3) provides direct energy cost savings by reducing fossil fuel dependence and improving operational efficiency. Circularity efforts (I2) may also reduce waste disposal costs and raw material expenses over time through expanded material reuse, lower hauling needs, and improved resource efficiency.

Potential disbenefits include upfront retrofitting and equipment costs, grid capacity limitations, limited contractor availability, and temporary operational disruptions during construction or upgrades. Circularity measures may require additional storage, sorting, and logistics facilities. These risks can be reduced by offering targeted incentives, improving permitting coordination, expanding workforce training, and phasing implementation requirements over time.

*Table 24. Industry Co-Benefits Summary*

| Measures | Improved Public Health Outcomes | Job Creation | Improved Climate Resilience | Reduced Energy or Operating Costs |
|---|---|---|---|---|
| I1: Mandate GHG Emissions Reporting and Decarbonization Planning for Large Buildings | X | X | X | X |
| I2: Establish an Industrial Material Efficiency and Waste Circularity Network | X | X | X | X |
| I3: Improve Electrification and Energy Efficiency of Industrial Operations and Systems | X | X | X | X |

# Industry Endnotes

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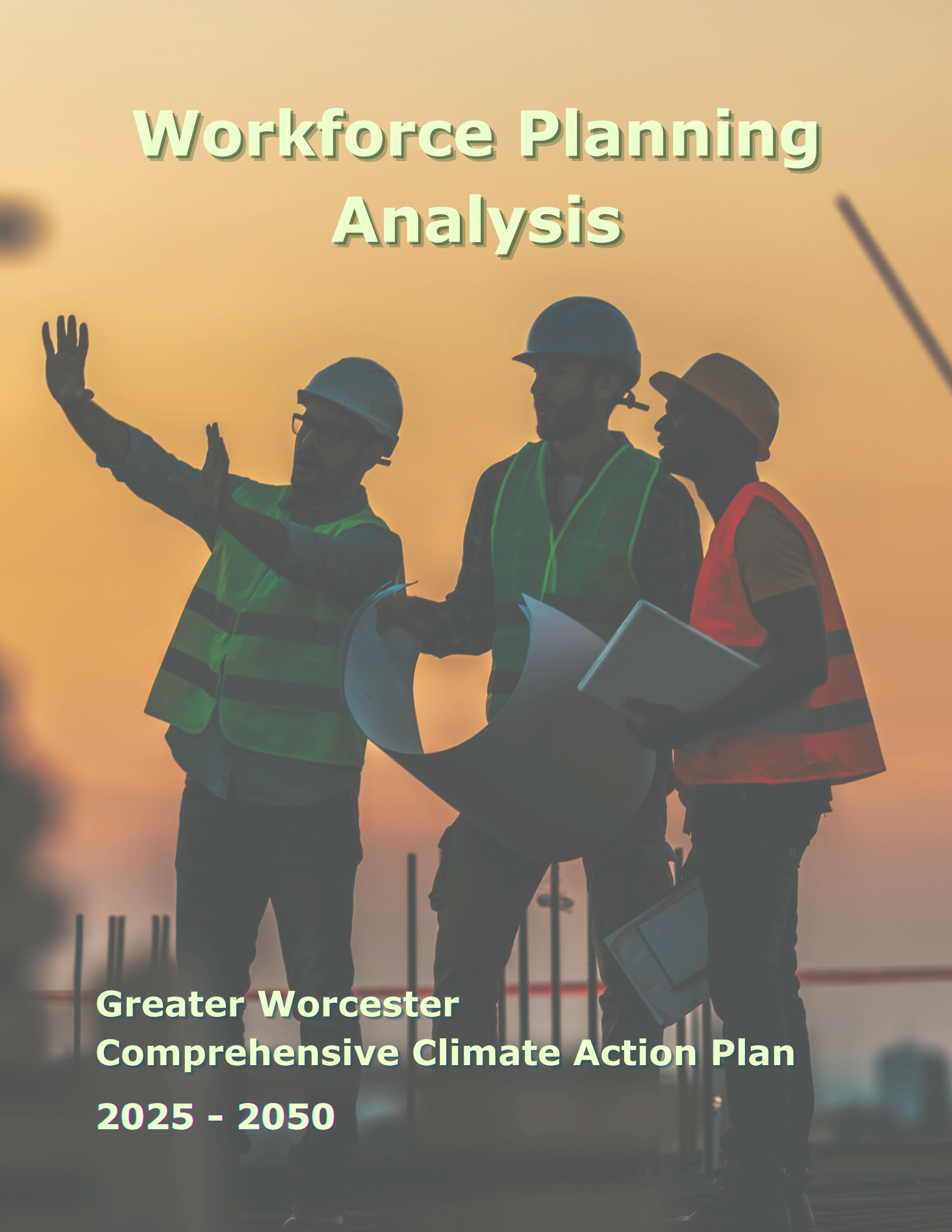
# Workforce Planning Analysis



## Greater Worcester Comprehensive Climate Action Plan

## 2025 - 2050

# Workforce Planning Analysis

The Greater Worcester Region has committed to an ambitious GWCCAP that includes twenty-eight individual measures across the Waste and Materials Management, Electricity Use and Generation, Transportation, Agricultural, Natural, and Working Lands, Commercial and Residential Buildings, and Industrial sectors. Collectively, these measures aim to drive the Region toward net-zero greenhouse gas emissions by 2050 while also catalyzing economic growth, public health co-benefits, and positive environmental resilience outcomes. These outcomes will only be achievable, however, if the Region can develop and maintain a skilled workforce to ensure successful implementation.

## 4.1 Priority Occupations

To ensure that the Region has and can maintain a skilled workforce, it is important to understand the priority occupations needed to implement each measure and the current and future supply of that workforce. The table below describes the priority occupations that will be needed to implement the GWCCAP proposed measures, the 2023 employment numbers for each occupation in the region, and their median hourly and annual wages.

*Table 25. Greater Worcester Region Priority Climate Action Occupations*

| Occupation Title | Occupation Classification Code | Sector | 2023 Employment | Location Quotient | Median Hourly Wage | Median Annual Wage |
|---|---|---|---|---|---|---|
| Bus and Truck Mechanics and Diesel Engine Specialists | 49-3031 | WMM, T, I | 560 | 1.06 | $ 31.62 | $ 65,760.00 |
| Civil Engineering Technologists and Technicians | 17-3022 | WMM, T, CRB, I | 30 | 0.27 | $ 28.43 | $ 59,130.00 |
| Civil Engineers | 17-2051 | WMM, T, CRB, I | 500 | 0.81 | $ 47.20 | $ 98,180.00 |
| Compliance Officers | 13-1041 | WMM, EGU, CRB, I | 540 | 0.75 | $ 37.50 | $ 78,000.00 |
| Computer and Information Systems Managers | 11-3021 | T, ANWL | 950 | 0.86 | $ 78.18 | $ 162,610.00 |
| Computer Occupations, All Other | 15-1299 | T, CRB, I | 470 | 0.58 | $ 39.69 | $ 82,560.00 |
| Conservation Scientists | 19-1031 | ANWL | 50 | 1.18 | $ 31.51 | $ 65,540.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Construction and Building Inspectors | 47-4011 | EGU, CRB, I | 290 | 1.18 | $ 36.89 | $ 76,740.00 |
| Construction Laborers | 47-2061 | CRB, I | 1400 | 0.74 | $ 24.61 | $ 51,190.00 |
| Construction Managers | 11-9021 | CRB, I | 400 | 0.65 | $ 60.62 | $ 126,090.00 |
| Electrical and Electronics Repairers, Commercial and Industrial Equipment | 49-2094 | EGU, CRB, I | 60 | 0.54 | $ 36.00 | $ 74,880.00 |
| Electrical and Electronics Repairers, Powerhouse, Substation, and Relay | 49-2095 | EGU, CRB, I | 90 | 2.05 | $ 48.37 | $ 100,610.00 |
| Electrical Engineers | 17-2071 | EGU, CRB, I | 280 | 0.82 | $ 54.26 | $ 112,850.00 |
| Electrical Power-Line Installers and Repairers | 49-9051 | EGU, CRB, I | 280 | 1.24 | $ 47.50 | $ 98,790.00 |
| Electrical, Electronic, and Electromechanical Assemblers, Except Coil Winders, Tapers, and Finishers | 51-2028 | EGU, CRB, I | 1180 | 2.37 | $ 21.59 | $ 44,900.00 |
| Electricians | 47-2111 | EGU, T, CRB, I | 1320 | 1 | $ 37.78 | $ 78,580.00 |
| Environmental Engineers | 17-2081 | EGU, ANWL, CRB | 60 | 0.79 | $ 49.64 | $ 103,240.00 |
| Environmental Science and Protection Technicians, Including Health | 19-4042 | ANWL | 50 | 0.89 | $ 28.73 | $ 59,750.00 |
| Environmental Scientists and Specialists, Including Health | 19-2041 | ANWL | 140 | 0.95 | $ 48.25 | $ 100,360.00 |
| Facilities Managers | 11-3013 | WMM, EGU, CRB, I | 340 | 1.37 | $ 49.53 | $ 103,020.00 |
| Farming, Fishing, and Forestry Occupations | 45-0000 | ANWL | 350 | 0.43 | $ 21.97 | $ 45,690.00 |
| Farmworkers, Farm, Ranch, and Aquacultural Animals | 45-2093 | ANWL | 40 | 0.59 | $ 17.79 | $ 37,010.00 |
| Hazardous Materials Removal Workers | 47-4041 | WMM, EGU, I | 120 | 1.26 | $ 21.02 | $ 43,730.00 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Heating, Air Conditioning, and Refrigeration Mechanics and Installers | 49-9021 | CRB, I | 510 | 0.7 | $ 32.21 | $ 67,000.00 |
| Industrial Engineering Technologists and Technicians | 17-3026 | I | 220 | 1.63 | $ 30.76 | $ 63,980.00 |
| Industrial Engineers | 17-2112 | I | 980 | 1.58 | $ 49.02 | $ 101,970.00 |
| Laborers and Freight, Stock, and Material Movers, Hand | 53-7062 | WMM, EGU, CRB, I | 4560 | 0.82 | $ 19.99 | $ 41,570.00 |
| Materials Engineers | 17-2131 | CRB, I | 140 | 2.96 | $ 50.22 | $ 104,460.00 |
| Materials Scientists | 19-2032 | CRB, I | 80 | 4.76 | $ 68.65 | $ 142,780.00 |
| Mechanical Engineers | 17-2141 | WMM, EGU, T, CRB, I | 580 | 1.12 | $ 48.25 | $ 100,370.00 |
| Power Plant Operators | 51-8013 | EGU, I | 270 | 4.58 | $ 48.98 | $ 101,870.00 |
| Refuse and Recyclable Material Collectors | 53-7081 | WMM, I | 250 | 1 | $ 27.88 | $ 57,980.00 |
| Shuttle Drivers and Chauffeurs | 53-3053 | T | 730 | 1.93 | $ 17.85 | $ 37,120.00 |
| Urban and Regional Planners | 19-3051 | WMM, EGU, T, ANWL, CRB, I | 90 | 1.08 | $ 37.99 | $ 79,020.00 |
| Water and Wastewater Treatment Plant and System Operators | 51-8031 | WMM | 290 | 1.31 | $ 30.35 | $ 63,120.00 |
| Welders, Cutters, Solderers, and Brazers | 51-4121 | CRB, I | 400 | 0.52 | $ 25.23 | $ 52,470.00 |

The following table presents state-level workforce data to illustrate projected employment trends and potential shortages through 2032. Datasets at the Region-level do not currently include forward-looking employment projections for a vast majority of the priority occupations critical to meeting the climate, clean energy, and resilience goals set forth in this GWCCAP. State-level data is used in this instance because it offers a more complete and reliable picture of the labor market than data available at the Region-level. The table below not only presents base and projected workforce levels, but it also gives an overview of how these occupations may be utilized in implementing the many measures discussed in this plan as well as any key skills that they may need.

*Table 26. Massachusetts Priority Climate Action Occupations*

| Occupation Title | Occupation Classification Code | Sector | Base (2022) | Projected (2032) | Employment Change | Percent Change | Average Annual Openings | Overview of Role | Key Skills |
|---|---|---|---|---|---|---|---|---|---|
| Agricultural Equipment Operators | 45-2091 | ANWL | 450 | 530 | 80 | 17.8% | 80 | Operate efficient/ low-emission equipment; implement precision agriculture, cover-crop seeding, and compost application to boost soil carbon. | tractor operation, precision agriculture, equipment maintenance, soil stewardship, safety, basic calibration, recordkeeping |
| Bus and Truck Mechanics and Diesel Engine Specialists | 49-3031 | WMM, T, I | 1510 | 1570 | 60 | 4.0% | 130 | Maintain high-efficiency vehicles; support EV/CNG fleet transitions and charging; reduce idling and leaks. | diagnostics (OBD/CAN), diesel aftertreatment, brakes/suspension, electrical systems, EV/hybrid drivetrains basics, PM & recordkeeping, shop safety |
| Bus Drivers, Transit and Intercity (SOC 2018) | 53-3052 | T | 1780 | 2000 | 220 | 12.4% | 260 | Operate high-occupancy transit that displaces car trips; support safe eco-driving and EV bus operations. | CDL/safe driving, eco-driving, route navigation, customer service, pre/post-trip inspection, incident reporting, EV charging basics |
| Civil Engineering Technicians | 17-3022 | WMM, T, CRB, I | 450 | 450 | 0 | 0.0% | 40 | Support design/ inspection of green infrastructure, low-carbon roads/ bridges, and stormwater | CAD drafting, survey support, materials testing, stormwater BMPs, field inspection, reporting/QA, GIS basics |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | controls that reduce flood risks. | |
| Civil Engineers | 17-2051 | WMM, T, CRB, I | 3210 | 3410 | 200 | 6.2% | 210 | Design resilient, low-carbon transport, water, and site systems; integrate green infrastructure and low-carbon materials. | site/civil design, hydrology & stormwater, LID/green infrastructure, specs & codes, AutoCAD/Civil 3D, construction admin, cost estimating |
| Compliance Officers | 13-1041 | WMM, EGU, CRB, I | 3690 | 3920 | 230 | 6.2% | 310 | Ensure regulatory compliance (air, water, waste), emissions reporting, EHS audits, and ESG program implementation. | EPA/OSHA/DEP rules, auditing & inspections, emissions/waste reporting, root-cause analysis, corrective actions, policy writing, training & communication |
| Computer and Information Systems Managers | 11-3021 | T, ANWL | 8500 | 9790 | 1290 | 15.2% | 710 | Oversee energy data, SCADA/AMI, smart-building and grid IT; manage cybersecurity for EV charging and DERs. | IT strategy, cybersecurity, networking/cloud, SCADA/OT coordination, data governance, project management, vendor management |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Computer Occupations, All Other (SOC 2018) | 15-1299 | T, CRB, I | 3230 | 3530 | 300 | 9.3% | 240 | Develop analytics, IoT, and controls for grid, fleets, and smart buildings to cut energy use and emissions. | scripting (Python), IoT/edge devices, APIs & data pipelines, PLC/controls basics, dashboards/BI, ML/analytics basics, version control |
| Conservation Scientists | 19-1031 | ANWL | 340 | 360 | 20 | 5.9% | 30 | Plan and monitor land conservation, forest health, and carbon sequestration; oversee restoration projects. | ecology/soils, monitoring & MRV, GIS/remote sensing, field sampling, restoration planning, statistics, stakeholder coordination |
| Construction and Building Inspectors | 47-4011 | EGU, CRB, I | 1420 | 1410 | -10 | -0.7% | 160 | Verify energy-code compliance, blower-door tests, insulation/ air-sealing, heat-pump installs, and electrification readiness. | building/energy code, plan review, site inspection, blower-door/duct testing basics, report writing, safety protocols, customer communication |
| Construction Laborers | 47-2061 | CRB, I | 8490 | 9140 | 650 | 7.7% | 820 | Perform site prep and installation for retrofits, solar, EV chargers, and green infrastructure projects. | site prep & cleanup, hand/power tools, material handling, demolition, basic concrete/carpentry, safety awareness, PPE use |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Construction Managers | 11-9021 | CRB, I | 4410 | 4750 | 340 | 7.7% | 360 | Direct decarb projects such as deep energy retrofits, electrification, DER/solar installs. | scheduling (CPM), budgeting/estimating, subcontractor management, QA/QC, safety compliance, Procore/MS Project, change orders |
| Electrical and Electronics Engineering Technicians | 17-3023 | EGU, CRB, I | 1050 | 1000 | -50 | -4.8% | 90 | Install/test inverters, BMS, and controls for renewables, storage, and efficient motors/drives. | instrumentation/test, PLC/VFD basics, wiring & panels, inverters/BMS, data acquisition, commissioning, documentation |
| Electrical and Electronics Repairers, Commercial and Industrial Equipment | 49-2094 | EGU, CRB, I | 300 | 280 | -20 | -6.7% | 20 | Maintain high-efficiency motors, drives, and controls to reduce electricity use in plants and buildings. | troubleshooting, VFDs/motors, PLCs/sensors, schematics, preventive maintenance, lockout/tagout, test instruments |
| Electrical and Electronics Repairers, Powerhouse, Substation, and Relay | 49-2095 | EGU, CRB, I | 70 | 80 | 10 | 14.3% | 10 | Maintain relay protection, SCADA, and substation assets enabling high renewable penetration. | relay testing, protective schemes, SCADA/RTUs, metering/CTs/PTs, high-voltage safety, schematics, commissioning |

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|---|---|---|---|---|---|---|---|---|---|
| Electrical Engineers | 17-2071 | EGU, CRB, I | 1640 | 1670 | 30 | 1.8% | 90 | Design interconnections, protection, storage, and microgrids; plan EV charging and building electrification systems. | power systems design, protection & relays, grounding/bonding, DER interconnection, EV charging design, ETAP/PSCAD modeling, codes/standards (NFPA/IEEE) |
| Electrical Power-Line Installers and Repairers | 49-9051 | EGU, CRB, I | 700 | 770 | 70 | 10.0% | 60 | Build/maintain T&D lines and service drops that support DERs and large-scale EV charging. | high-voltage work, rigging/climbing/bucket ops, splicing/terminations, switching/tagging, fault location, NESC safety, storm response |
| Electrical, Electronic, and Electromechanical Assemblers, Except Coil Winders, Tapers, and Finishers | 51-2028 | EGU, CRB, I | 3490 | 3310 | -180 | -5.2% | 340 | Assemble components for renewables, EVs, batteries, and high-efficiency equipment. | mechanical systems, equipment operation, maintenance, safety, basic troubleshooting |
| Electricians | 47-2111 | EGU, T, CRB, I | 6820 | 7590 | 770 | 11.3% | 700 | Install EV chargers, heat pumps, solar interconnects, smart panels, and building controls. | NEC/code compliance, panel/wiring/conduit, EVSE & PV interconnects, troubleshooting & meters, lockout/tagout, blueprint reading, controls & smart panels |

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|---|---|---|---|---|---|---|---|---|---|
| Environmental Engineering Technicians | 17-3025 | EGU, ANWL, CRB | 150 | 160 | 10 | 6.7% | 10 | Sample/monitor, operate BMPs, and support treatment/ process upgrades that save energy and reduce emissions. | sampling & chain-of-custody, lab methods/ instrumentation, SCADA basics, BMP O&M, data logging/QAQC, CAD/reporting, safety/HAZWOPER |
| Environmental Engineers | 17-2081 | EGU, ANWL, CRB | 430 | 460 | 30 | 7.0% | 30 | Design landfill-gas control, wastewater energy optimization, industrial emission controls, and LCA-based process changes. | process design, air/water modeling, permitting (EPA/DEP), LCA basics, data analysis, project management, treatment optimization |
| Environmental Science and Protection Technicians, Including Health (SOC 2018) | 19-4042 | ANWL | 300 | 320 | 20 | 6.7% | 30 | Collect field data for air/water/soil; support compliance and mitigation at sites and facilities. | air/water/soil sampling, instrument calibration, QA/QC protocols, data entry, hazard communication, basic GIS, reporting |
| Environmental Scientists and Specialists, Including Health | 19-2041 | ANWL | 870 | 950 | 80 | 9.2% | 80 | Model emissions/ dispersion, assess impacts, and design mitigation and restoration strategies. | impact assessment, dispersion/fate modeling, risk assessment, statistics, GIS/remote sensing, field methods, stakeholder engagement |
| Facilities Managers | 11-3013 | WMM, EGU, CRB, I | 1780 | 1910 | 130 | 7.3% | 150 | Manage building energy, retro-commissioning, electrification, and demand response; oversee O&M for efficiency. | energy management, CMMS, BAS/controls, procurement/vendor management, O&M planning, retro- |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | commissioning, budgeting & KPIs |
| Farm Equipment Mechanics and Service Technicians | 49-3041 | ANWL | 140 | 170 | 30 | 21.4% | 20 | Maintain efficient farm machinery; support transition to electric or biofuel equipment where feasible. | engines/hydraulics, electrical/diagnostics, welding, PM, equipment calibration, safety, recordkeeping |
| Farmers, Ranchers, and Other Agricultural Managers | 11-9013 | AWNL | 7640 | 8060 | 420 | 5.5% | 850 | Adopt regenerative practices, reduce fertilizer/pesticide use, and implement agroforestry/soil-carbon practices. | soil health/IPM, crop planning, irrigation, budgeting/marketing, equipment management, labor supervision, recordkeeping |
| Farmworkers and Laborers, Crop, Nursery, and Greenhouse | 45-2092 | AWNL | 4750 | 4860 | 110 | 2.3% | 720 | Plant/maintain trees, native plantings, and soil-health practices that sequester carbon. | planting/pruning, irrigation, pest monitoring, hand tools/equipment, harvest/handling, plant ID, safety |
| Farmworkers, Farm, Ranch, and Aquacultural Animals | 45-2093 | AWNL | 1250 | 1440 | 190 | 15.2% | 220 | Implement manure management, rotational grazing, and methane-reducing practices. | animal care, feeding/monitoring, manure handling, equipment operation, biosecurity, recordkeeping, safety |

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|---|---|---|---|---|---|---|---|---|---|
| Foresters | 19-1032 | AWNL | 150 | 160 | 10 | 6.7% | 10 | Plan harvests/restoration to maximize long-term carbon storage; manage wildfire risk and urban canopy. | silviculture, forest inventory/cruising, GIS/remote sensing, timber sale admin, prescribed fire, forest health, stakeholder coordination |
| Hazardous Materials Removal Workers | 47-4041 | WMM, EGU, I | 1030 | 1090 | 60 | 5.8% | 120 | Abate asbestos/lead for deep retrofits; handle contaminated wastes to enable clean construction and reuse. | HAZWOPER, asbestos/lead abatement, containment & negative air, waste handling, air monitoring, site safety |
| Heating, Air Conditioning, and Refrigeration Mechanics and Installers | 49-9021 | CRB, I | 2670 | 2900 | 230 | 8.6% | 250 | Install and service heat pumps/VRF, controls, and high-efficiency refrigeration; phase out high-GWP refrigerants. | heat pumps/VRF, refrigeration cycle, EPA 608, brazing & recovery, controls/thermostats, airflow/duct design, commissioning & diagnostics |
| Industrial Engineering Technicians | 17-3026 | I | 880 | 890 | 10 | 1.1% | 80 | Support lean/process improvements, energy mapping, and waste-heat recovery projects. | time/motion studies, data collection, CAD/layouts, SPC/quality tools, Kaizen/5S, reporting, shop floor coordination |

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|---|---|---|---|---|---|---|---|---|---|
| Industrial Engineers | 17-2112 | I | 3780 | 4110 | 330 | 8.7% | 250 | Redesign processes, right-size equipment, and integrate electrification and automation to cut energy use. | lean/six sigma, process mapping, capacity planning, simulation/ modeling, cost/energy analysis, change management, data skills |
| Insulation Workers, Floor, Ceiling, and Wall | 47-2131 | CRB, I | 320 | 340 | 20 | 6.3% | 30 | Install insulation/ air-sealing to reduce heating/cooling loads in buildings. | attic/wall/floor insulation, air sealing, vapor barriers, dense-pack/blown-in, weatherization, PPE & safety, jobsite prep |
| Insulation Workers, Mechanical | 47-2132 | CRB, I | 80 | 80 | 0 | 0.0% | 10 | Insulate pipes/ducts/ equipment to reduce thermal losses in buildings and industry. | pipe/duct insulation, jacketing/cladding, vapor barriers, spec reading, scaffolds/ladders, PPE & safety, QA/QC |
| Laborers and Freight, Stock, and Material Movers | 53-7062 | WMM, EGU, CRB, I | 13030 | 13640 | 610 | 4.7% | 1780 | Support recycling/materials handling, site logistics, and safe material movement for retrofits and plants. | technical fundamentals, problem solving, data literacy, safety, communication |
| Landscape Architects | 17-1012 | ANWL, CRB | 110 | 110 | 0 | 0.0% | 10 | Design shade/green infrastructure, native plantings, and stormwater features that lower urban heat and flooding. | site analysis/design, planting design, stormwater/LID, AutoCAD/Adobe/GIS, specs & codes, public engagement, cost estimating |

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|---|---|---|---|---|---|---|---|---|---|
| Materials Engineers | 17-2131 | CRB, I | 230 | 240 | 10 | 4.3% | 20 | Develop low-carbon materials (cement substitutes, lightweight alloys) and recycling-friendly designs. | materials selection, testing/qualification, failure analysis, cement/pozzolan knowledge, recycling design, specs/standards, LCA basics |
| Materials Scientists | 19-2032 | CRB, I | 180 | 190 | 10 | 5.6% | 10 | Advance batteries, membranes, and bio-based materials for clean energy systems. | materials characterization, battery/polymer chemistry, XRD/SEM/DSC, lab safety, data analysis, experimental design, tech transfer |
| Mechanical Engineers | 17-2141 | WMM, EGU, T, CRB, I | 3080 | 3330 | 250 | 8.1% | 200 | Design efficient HVAC, heat pumps, industrial systems, and thermal storage; integrate controls. | thermodynamics/heat transfer, HVAC design, pumps/fans, CAD/FEA, controls/BMS integration, specs & commissioning, energy analysis |
| Power Plant Operators | 51-8013 | EGU, I | 330 | 320 | -10 | -3.0% | 30 | Operate flexible/ low-carbon generation and CHP; optimize efficiency and integrate renewables. | DCS/SCADA operations, turbine/boiler basics, emissions control, dispatch & load following, procedures & safety, water/steam chemistry, troubleshooting |

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|---|---|---|---|---|---|---|---|---|---|
| Rail Car Repairers | 49-3043 | T | 300 | 320 | 20 | 6.7% | 30 | Maintain rail rolling stock to keep electrified/ efficient transit reliable and safe. | mechanical systems, air brakes, electrical wiring, welding basics, inspections, fault finding, safety procedures |
| Rail-Track Laying and Maintenance Equipment Operators | 47-4061 | T | 90 | 100 | 10 | 11.1% | 10 | Construct/maintain rail that enables mode shift to low-carbon transit and freight. | track geometry, heavy equipment ops, tamping/ ballast, survey/layout, fastening systems, work zone safety, maintenance |
| Refuse and Recyclable Material Collectors | 53-7081 | WMM, I | 600 | 650 | 50 | 8.3% | 80 | Enable diversion and methane avoidance; support route optimization and alt-fuel/EV trucks. | route operations, material ID/sorting, vehicle checks, safety & PPE, customer service, basic maintenance, EV/alt-fuel basics |
| Shuttle Drivers and Chauffeurs | 53-3053 | T | 2920 | 3370 | 450 | 15.4% | 470 | Provide shared mobility; accelerate EV adoption and safe driving to cut per-mile emissions. | CDL/safe driving, eco-driving, route navigation, customer service, pre/post-trip inspection, incident reporting, EV charging basics |
| Solar Photovoltaic Installers | 47-2231 | EGU | 240 | 330 | 90 | 37.5% | 30 | Install and maintain rooftop/ground-mount PV that displaces fossil electricity. | PV mounting & layout, DC/AC wiring, NEC Article 690, fall protection, inverter/startup, troubleshooting, site assessment |

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|---|---|---|---|---|---|---|---|---|---|
| Subway and Streetcar Operators | 53-4041 | T | 320 | 340 | 20 | 6.3% | 30 | Operate zero-tailpipe transit that reduces VMT and congestion emissions. | operations procedures, signaling/communications, situational awareness, customer service, emergency response, equipment inspections, rules compliance |
| Surveying and Mapping Technicians | 17-3031 | ANWL, CRB | 300 | 310 | 10 | 3.3% | 40 | Collect geospatial data for renewable siting, flood mapping, and right-of-way planning. | GPS/RTK/total station, data collection, CAD drafting, GIS basics, control/benchmarks, reading plans, QA/QC |
| Tree Trimmers and Pruners | 37-3013 | ANWL | 1650 | 1730 | 80 | 4.8% | 220 | Maintain urban canopy and utility clearance; reduce outages and support grid reliability. | climbing/rigging, chainsaw operation, arboriculture/ pruning, chip/cleanup, utility clearance, jobsite safety, equipment inspection |
| Urban and Regional Planners | 19-3051 | WMM, EGU, T, ANWL, CRB, I | 640 | 680 | 40 | 6.3% | 60 | Plan zoning/TOD, infill, greenways, and renewable/EV siting to reduce VMT and sprawl. | zoning & land-use, GIS & data analysis, public engagement, site plan review, grant writing, policy development, reporting/maps |
| Vocational Education Teachers, Postsecondary | 25-1194 | EGU, CRB, I | 490 | 530 | 40 | 8.2% | 40 | Build training pipelines for clean-energy trades and operations. | curriculum design, instructional methods, assessment, industry alignment, lab safety, student advising, partnerships |

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|---|---|---|---|---|---|---|---|---|---|
| Water and Wastewater Treatment Plant and System Operators | 51-8031 | WMM | 1130 | 1080 | -50 | -4.4% | 100 | Optimize aeration and pumps, capture biogas, and reduce energy and methane in utilities. | process control, SCADA/HMI, lab testing, pumps/blowers, nutrient removal, biosolids/biogas basics, safety & compliance |
| Welders, Cutters, Solderers, and Brazers | 51-4121 | CRB, I | 1250 | 1300 | 50 | 4.0% | 130 | Fabricate and retrofit clean-energy and industrial equipment (racks, piping, EV/bus infrastructure). | SMAW/GMAW/GTAW, blueprint reading, fit-up & fixtures, metallurgy basics, QA/QC, oxy-fuel/plasma cutting, safety |

## 4.2 Workforce Shortages

Achieving net-zero GHG emissions by 2050 across the Greater Worcester Region will require a rapid and sustained expansion of the Region's clean energy and resilience workforce. Though this plan and both Massachusetts and Connecticut have set ambitious climate mandates, the Region's labor market is struggling to keep stride with accelerating demand for skilled workers in these priority occupations.[202] The Greater Worcester Region, which encompasses urban centers like Worcester, Leominster, and Fitchburg in Massachusetts, and Windham County in eastern Connecticut, is at the heart of this workforce transformation. Yet, persistent shortages in training capacity, credentialing pathways, apprenticeships, job quality, and contractor readiness threaten to undermine the scale and pace of clean energy deployment. These challenges, which are rooted in structural workforce barriers, regulatory complexity, and socioeconomic inequities, risk worsening over the next two decades if unaddressed, slowing the Greater Worcester Region's progress towards electrifying buildings, decarbonizing transportation, and transforming its energy infrastructure.

### Limited Access to Training and Pre-Apprenticeship Pipelines

In the Region and across the state, limited access to vocational and pre-apprenticeship training programs remains one of the first major hurdles to expanding the net-zero workforce. Vocational-technical schools often operate at or above capacity with demand for school seats outpacing supply, leaving many interested students without entry points into these career pathways. In Massachusetts, for example, the Worcester Technical High School most recently had a waitlist of about 700 students seeking admission.[203] The Massachusetts Association of Vocational Administrators estimates that 6,000 to 11,000 students statewide are waiting for a spot in a vocational program.[204] These waitlists show that young people are motivated to move into trades and technical careers but cannot gain entry into training pipelines.

Beyond vocational technical high schools, evening continuing education and pre-apprentice training programs offer another opportunity for entry into the clean-energy workforce. Pre-apprentice training programs, such as those supported by the Massachusetts Clean Energy Center and the Connecticut Office of Workforce Development, intend to produce new technical workers. However, barriers to accessing these programs have reduced their ability to produce new workers that meet anticipated needs. These barriers are multidimensional as many programs are oversubscribed or geographically inaccessible, particularly in rural communities.[205] Adult learners, career switchers, and individuals with childcare or transportation constraints have a more difficult time attending programs structured around traditional weekday schedules.[206] Moreover, the majority of workforce training initiatives focus on entry-level skills and lack clear pathways for advancement. This makes it difficult to progress into higher-skill, higher-wage roles, exacerbating retention challenges.[207] Without significant investment in expanding training capacity, these barriers will intensify as clean energy deployment accelerates in the 2030s and 2040s.

### Complex, Changing, and Hard-to-Navigate Licensure and Certifications

The regulatory landscape for clean energy workforce credentialing in the Region is complex, fragmented, and can be confusing for both workers and employers. Many clean energy occupations

require multiple, overlapping licenses and certifications across federal, state, and even manufacturer-specific systems. For example, HVAC technicians in Massachusetts are required to obtain a state refrigeration license for systems exceeding 10 tons, which involves 6,000 hours of work under supervision in addition to completion of an accredited training program.[208] HVAC technicians must also pass the federal EPA Section 608 certification to legally handle certificates.[209] And for those working on heat pumps, some employers require additional manufacturer-specific credentials, like the Mitsubishi Electric's Diamond Contractor Certification, which adds cost and training time before employment is possible.[210]

Even experienced tradespeople can face steep time and cost hurdles to meet these requirements.[211] Licensing and certification requirements are not static and often evolve alongside new technologies, refrigerants, safety standards, and policy requirements, requiring workers to frequently retrain or recertify in order to remain employable.[212] In addition to increased costs and times, these dynamics can also add to uncertainty in career planning, discouraging prospective employees from entering these trades and further slowing growth. As electrification increases and technologies change, licensing complexity is also likely to increase. Emerging refrigerants with lower global warming potential, such as R-32 and R-454B, will require updated training and handling certifications.[213] Decarbonization policies may also expand mandatory standards for workforce qualifications, particularly around safety, energy code compliance, and performance verification. Without regulatory reform and streamlined credentialing pathways, these evolving requirements could deepen workforce needs, extend project timelines, and constrain market growth.[214]

## Limited Apprenticeship Seats and Restrictive Ratios

Apprenticeships are the backbone of workforce development for skilled trades including electrical work, HVAC installation, and plumbing, all of which are essential to growing clean energy solutions. Yet, the Region's apprenticeship capacity remains constrained by both limited program availability and restrictive supervision ratios. In Massachusetts, current electrical regulations require that one licensed journeyman electrician may supervise only one apprentice at a time, significantly capping the number of new entrants who can accrue required on-the-job hours.[215] Legislation introduced in 2025 proposes raising the ratio to 2:1 to help alleviate the backlog, but as of late 2025, the change has not been adopted.[216] Connecticut faces similar constraints with the Department of Labor's apprenticeship rules requiring a 1:1 ratio up to three apprentices and a 1:3 ratio beyond that, which employers report slows pipeline development and limits project staffing.[217] In 2025, the Connecticut General Assembly passed Senate Bill 1465 to advance ratio relief allowing contractors to request exceptions to the standard 1:1 journeyman ratio.[218] However, many smaller contractors lack the administrative capacity to navigate exceptions or apply for ratio relief, leaving apprenticeship seats unfilled even amid strong demand.[219] These ratio restrictions were put in place out of safety and quality considerations but also reveal structural rigidity in the workforce development system. Meanwhile, apprenticeship program seats, particularly in rural communities, remain scarce or oversubscribed, with long wait times for entry.[220] As a result of these limited seats, many prospective workers face significant delays in entering the clean energy workforce. Like other workforce challenges, delays in accessing apprenticeship programs not only limits the current labor supply but also discourage potential entrants from pursuing careers in the trades altogether, creating a self-reinforcing shortage over time.

## Job-Quality Barriers

While demand for clean energy workers continues to grow, many jobs across these industries struggle to attract and retain workers due to persistent job-quality issues. Barriers such as low starting wages, inadequate benefits, lack of childcare, and unreliable transportation disproportionately affect entry-level workers and individuals from historically marginalized communities. According to the Massachusetts Department of Economic Research, childcare, transportation, and housing costs are among the leading reasons workers remain out of the labor force, particularly in trades occupations that require early start times and changing jobsite locations.[221] In Connecticut, the Office of Workforce Strategy similarly identifies childcare and transportation access as significant barriers to workforce participation, especially in urban centers and rural areas without access to public transit.[222] Workers who cannot afford reliable childcare often cannot participate in full-time training or field work. And for those who can afford childcare, they may have difficulty finding care during early start times common on job sites. Limited public transportation options across the Region make it difficult for workers without personal vehicles to access job sites or training centers.[223] Clean-energy field work often requires movement between jobs during the day, and without a personal vehicle or access to reliable transit, workers may struggle to access these job sites. In addition, rising housing costs near major employment centers, like Worcester and Hartford, can force workers to commute long distances, a burden that disproportionately impacts low-income and entry-level employees.[224] The result is a workforce pipeline that is narrower and less diverse than it could be, with many qualified individuals unable to enter or remain in the industry due to systemic barriers unrelated to skill or interest. As demand for clean energy labor intensifies, job-quality barriers could become a decisive factor in whether the Region can meet its workforce needs. If wages do not keep pace with the cost of living, employers will struggle to compete with higher-paying industries like construction, manufacturing, or logistics, leading to chronic labor shortages. Additionally, without systemic solutions to childcare and transportation challenges, large segments of the workforce, particularly women, caregivers, and low-income residents, will remain excluded from the clean energy economy.

# 4.3 Workforce Development Opportunities

The transition to a net-zero GHG emissions future will depend as much on people as it does on technology. In Massachusetts and Connecticut, meeting mid-century climate goals will require an unprecedented scale-up of skilled labor to design, install, operate, and maintain the technologies and infrastructure that underpin the net-zero economy. As noted, the GWCCAP calls for a 50% reduction in emissions by 2030 and net-zero emissions by 2050, which will require retrofitting thousands of buildings, electrifying transportation systems, modernizing the electric grid, and rapidly expanding renewable energy capacity. Yet, as noted in the previous sub-section, persistent challenges have workforce capacity far below what these targets demand. Addressing these challenges requires a coordinated, forward-looking workforce development strategy that not only increases the number of workers but also diversifies the talent pool, accelerates credentialing, and improves the quality and accessibility of clean energy careers. By investing in vocational and pre-apprenticeship programs, streamlining licensing and certification pathways, reforming apprenticeship structures, and improving job quality, the Greater Worcester Region can position itself as a regional leader in the clean energy transition.

## Expand and Modernize Vocational and Pre-Apprenticeship Capacity in Secondary and Post-Secondary Education

Just as access to vocational and pre-apprenticeship programs represents the first major workforce hurdle, expansion of vocational-technical capacity, adding new training seats, and reforming curricula to better align with decarbonization needs presents a foundational development opportunity to increase the number of high school and adult learners entering clean energy trades programs. In Massachusetts, the Healey-Driscoll administration has proposed adding 3,000 new career and technical education seats over three years and to shift lottery-based admissions to reduce bias in selective entry.[225] This career and technical education reform provides an opportunity to improve access for students historically excluded from vocational education. However, admissions reform alone is insufficient if program capacity remains stagnant. Many of the Commonwealth's regional vocational-technical schools report waitlists exceeding thousands of students annually, illustrating demand far outpacing availability.[226] Expanding facilities, increasing teaching staff, and developing new Chapter 74 clean energy trade programs revolving around technologies, such as heat pump installation, solar PV design, and EV infrastructure, will ensure that more students, especially those motivated to enter trades directly, can access these pathways. Beyond vocational programs, workforce planners must expand pre-apprenticeship and accelerated adult training programs to serve career changers, unemployed workers, and underemployed populations. Short-term credential programs, offered in partnership with community colleges and workforce boards, can provide stackable certifications and on-ramps to apprenticeships or entry-level positions in clean energy sectors. Community colleges have already begun adding HVAC and energy-efficiency related coursework, with several running evening and accelerated programs to suit working adults, like Quinsigamond Community College in Worcester, MA.[227] On the state's side, initiatives like MassCEC's "Equity Workforce Training" grants have shown how targeted funding can successfully create training opportunities for underrepresented communities, but these programs must be scaled significantly to meet projected 2050 labor demand.[228] Utilization of mobile training centers could deliver short-format, stackable skills labs to rural communities and underserved neighborhoods that lack nearby training centers. The Eastern Connecticut Workforce Investment Board already utilizes a similar mobile model through the EASTCONN Mobile Manufacturing Lab which travels to schools educate youth about the manufacturing industry.[229] This should be adapted for clean-energy modules and scaled across the Region. Furthermore, partnerships with employers, labor unions, and industry associations are critical to ensure these programs remain aligned with real-world needs and lead to employment. If implemented strategically, this investment will yield a continuous flow of new workers entering the trades directly after high school or accelerated programs, closing the supply gap.[230]

## Streamline Licensing, Certification, and Credentialing Pathways

Streamlining licensing requirements through policy reform, reciprocity agreements, modular credentialing, and competency-based testing would lower barriers for new entrants and accelerate the readiness of workers for critical climate-aligned jobs. In Massachusetts, discussions of portable credentialing frameworks and modernized occupation licensing to reduce these redundant barriers have already begun.[231] And in Connecticut, while conversations about licensing in trades have been absent, there have been strides made in the education sector. Connecticut expanded a northeastern reciprocity agreement for teacher certification so that educators who are certified in Pennsylvania, New York, and Massachusetts can apply for Connecticut certification more easily.[232] Coordinated

policy reform could consolidate redundant requirements or offer integrated "clean energy technician" credentials that cover multiple competencies under one streamlined process. And given that the Greater Worcester Region crosses state borders, interstate coordination will also be essential. Mutual recognition of licenses and certifications between Massachusetts and Connecticut, similar to existing agreements in nursing or teaching, could improve labor mobility and help employers staff projects more efficiently. Though the northeastern reciprocity agreement for teacher certification is not a direct trade example, it can provide a model that could be adapted for HVAC, electrical, building performance, or other related clean energy trades. Additionally, competency-based testing and modular credentials could allow workers to demonstrate proficiency in specific areas, like refrigerants, heat pump installation, or advanced electrical work, without completing entire multi-year programs, creating a faster pathway to employment for experienced workers transitioning from adjacent fields.[233] By simplifying and harmonizing credentialing, the Region can significantly shorten training-to-employment timelines, reduce workforce attrition, and increase the overall number of certified workers in the labor pool.

## Reform Apprenticeship Structures and Expand Work-Based Learning Opportunities

To increase the number of apprenticeships, the Region should reform apprenticeship ratios to allow greater supervision flexibility, such as 2:1 ratios. This can expand the number of apprentices who gain on-the-job experience accelerating the flow of new workers into the clean-energy field.[234] The Massachusetts Legislature is considering to vote to enact Senate Bill 290, An Act Relative to the Apprentice Ration for Licensed Electricians, to expand the apprenticeship supervision ratio to 2:1, and Connecticut could consider enacting similar legislation to allow for ratio relief without burdening small contractors with administrative hurdles.[235]

Expanding apprenticeship programs must go hand in hand with broader workforce development efforts. Community colleges and workforce boards can develop hybrid programs that combine classroom instruction with paid apprenticeships, reducing barriers for participants who cannot afford unpaid training. Federal and state funding, like the US Department of Labor's Apprenticeship Building America grant, can support employers in creating new positions and offset costs associated with mentoring and supervision.[236] These partnerships are especially critical for smaller contractors who often lack the resources needed to sponsor apprentices independently.[237]

## Improve Job Quality and Benefits to Support the Expansion of Labor Participation

Policymakers and workforce planners can address workforce challenges by incentivizing higher wages and benefits, supporting employer-provided or subsidized childcare, improving public transit access to training centers and job sites, and investing in workforce housing near major employment hubs. Connecticut's Office of Workforce Strategy has identified childcare and transportation as central barriers to workforce participation and is exploring public-private partnerships to address these challenges.[238] A practical way to unlock workforce participation is to co-fund childcare with community-based organizations (CBOs). Massachusetts utilizes Commonwealth Cares for Children (C3) stabilization grants to sustain provider operations and quality investments, which local workforce boards could leverage by formalizing referral and voucher pilots with neighborhood

providers.[239] In Connecticut, the CareerConneCT initiative allows grantees to use funding for participant support services, such as childcare and transportation, enabling CBO-led training partnerships so that trainees can attend evening programs.[240] They are further adding childcare supply through a new Early Childhood Education Endowment which intends to provide thousands of additional subsidized childcare slots through programs like Smart Start and Early Start CT, explicitly supporting working families.[241] Programs like these should be adopted across the entire Region to make it more feasible to facilitate childcare partnerships between CBOs and clean-energy cohorts.

Employer-led solutions, such as flexible scheduling and transportation stipends, can further enhance participation, especially for underrepresented populations. Expanding fare-free public transit, like Worcester's WRTA fare-free program[242], or allowing for training grants to be used for transportation assistance, like Connecticut's Career ConneCT, are strategies the Region should implement to expand access to jobsites.[243] And by ensuring that jobs offer family-sustaining wages and necessary supports, the Greater Worcester Region can tap into currently underutilized labor segments including women, older workers, and rural residents. Higher and more predictable pay, paired with basic benefits, will raise competition and retention rates for these jobs. Over time, these job quality improvements will close persistent workforce gaps and build a more resilient and stable labor force capable of meeting the needs set forth in the GWCCAP.

# Workforce Planning Endnotes

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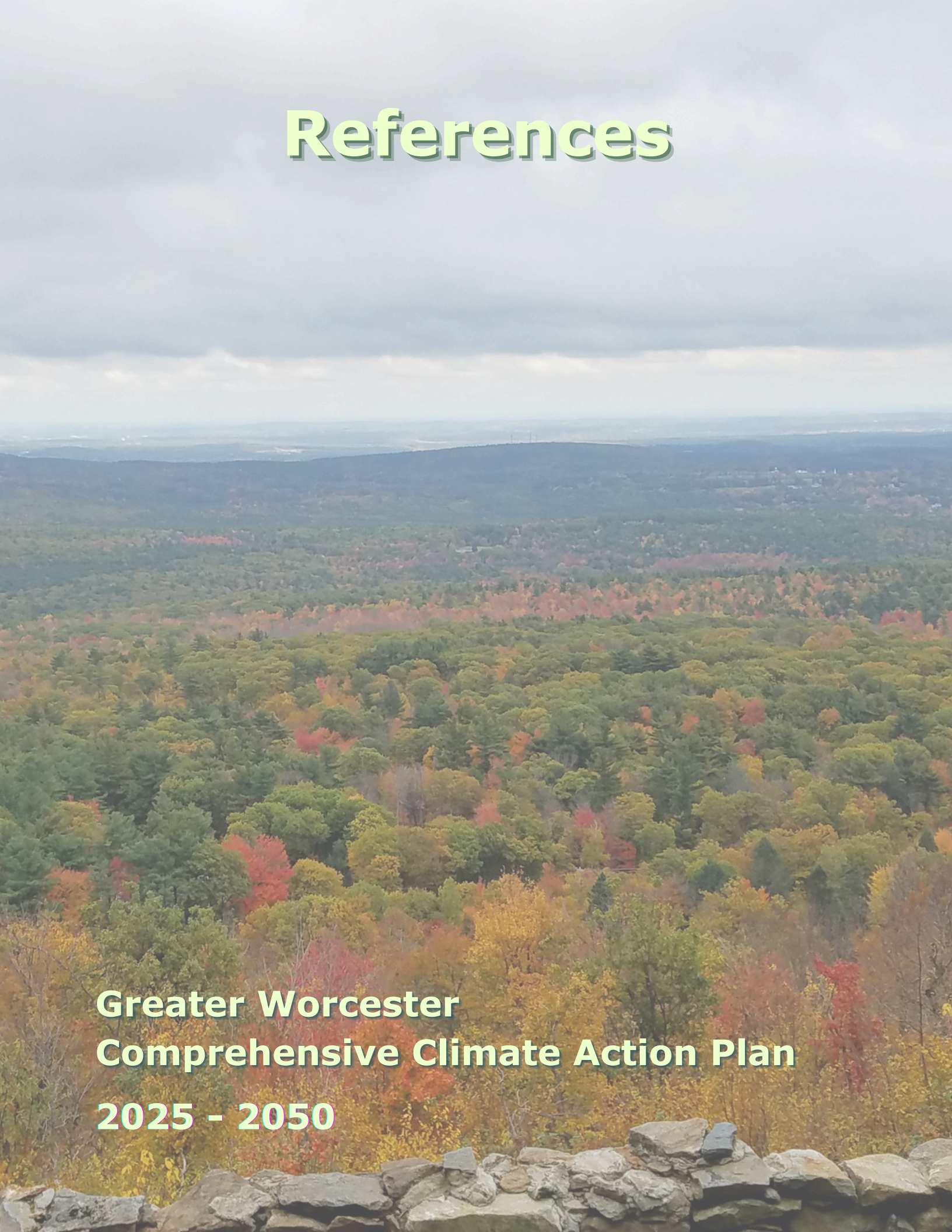

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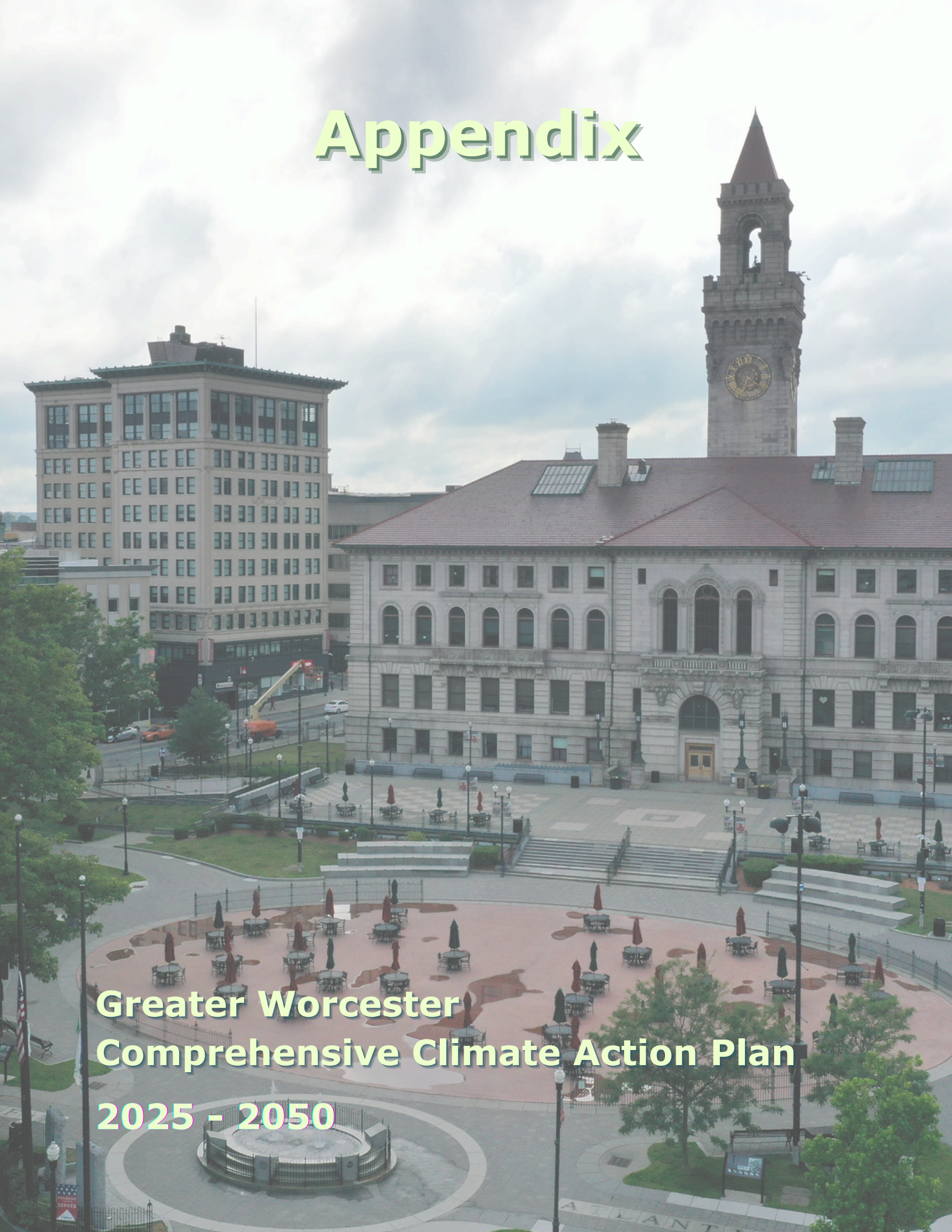
# Appendix



## Greater Worcester Comprehensive Climate Action Plan

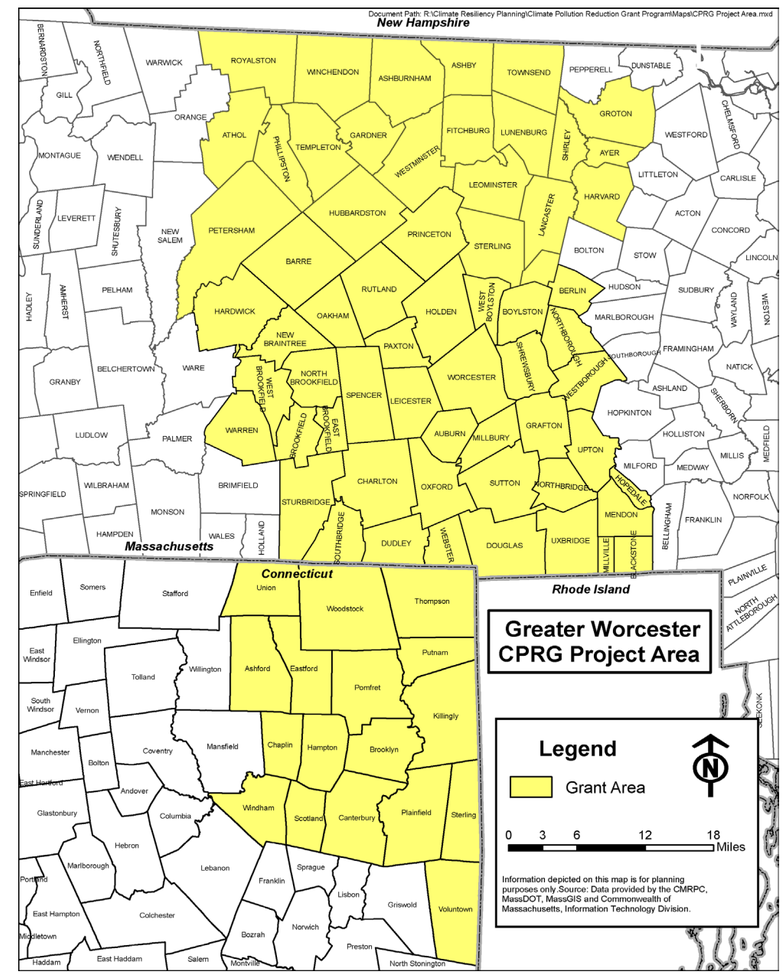
## 2025 - 2050

# Worcester, MA-CT Metropolitan Statistical Area Regional Greenhouse Gas Emissions Inventory

This regional greenhouse gas emissions inventory is a requirement of the Climate Pollution Reduction Grant (CPRG) program funded by the Environmental Protection Agency (EPA). It includes 80 communities across Massachusetts and Connecticut that were included in the Metropolitan Statistical Area (MSA) and was conducted for the inventory year of 2022.

The Metropolitan Area Planning Council's (MAPC) Community GHG Inventory Tool was used as the foundation for the inventory methodology and expanded to encompass all communities. Please refer to the Comprehensive Climate Action Plan (CCAP) and supporting documents for more information on data sources, assumptions, and methodology.

It should be noted as a limitation of this plan that the baseline emissions inventory is an estimate and does not account for all factors contributing to emissions and the prevention of emissions in the Region due to lack of data availability




### Using This Tool

Sheets and column headers are color coded to aid in understanding of the calculation process.

Some column headers have comments which describe the relevant location in the MAPC Community GHG Inventory Tool, which served as the foundation for this tool.

| Sheet Description | Sheet Color |
|---|---|
| SUMMARY | |
| SECTOR SUMMARY | |
| SOURCES | |
| SUPPLEMENTARY | |

| Column Header Description | Column Header Color |
|---|---|
| RAW DATA | |
| INTERMEDIARY CALCULATIONS | |
| IMPORTANT CALCULATED STEP | |
| EMISSIONS FACTORS | |
| EMISSIONS | |

# Supplemental Tables

The following tables contain emissions factors and other values from sources such as the EPA, Census Bureau, and Massachusetts state agencies which are used throughout the calculations.

**Supplemental Table 1: List Investor-owned Utilities and % Non-emitting Sales**

| Investor-owned Utility | % Of Sales Reported to MA DEP as "Non-emitting MWh" |
|---|---|
| *Eversource* | 40.2% |
| *NGRID* | 42.1% |
| *Until* | 43.2% |

*Source: MA DEP GHG Reporting Program Data. Appendix 2B, "Table 9: Individual 2021 Electric Utility and Competitive Supplier Percent of Sales Claimed as Unit-Specific Generation".*
*https://www.mass.gov/lists/massachusetts-greenhouse-gas-ghg-reporting-program-data*

-

**Supplemental Table 2: IPCC AR5 100-Year Global Warming Potentials without Climate-carbon Feedbacks**

| Methane (CH4) | Nitrous Oxide (N2O) |
|---|---|
| 28 | 265 |

*Source: IPCC Global Warming Potentials*
*https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf*

**Supplemental Table 3: Inputs for Emissions Factors**

| Greenhouse Gas | Combined Retail Level Electricity Emission Factor (lbs CO2e/MWh) | Non-Biogenic Retail Level Electricity Emission Factor (lbs CO2e/MWh) |
|---|---|---|
| CO2 | 540 | - |
| CH4 | 0.043 | - |
| N2O | 0.006 | - |
| CO2e | - | 637 |

**Supplemental Table 4: Emission Factors MA DEP 2022 Massachusetts-based Retail Level Electricity Emission Factor**

| Greenhouse Gas | 2022 Combined Retail Level Electricity Emission Factor (lbs CO2e/MWh) | 2022 Non-Biogenic Retail Level Electricity Emission Factor (lbs CO2e/MWh) |
|---|---|---|
| CO2 | 540 | 634 |
| CH4 | 0.043 | 0.050 |
| N2O | 0.006 | 0.007 |
| CO2e | 543 | 637 |

*Source: MA DEP GHG Reporting Program Data*
*https://www.mass.gov/lists/massachusetts-greenhouse-gas-ghg-reporting-program-data"In order to determine the utility-specific and CCA-specific emission factors, from the MassDEP GHG Reporting Program Summary report for Retail Sellers of Electricity Emissions in the inventory year was referenced. Per guidance from DEP, and in accordance with the State's GHG inventory, the "Massachusetts-based approach" non-biogenic electricity emissions factor after accounting for particular generating units from Table 2 was used as the base assumption. The Massachusetts-based consumer retail level combined electricity factors for CO2, CH4, and N2O from Appendix 3, Table 12, are used to estimate the breakdown of different gases."*

**Supplemental Table 5: 2022 Community Choice Aggregation**

| | Class I (with carve outs) |
|---|---|
| **RPS minimum compliance percentage** | 20% |
| **CCA 2022 Minimum** | 48.71% |

*Source: MA DOER Program Summaries*
*https://www.mass.gov/info-details/program-summaries*
*https://www.mass.gov/doc/ma-minimum-standards-through-2030/download*

**Supplemental Table 6: Inputs for Emission Factors**

| Fuel Type | kg CO2/MMBTU | MT CO2/MMBTU | MT CH4/MMBTU | MT N2O/MMBTU |
|---|---|---|---|---|
| *Natural Gas* | 53.06 | 0.05306 | 0.000001 | 0.0000001 |
| *Distillate Fuel Oil No. 2* | 73.96 | 0.07396 | 0.000003 | 0.0000006 |
| *Propane* | 62.87 | 0.06287 | 0.000003 | 0.0000006 |
| **Fuel Type** | **kg CO2/MMBTU** | **MT CO2/Therm** | **MT CH4/Therm** | **MT N2O/Therm** |
| *Natural Gas* | 53.06 | 0.005304939 | 0.0000001 | 0.00000001 |
| *Source: EPA Emissions Factor Hub https://www.epa.gov/climateleadership/ghg-emission-factors-hub* | | | | |

**Supplemental Table 7: Emission Factors by Fuel Type**

| Fuel Type | CO2 | Units | CH4 | Units | N2O | Units |
|---|---|---|---|---|---|---|
| *Diesel* | 0.01020648 | MTCO2/gallon | 0.00000050 | MTCH4/gallon | 0.0000004 | MTN2O/gallon |
| *Gasoline* | 0.008775 | MTCO2/gallon | 0.00000043 | MTCH4/gallon | 0.0000003 | MTN2O/gallon |
| *Compressed Natural Gas* | 0.05444 | kg CO2/scf | 0.133 | g CH4/mile | 0.004 | g N2O/mile |
| *Compressed Natural Gas* | 0.00005444 | MTCO2/scf | 0.000000133 | MTCH4/mile | 0.000000004 | MTN2O/mile |
| *LPG* | 0.00568 | MTCO2/gallon | 0.000000013 | MTCH4/gallon | 0.000000004 | MTN2O/gallon |
| *Hydrogen* | | | | | | |
| *Source: EPA Emissions Factor Hub https://www.epa.gov/climateleadership/ghg-emission-factors-hub* | | | | | | |

**Supplemental Table 8: Investor-owned Utility Electricity Emission Factor: Regional Public Transit**

| Rate Option | DEP Generic "Massachusetts-based" CO2 Electricity Emission Factor (lbs CO2 / MWh) | DEP Generic "Massachusetts-based" CH4 Electricity Emission Factor (lbs CH4 / MWh) | DEP Generic "Massachusetts-based" N2O Electricity Emission Factor (lbs N2O / MWh) | % Of Sales Reported to MA DEP as "Non-emitting MWh" | Emissions Rate (MT CO2/kWh) | Emissions Rate (MT CH4/kWh) | Emissions Rate (MT N2O/kWh) |
|---|---|---|---|---|---|---|---|
| *Average Investor-owned Utility* | 634 | 0.05046 | 0.00704 | 41.2% | 0.0001691 | 0.00000001 | 0.00000000188 |
| The above electricity emission factor is only used to calculate electricity emissions associated with regional public transportation. The emission factor is based on the IOU average emission factor. | | | | | | | |

**Supplemental Table 9: Stationary Energy - Buildings - Commercial & Industrial Fuel Oil: Employment & Establishments by NAICS Code and Business Activity VLookup**

| North American Industry Classificatic | EIA Principal Business Activity | Subsector |
|---|---|---|
| 111 | Crop production | Other |
| 112 | Animal production and aquaculture | Other |
| 113 | Forestry and logging | Other |
| 114 | Fishing, hunting and trapping | Other |
| 115 | Agriculture and forestry support activities | Other |
| 212 | Mining, except oil and gas | Other |
| 213 | Support activities for mining | Other |
| 221 | Utilities | Other |
| 236 | Construction of buildings | Other |
| 237 | Heavy and civil engineering construction | Other |
| 238 | Specialty trade contractors | Other |
| 311 | Food | Industrial |
| 312 | Beverage and Tobacco Products | Industrial |
| 313 | Textile Mills | Industrial |
| 314 | Textile Product Mills | Industrial |
| 315 | Apparel | Industrial |
| 316 | Leather and Allied Products | Industrial |
| 321 | Wood Products | Industrial |
| 322 | Paper | Industrial |
| 323 | Printing and Related Support | Industrial |
| 324 | Petroleum and Coal Products | Industrial |
| 325 | Chemicals | Industrial |
| 326 | Plastics and Rubber Products | Industrial |
| 327 | Nonmetallic Mineral Products | Industrial |
| 331 | Primary Metals | Industrial |
| 332 | Fabricated Metal Products | Industrial |
| 333 | Machinery | Industrial |
| 334 | Computer and Electronic Products | Industrial |
| 335 | Electrical Equip., Appliances, and Components | Industrial |
| 336 | Transportation Equipment | Industrial |
| 337 | Furniture and Related Products | Industrial |
| 339 | Miscellaneous | Industrial |

| | | |
|---|---|---|
| 423 | Warehouse/ Storage | Commercial |
| 424 | Warehouse/ Storage | Commercial |
| 425 | Electronic markets and agents and brokers | Other |
| 441 | Retail (non-mall) | Commercial |
| 442 | Retail (non-mall) | Commercial |
| 443 | Retail (non-mall) | Commercial |
| 444 | Retail (non-mall) | Commercial |
| 445 | Food Sales | Commercial |
| 446 | Retail (mall) | Commercial |
| 447 | Service | Commercial |
| 448 | Retail (mall) | Commercial |
| 451 | Retail (non-mall) | Commercial |
| 452 | Retail (non-mall) | Commercial |
| 453 | Retail (non-mall) | Commercial |
| 454 | Office | Commercial |
| 449 | Furniture, Home Furnishings, Electronics, and Appliance | Commercial |
| 455 | General Merchandise Retailers | Commercial |
| 456 | Health and Personal Care Retailers | Commercial |
| 457 | Gasoline Stations and Fuel Dealers | Commercial |
| 458 | Clothing, Clothing Accessories, Shoe, and Jewelry R | Commercial |
| 459 | Sporting Goods, Hobby, Musical Instrument, Book, a | Commercial |
| 481 | Office | Commercial |
| 482 | Public Assembly | Commercial |
| 483 | Service | Commercial |
| 484 | Service | Commercial |
| 485 | Public Assembly | Commercial |
| 486 | Pipeline transportation | Other |
| 487 | Public Assembly | Commercial |
| 488 | Service | Commercial |
| 491 | Service | Commercial |
| 492 | Service | Commercial |
| 493 | Warehouse/ Storage | Commercial |
| 511 | Office | Commercial |
| 512 | Public Assembly | Commercial |
| 513 | Publishing Industries | Commercial |
| 515 | Public Assembly | Commercial |
| 516 | Office | Commercial |
| 517 | Office | Commercial |
| 518 | Office | Commercial |
| 519 | Office | Commercial |
| 521 | Office | Commercial |
| 522 | Office | Commercial |
| 523 | Office | Commercial |
| 524 | Office | Commercial |
| 525 | Office | Commercial |
| 531 | Office | Commercial |
| 532 | Retail (non-mall) | Commercial |
| 533 | Office | Commercial |
| 541 | Office | Commercial |
| 551 | Office | Commercial |
| 561 | Office | Commercial |
| 562 | Other | Commercial |
| 611 | Education | Commercial |
| 621 | Outpatient Health Care | Commercial |
| 622 | Inpatient Health Care | Commercial |
| 623 | Lodging | Commercial |
| 624 | Office | Commercial |
| 711 | Public Assembly | Commercial |
| 712 | Public Assembly | Commercial |
| 713 | Public Assembly | Commercial |
| 721 | Lodging | Commercial |
| 722 | Food Service | Commercial |
| 811 | Service | Commercial |
| 812 | Service | Commercial |

| | | |
|---|---|---|
| 813 | Religious Worship | Commercial |
| 814 | Private Households | Other |
| 921 | Office | Commercial |
| 922 | Public Order/ Safety | Commercial |
| 923 | Office | Commercial |
| 924 | Office | Commercial |
| 925 | Office | Commercial |
| 926 | Office | Commercial |
| 927 | Other | Commercial |
| 928 | Office | Commercial |
| *Source: MA DER Employment and Wages (ES-202) https://lmi.dua.eol.mass.gov/lmi/EmploymentAndWages* | | |

**Supplemental Table 10: Electricity Emissions Factors - Connecticut**

| eGrid Region | CO2 (lb/MWh) | CH4 (lb/MWh) | N2O (lb/MWh) | CO2e (lb/MWh) | CO2e (MTCO2e/MWh) | CO2e (MTCO2e/kWh) | CO2 Factor (MT/kWh) | CH4 Factor (MT/kWh) | N2O Factor (MT/kWh) |
|---|---|---|---|---|---|---|---|---|---|
| **NEWE (NPCC New England)** | 539.4 | 0.072 | 0.009 | 543.801 | 0.246663783 | 0.000246664 | 0.000244668 | 0.0000000327 | 0.0000000041 |
| *Source: EPA Emissions Factor Hub https://www.epa.gov/climateleadership/ghg-emission-factors-hub* | | | | | | | | | |

**Supplemental Table 11: Stationary Energy - Buildings - MASSACHUSETTS Electricity Transmission & Distribution Grid Loss Factor**

| Total Disposition (MWh) | Direct Use (MWh) | Total Disposition Excluding Direct Use (MWh) | Estimated Losses (MWh) | Grid Loss Factor (%) |
|---|---|---|---|---|
| 54,487,601 | 838,517 | 53,649,084 | 2,757,769 | 5.14% |
| *Source: EIA State Electricity Profiles 2022 https://www.eia.gov/electricity/state/archive/2022/massachusetts/* | | | | |

**Supplemental Table 12: Stationary Energy - Buildings - CONNECTICUT Electricity Transmission & Distribution Grid Loss Factor**

| Total Disposition (MWh) | Direct Use (MWh) | Total Disposition Excluding Direct Use (MWh) | Estimated Losses (MWh) | Grid Loss Factor (%) |
|---|---|---|---|---|
| 43,054,099 | 857,003 | 42,197,096 | 1,501,966 | 3.56% |
| *Source: EIA State Electricity Profiles 2022 https://www.eia.gov/electricity/state/archive/2022/connecticut/* | | | | |

**Supplemental Table 13: Fugitive Emission Factor for Distribution Sector Natural Gas**

| Description | Data | Source |
|---|---|---|
| *Volume of Natural Gas per Heat Energy (m3 gas /therm gas)* | 2.83 | Universal Conversion |
| *Density of Natural Gas at Standard Temperature and Pressure (kg gas/m3 gas)* | 0.7 | GHG Protocol Calculation Tool for Direct Emissions |
| *Mass of Natural Gas per Therm of Natural Gas (kg gas/therm gas)* | 1.981 | Calculated |
| *Mass of Natural Gas per Therm of Natural Gas (MT gas/therm gas)* | 0.001981 | Calculated |
| *Methane Content in Distribution Sector Natural Gas (%)* | 93% | Natural Gas and Petroleum Systems in the GHG Inventory, Annex 3.6, Table 3.6-11 |
| *Carbon Dioxide Content in Distribution Sector Natural Gas (%)* | 1% | Natural Gas and Petroleum Systems in the GHG Inventory, Annex 3.6, Table 3.6-11 |
| *Methane Mass per Therm of Natural Gas (MT CH4/therm)* | 0.00185 | Calculated |
| *Carbon Dioxide Mass per Therm of Natural Gas (MT CO2/therm)* | 0.00002 | Calculated |
| *Fugitive Natural Gas Emission Factor (MT CH4/therm)* | 0.00185 | Calculated |
| *Fugitive Natural Gas Emission Factor (MT CO2/therm)* | 0.00002 | Calculated |

**Supplemental Table 14: Stationary Energy - Buildings - MASSACHUSETTS - Residential Fuel Oil Consumption & Emissions**

| Housing Type | U.S. Average Site Energy Consumption of Fuel Oil (Gallons/Year) | Millions Housing Units in MA | Percent of Total Housing Units in Massachusetts | MA Average Site Energy Consumption of Fuel Oil (Gallons / Year / Site) |
|---|---|---|---|---|
| Single-Family- Detached | 581.0 | 1.4 | 51% | 812.6 |
| Single-Family- Attached | 407.0 | 0.2 | 6% | 569.2 |
| Multi-Family, 2-4 Units | 343.0 | 0.5 | 20% | 479.7 |
| Multi-Family, 5+ Units | 224.0 | 0.6 | 22% | 313.3 |
| Mobile Homes | 309.0 | 0.0 | 1% | 432.1 |
| | **Residential Total** | **2.74** | | |
| **U.S. Average Residential Site Energy Consumption of Fuel Oil adjusted based on MA Housing Stock (Gallons / Year / Site)** | 443 | | | |
| **Massachusetts Average Residential Site Energy Consumption of Fuel Oil (Gallons / Year / Site)** | 619 | | | |
| **Adjustment Ratio** | 140% | | | |

*Source: EIA Table CE2.1 https://www.eia.gov/consumption/residential/data/2020/c&e/pdf/ce2.1.pdf*
*Residential Energy Consumption Survey Dashboard*
*https://experience.arcgis.com/experience/cbf6875974554a74823232f84f563253?src=%E2%80%B9%20Consumption%20%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-b1*

**Supplemental Table 15: Stationary Energy - Buildings- CONNECTICUT - Residential Fuel Oil Consumption & Emissions**

| Housing Type | U.S. Average Site Energy Consumption of Fuel Oil (Gallons/Year) | Millions Housing Units in CT | Percent of Total Housing Units in Connecticut | CT Average Site Energy Consumption of Fuel Oil (Gallons / Year / Site) |
|---|---|---|---|---|
| Single-Family- Detached | 581.0 | 0.765 | 84% | 720.8 |
| Single-Family- Attached | 407.0 | 0.051 | 6% | 504.9 |
| Multi-Family, 2-4 Units | 343.0 | 0.053 | 6% | 425.5 |
| Multi-Family, 5+ Units | 224.0 | 0.039 | 4% | 277.9 |
| Mobile Homes | 309.0 | 0.008 | 1% | 383.4 |
| | **Residential Total** | **0.915** | | |
| **U.S. Average Residential Site Energy Consumption of Fuel Oil adjusted based on MA Housing Stock (Gallons / Year / Site)** | 507 | | | |
| **Connecticut Average Residential Site Energy Consumption of Fuel Oil (Gallons / Year / Site)** | 629 | | | |
| **Adjustment Ratio** | 124% | | | |

*Source: EIA Table CE2.1 https://www.eia.gov/consumption/residential/data/2020/c&e/pdf/ce2.1.pdf*
*Residential Energy Consumption Survey Dashboard*
*https://experience.arcgis.com/experience/cbf6875974554a74823232f84f563253?src=%E2%80%B9%20Consumption%20%20%20%20%20%20Residential%20Energy%20Consumption%20Survey%20(RECS)-b1*

**Supplemental Table 16: Allocating Electric Vehicle Electricity Consumption to Building Subsectors**

| Vehicle Type | Percent of Electricity Consumption Allocated to "Residential (Res. Data)" Subsector | Percent of Electricity Consumption Allocated to "Commercial" Subsector |
|---|---|---|
| Passenger Vehicles | 80% | 20% |
| Commercial & Govt. Vehicles | 0% | 100% |
| Percent of passenger vehicle electricity consumption attributable to the Residential Subsector based on data from the Department of Energy and National Renewable Energy Lab (NREL) indicates 80% of electric vehicle charging occurs at home. It was assumed that the remainder of passenger vehicle charging and all of commercial vehicle charging occurs at buildings in the Commercial & Institutional Buildings & Manufacturing Industries Subsector. | | NREL Source https://www.nrel.gov/docs/fy21osti/78540.pdf |

| Supplemental Table 17: Agriculture - Enteric Fermentation and Manure Management | |
|---|---|
| **Emission Factors for Manure Management** | |
| **Animal Type** | **Emissions Factor (kg CH4/head/year)** |
| Dairy Cattle | 64.1 |
| Beef cattle | 1.9 |
| Swine | 11.6 |
| Sheep | 0.4 |
| Goats | 0.1 |
| Poultry | 0.05 |
| Horses | 1.2 |
| **Emission factors for Enteric Fermentation** | |
| **Animal Type** | **Emissions Factor (kg CH4/head/year)** |
| Dairy Cattle | 118 |
| Non - dairy | 47 |
| Sheep | 8 |
| Goats | 5 |
| Swine | 1.5 |
| Horses | 18 |

*Source: IPCC and EPA US GHG Inventory*
*Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022 – Agriculture Table 5-9*
*https://www.epa.gov/system/files/documents/2024-02/us-ghg-inventory-2024-chapter-5-agriculture.pdf*

*Cattle: Table 6 Pg. 312 Other Livestock: Table 7 Pg. 313*
*https://www.ipcc-nggip.iges.or.jp/public/gp/bgp/4_1_CH4_Enteric_Fermentation.pdf*

**Supplemental Table 18: Agriculture - County-wide Emissions Scaling Method**

| County | Total Agriculture Land County-wide: Pasture/Hay only (sq m) | Total Agriculture Land MSA ONLY: *Pasture/Hay only (sq m)* | % of MSA |
|---|---|---|---|
| New London | 778,311,568 | 28,122,756.25 | **4%** |
| Tolland | 501,704,934 | 14,075,909.35 | **3%** |
| Windham | 749,336,314 | 749,336,313.82 | **100%** |
| Middlesex | 52,192,800 | 13,358,700.00 | **26%** |
| Worcester | 174,815,100 | 173,483,100.00 | **99%** |

*Source: National Land Cover Database 2021 https://www.mrlc.gov/data/nlcd-2021-land-cover-conus*

| Supplemental Table 19: Carbon Sequestration Factors | |
|---|---|
| **Carbon Sequestration Factor** | (metric ton C/hectare/year) |
| **Average** | 2.23 |

*Source: EPA State Inventory Tools, Land-Use Land Use Change and Forestry module.*

**Supplemental Table 20: MA Statewide Agriculture Emissions - EPA Statewide Inventory Emissions Tool**

| Sector | MMTCO2e | MMTN2O | Source |
|---|---|---|---|
| Liming | 0.0127977 | | MassDEP Emissions Inventories. Appendix C: Massachusetts Annual Greenhouse Gas Emissions Inventory: 1990-2021, with Partial 2022 & 2023 Data. |
| Urea Fertilization | 0.0005225 | | |
| Ag Soils | 0.0767007 | 0.000257 | |
| MA State 2021 Total Cropland in sq m | 231,934,500 | | 2021 National Land Cover Data https://www.mrlc.gov/data/nlcd-2021-land-cover-conus |

**Supplemental Table 21: CT Statewide Agriculture Emissions - EPA Statewide Inventory Emissions Tool**

| Sector | MMTCO2e | MMTN2O | Source |
|---|---|---|---|
| Liming | | | 2022 Statewide Emissions inventory for Connecticut has no urea or liming https://portal.ct.gov/deep/climate-change/ct-greenhouse-gas-inventory-reports |
| Urea Fertilization | | | |
| Ag Soils | | 0.000132 | |
| CT State 2021 Total Cropland in sq m | 192,491,100 | | 2021 National Land Cover Data https://www.mrlc.gov/data/nlcd-2021-land-cover-conus |

| Supplemental Table 22: Private On-road Electric Vehicles Fuel Efficiency | | | | |
|---|---|---|---|---|
| **Make** | **Model** | **Year** | **Vehicle Efficiency (kWh/mile)** | **Vehicle Year, Make, and Model from Fueleconomy.gov** |
| Tesla | Model 3 | 2018 | 0.27 | *2018 Tesla Model 3 Mid Range* |
| Toyota | Rav4 Prime | 2021 | 0.36 | *2021 Toyota RAV4 Prime 4WD* |
| Tesla | Model 3 | 2021 | 0.24 | *2021 Tesla Model 3 Standard Range Plus RWD* |
| Toyota | Prius Prime | 2017 | 0.25 | *2017 Toyota Prius Prime* |
| Chevrolet | Volt | 2017 | 0.31 | *2017 Chevrolet Volt* |
| Tesla | Model 3 | 2019 | 0.26 | *2019 Tesla Model 3 Standard Range* |
| Tesla | Model 3 | 2020 | 0.26 | *2020 Tesla Model 3 Standard Range* |
| | **Average of All Vehicles:** | | **0.28** | |

*Source: The Massachusetts Vehicle Census does not provide emissions rates or fuel efficiencies for electric vehicles. In order to estimate fuel efficiency of electric vehicles, data on fuel efficiency from FuelEconomy.gov for the seven best selling electric vehicles of 2022 was used.*

| Supplemental Table 23: Air Travel Emissions Factors (Medium Haul Flight) | | | | | |
|---|---|---|---|---|---|
| **CO2 Emissions Factor kg CO2/passenger-mile** | **CH4 Emissions Factor g CH2/passenger-mile** | **N2O Emissions Factor g N2O/passenger-mile** | **CO2 Emissions Factor MT CO2/passenger-mile** | **CH4 Emissions Factor MT CH2/passenger-mile** | **N2O Emissions Factor MT N2O/passenger-mile** |
| 0.129 | 0.0006 | 0.0041 | 0.000129 | 0.000000001 | 0.000000004 |

*Source: EPA Emissions Factor Hub https://www.epa.gov/climateleadership/ghg-emission-factors-hub*

| Supplemental Table 23: Stationary Energy - Buildings - MASSACHUSETTS - Residential Propane Consumption & Emissions | | | | | |
|---|---|---|---|---|---|
| **Housing Type** | **U.S. Average Site Energy Consumption of Propane (Gallons/Year)** | **Millions Housing Units in MA** | **Percent of Total Housing Units in Massachusetts** | **MA Average Site Energy Consumption of Propane (Gallons / Year / Site)** | **Source** |
| Single-Family- Detached | 425.0 | 1.4 | 51% | 594.4 | EIA Table CE2.1 Annual household site fuel consumption in the US - totals and |
| Single-Family- Attached | 305.0 | 0.2 | 6% | 426.6 | |
| Multi-Family, 2-4 Units | 135.0 | 0.5 | 20% | 188.8 | |
| Multi-Family, 5+ Units | 125.0 | 0.6 | 22% | 174.8 | |
| Mobile Homes | 284.0 | 0.0 | 1% | 397.2 | |
| | **Residential Total** | **2.74** | | | |
| **U.S. Average Residential Site Energy Consumption of Propane adjusted based on MA Housing Stock (Gallons / Year / Site)** | 387 | Residential Energy Consumption Survey Dashboard (arcgis.com) | | | |
| **Massachusetts Average Residential Site Energy Consumption of Propane (Gallons / Year / Site)** | 345 | | | | |
| **Adjustment Ratio** | 89% | | | | |

| Supplemental Table 24: CT Municipal Vehicle Assumptions | | |
|---|---|---|
| Average vehicles per capita | 0.015 | Source: Average data from 62 Massachusetts municipalities which range in population from about 3,000 to 25,00 people. MA data sourced from Mass Energy Insight (MEI) and the MA Vehicle Census. |
| Average gasoline fuel usage per vehicle | 544.9 | |
| Average diesel fuel usage per vehicle | 544.4 | |
| Average percent of gasoline vehicles | 0.65 | |
| Average percent of diesel vehicles | 0.35 | |

**Conversion Factors Table 1:** These universal and source specific source conversions remain constant and have been referenced in various sectors for accurate calculations.

| Conversion From: | Conversion To: | Multiply By: | Source |
|---|---|---|---|
| Gallon Distillate Fuel Oil No. 2 | MMBTU | 0.138 | EPA Emissions Factor Hub |
| Propane | MMBTU | 0.091 | EPA Emissions Factor Hub |
| Gram (g) | Metric Ton (MT) | 0.000001 | Universal Conversion |
| Kilogram (kg) | Metric Ton (MT) | 0.001 | Universal Conversion |
| kWh | MMBTU | 0.00341214 | Universal Conversion |
| Megawatt-hour (MWh) | Kilowatt-hour (kWh) | 1000 | Universal Conversion |
| Million Metric Tons (MMT) | Metric Ton (MT) | 1000000 | Universal Conversion |
| Pound (lb) | Metric Ton (MT) | 0.000453592 | Universal Conversion |
| Short Ton | Metric Ton | 0.907185 | Universal Conversion |
| Short Ton | Kilogram (kg) | 907.185 | Universal Conversion |
| Short Ton | Gigagram (Gg) | 0.000907185 | Universal Conversion |
| Standard Cubic Foot (SCF) Natural Gas | Million British Thermal Units (MMBTU) | 0.00102 | Universal Conversion |
| Therm | Million British Thermal Units (MMBTU) | 0.0999761 | Universal Conversion |
| Pound (lb) | Kilograms (kg) | 0.453592 | Universal Conversion |
| Million British Thermal Units (MMBTU) | Therm | 10.0020004 | Universal Conversion |
| Carbon | Carbon Dioxide Equivalent | 3.666666667 | Universal Conversion |
| Square Meter | Hectare | 0.0001 | Universal Conversion |
| Compressed Natural Gas Gasoline Gallon Equivalent (GGE) | Standard cubic feet (scf) | 123.57 | Alternative Fuels Data Center |
| Propane (LPG) Gasoline Gallon Equivalent (GGE) | Gallons Propane (LPG) | 1.351351351 | Alternative Fuels Data Center |
| kWh | MWh | 0.001 | Universal Conversion |
| Therms | Ccf | 1.037 | Universal Conversion |

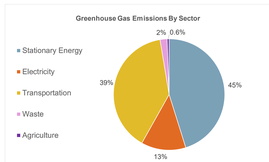
## Summary Table 1: Community-wide Emissions Summary by Sector, Subsector, Source, Scope & Gas

| Sector | Subsector | Source | Scope | Carbon Dioxide Emissions (MT CO2) | Methane Emissions (MT CH4) | Nitrous Oxide Emissions (MT N2O) | Carbon Dioxide Equivalent Emissions (MT CO2e) | Carbon Dioxide Equivalent Emissions (MMT CO2e) | Percent of Total |
|---|---|---|---|---|---|---|---|---|---|
| Stationary Energy & Electricity | Residential Buildings | Electricity | 2 | 504,850.39 | 45.44 | 6.15 | 507,553 | 0.5076 | 5.3% |
| | | Electricity T&D Losses | 3 | 25,228.84 | 2.20 | 0.30 | 25,370 | 0.0254 | 0.3% |
| | | Fuel Oil | 1 | 1,068,671.64 | 43.35 | 8.67 | 1,072,183 | 1.0722 | 11.3% |
| | | Propane | 1 | 383,718.85 | 18.31 | 3.66 | 385,202 | 0.3852 | 4.0% |
| | | Natural Gas | 1 | 515,435.95 | - | - | 515,436 | 0.5154 | 5.4% |
| | | Nat. Gas Dist. Losses | 1 | 48.12 | 4,494.34 | - | 125,890 | 0.1259 | 1.3% |
| | Commercial & Institutional Buildings & Manufacturing Industries | Electricity | 2 | 666,936.04 | 58.32 | 7.99 | 670,676 | 0.6707 | 7.0% |
| | | Electricity T&D Losses | 3 | 31,825.45 | 2.70 | 0.37 | 31,798 | 0.0318 | 0.3% |
| | | Fuel Oil | 1 | 141,053.71 | 5.72 | 1.14 | 141,517 | 0.1415 | 1.5% |
| | | Propane | 1 | 101,991.76 | 4.87 | 0.97 | 102,386 | 0.1024 | 1.1% |
| | | Natural Gas | 1 | 1,054,877.07 | 9,217.89 | 1.99 | 1,313,805 | 1.3136 | 13.8% |
| | | Nat. Gas Dist. Losses | 1 | 98.46 | 9,198.51 | - | 257,643 | 0.2576 | 2.7% |
| | | Off-Road (Various Fuels) | 1 | 215,333.02 | 93.46 | - | 217,950 | 0.2179 | 2.3% |
| | Construction | Off-Road (Various Fuels) | 1 | 166,581.99 | 5.19 | - | 166,727 | 0.1667 | 1.8% |
| Transportation | On-road | CNG | 1 | 564.95 | 0.20 | 0.01 | 567 | 0.0006 | 0.0% |
| | | Diesel | 1 | 327,473.24 | 16.18 | 11.56 | 330,890 | 0.3310 | 3.5% |
| | | Electricity | 2 | 4,242.15 | 0.46 | 0.06 | 4,271 | 0.0043 | 0.0% |
| | | Electricity T&D Losses | 3 | 179.87 | 0.02 | 0.00 | 181 | 0.0002 | 0.0% |
| | | Gasoline | 1 | 3,264,414.02 | 161.26 | 115.23 | 3,299,466 | 3.2995 | 34.7% |
| | | Propane | 1 | 997.83 | 0.00 | 0.00 | 998 | 0.0010 | 0.0% |
| | Rail | Diesel | 1 | 98,579.95 | 4.87 | 3.48 | 99,638 | 0.0996 | 1.0% |
| Waste | Solid Waste Disposal | Methane Commitment | 1 | - | 466.65 | - | 13,970 | 0.0136 | 0.1% |
| | Biological Treatment of Waste | Direct Emissions | 1 | - | 40.51 | 3.04 | 1,939 | 0.0019 | 0.0% |
| | Incineration and Open Burning | Incineration | 1 | 5,444.46 | 0.01 | 1.59 | 5,866 | 0.0059 | 0.1% |
| | Wastewater Treatment and Discharge | Effluent | 1 | - | 4,464.94 | 91.89 | 146,719 | 0.1467 | 1.5% |
| | Solid Waste Disposal | Methane Commitment | 3 | - | 644.28 | - | 18,040 | 0.0180 | 0.2% |
| | Incineration and Open Burning | Incineration | 3 | 5,117.29 | 0.03 | 8.41 | 7,348 | 0.0073 | 0.1% |
| Agriculture | Fertilizer & Agricultural Soils | Fertilizer Application | 1 | - | - | - | 15,127 | 0.0151 | 0.2% |
| | Enteric Fermentation | Livestock | 1 | - | 961.57 | - | 27,464 | 0.0275 | 0.3% |
| | Manure Management | Livestock | 1 | - | 425.92 | - | 11,926 | 0.0119 | 0.1% |
| Industrial Processes* | Industrial Processes | Industrial Processes | 1 | - | - | - | - | - | - |
| Natural & Working Lands | Forest Land | Carbon sequestration | - | (2,831,780.73) | - | - | (2,831,781) | (2.83) | - |
| | | | Gross Emissions | 8,583,316 | 30,418 | 256 | 9,918,023 | 9.92 | |
| | | | Net Emissions | 5,751,535 | 30,418 | 256 | 6,656,242 | 6.69 | |
| Aviation | Passenger Air Travel | Various Fuels | 3 | 16,705.16 | 0.03 | 0.20 | 16,756 | 0.0168 | 0.2% |

* Many of the industrial process sources included in the MA DEP GHG inventories are not applicable to the MSA or have a wide range of use types and therefore could not be appropriately scaled down and allocated to the MSA.

## Summary Table 2: Community-wide Emissions Summary by Sector & Subsector

| Sector | Subsector | MTCO2e | MMTCO2e | MMTCO2e Totals for BAU Scenario |
|---|---|---|---|---|
| Stationary Energy | Residential Stationary | 1,972,621 | 1.97 | 1.97 |
| | C/I Stationary | 1,942,185 | 1.94 | 1.94 |
| | Natural Gas T&D | 383,532 | 0.38 | 0.38 |
| Electricity | Electricity | 1,178,228 | 1.18 | 1.20 |
| | Electricity T&D | 57,169 | 0.06 | |
| Transportation | On-road | 3,635,470 | 3.64 | 3.74 |
| Waste | Waste | 185,483 | 0.19 | 0.19 |
| Agriculture | Agriculture | 54,537 | 0.05 | 0.05 |
| Industrial Processes | Industrial Processes | - | - | - |
| Natural & Working Lands | Carbon Sequestration | (2,831,781) | (2.83) | (2.83) |
| | Gross Emissions | 9,317,264 | 9.32 | 9.32 |
| | Net Emissions | 6,485,254 | 6.69 | 6.69 |




## Summary Table 3: Community-wide Emissions Summary by Sector

| Sector | MTCO2e | MMTCO2e | Percent |
|---|---|---|---|
| Stationary Energy | 4,298,538 | 4.30 | 45% |
| Electricity | 1,235,398 | 1.24 | 13% |
| Transportation | 3,736,066 | 3.74 | 39% |
| Waste | 185,483 | 0.19 | 2% |
| Agriculture | 54,537 | 0.05 | 0.6% |
| Natural & Working Lands | (2,831,781) | (2.83) | |
| Gross Emissions | 9,518,023 | 9.52 | 100% |
| Net Emissions | 6,656,242 | 6.69 | |

## Summary Table 4: Community-wide Emissions Summary by Sector, Subsector, & Scope

| Sector | Subsector | Total Emissions (MT CO2e) | Scope 1 Emissions (MT CO2e) | Scope 2 Emissions (MT CO2e) | Scope 3 Emissions (MT CO2e) |
|---|---|---|---|---|---|
| Stationary Energy | Residential Buildings | 2,098,710 | 2,098,710 | - | - |
| | C&I Buildings & Manufacturing Industries | 2,033,101 | 2,033,101 | - | - |
| | Construction | 166,727 | 166,727 | - | - |
| Electricity | Electricity | 1,178,228 | - | 1,178,228 | - |
| | Electricity T&D Losses | 57,169 | - | - | 26,561 |
| Transportation | On-road | 3,636,428 | 3,631,016 | 4,271 | 181 |
| | Railways | 99,638 | 99,638 | - | - |
| Waste | Solid Waste Disposal | 31,610 | 13,570 | - | 18,040 |
| | Biological Treatment of Waste | 1,939 | 1,939 | - | - |
| | Incineration and Open Burning | 13,214 | 5,866 | - | 7,348 |
| | Wastewater Treatment and Discharge | 146,719 | 146,719 | - | - |
| | Fertilizer & Agricultural Soils | 15,127 | 15,127 | - | - |
| Agriculture | Enteric Fermentation | 27,464 | 27,464 | - | - |
| | Manure Management | 11,926 | 11,926 | - | - |
| Natural & Working Lands | Carbon Sequestration | (2,831,780.73) | - | - | - |
| All Sectors & Subsectors | | 9,518,023 | 8,251,827 | 1,182,499 | 51,130 |

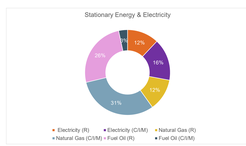
## Summary Table 6: Community-wide Summary of Building Energy Use by Sector

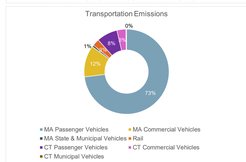
| Subsector | Source | Emissions (MTCO2e) | % of Total Energy Emissions |
|---|---|---|---|
| Residential Buildings | Res. Electricity | 507,553 | 24.2% |
| | Res. Fuel Oil | 1,072,183 | 51.2% |
| | Res. Natural Gas | 515,436 | 24.6% |
| Commercial & Institutional Buildings and Facilities + Manufacturing Industries* | Comm. & Man. Electricity | 670,676 | 33.5% |
| | Comm. & Man. Fuel Oil | 141,517 | 6.7% |
| | Comm. & Man. Natural Gas | 1,313,805 | 61.8% |
| All Buildings | Electricity | 1,178,228 | 27.9% |
| | Fuel Oil | 1,213,700 | 28.8% |
| | Natural Gas | 1,829,241 | 43.3% |

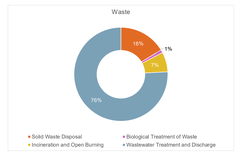
The above energy consumption and emissions data exclude electricity transmission and distribution losses associated with electricity and natural gas. See "Stationary Energy Summary" worksheet for a detailed breakdown of transmission and distribution losses.

## Summary Table 9: Community-wide Emissions Summary by Sector and Subsector

| Sector | Subsector | Total Emissions (MT CO2e) | % of Total Emissions | % of Emissions in Respective Sector |
|---|---|---|---|---|
| Stationary Energy | Residential Buildings | 2,098,710 | 22.0% | 48.8% |
| | C&I Buildings & Manufacturing Industries | 2,033,101 | 21.4% | 47.3% |
| | Construction | 166,727 | 1.8% | 3.9% |
| Electricity | Electricity | 1,178,228 | 12.4% | 27.4% |
| | Electricity T&D Losses | 57,169 | 0.6% | 1.3% |
| Transportation | MA Passenger Vehicles | 2,727,801 | 28.7% | 73.2% |
| | MA Commercial Vehicles | 449,809 | 4.7% | 12.1% |
| | MA State & Municipal Vehicles | 104,136 | 1.1% | 2.7% |
| | Rail | 99,638 | 1.0% | 2.7% |
| | CT Passenger Vehicles | 296,791 | 3.1% | |
| | CT Commercial Vehicles | 127,127 | 1.3% | 3.4% |
| | CT Municipal Vehicles | 9,495 | 0.1% | 0.3% |
| Waste | Solid Waste Disposal | 13,570 | 0.1% | 7.3% |
| | Biological Treatment of Waste | 1,939 | 0.0% | 1.0% |
| | Incineration and Open Burning | 13,214 | 0.1% | 6.8% |
| | Wastewater Treatment and Discharge | 146,719 | 1.5% | 79.8% |
| Agriculture | Fertilizer & Agricultural Soils | 15,127 | 0.002 | 28% |
| | Enteric Fermentation | 27,464 | 0.003 | 50% |
| | Manure Management | 11,926 | 0.1% | 22% |
| Natural & Working Lands | Carbon Sequestration | (2,831,780.73) | | |
| | All Sectors & Subsectors | 9,518,023 | 100% | |



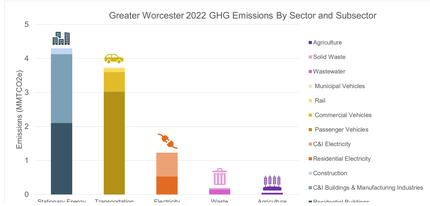



## Summary Table 10: Community-wide Emissions Summary by Sector and Subsector

| Sector | Subsector | Total Emissions (MT CO2e) | % of Total Emissions | % of Emissions in Respective Sector |
|---|---|---|---|---|
| Stationary Energy | Residential Buildings | 2,098,710 | 22.0% | 48.8% |
| | C&I Buildings & Manufacturing Industries | 2,033,101 | 21.4% | 47.3% |
| | Construction | 166,727 | 1.8% | 3.9% |
| Electricity | Electricity | 1,178,228 | 12.4% | 27.4% |
| | Electricity T&D Losses | 57,169 | 0.6% | 1.3% |
| Transportation | Passenger Vehicles | 3,024,392 | 31.8% | 70.4% |
| | Commercial Vehicles | 576,766 | 6.1% | 13.4% |
| | Municipal | 35,279 | 0.4% | 0.8% |
| | Rail | 99,638 | 1.0% | 2.3% |
| Waste | Solid Waste Disposal | 31,610 | 0.3% | 0.7% |
| | Biological Treatment of Waste | 1,939 | 0.0% | 0.0% |
| | Incineration and Open Burning | 13,214 | 0.1% | 0.3% |
| | Wastewater Treatment and Discharge | 146,719 | 1.5% | 3.4% |
| Agriculture | Fertilizer & Agricultural Soils | 15,127 | 0.2% | 0.4% |
| | Enteric Fermentation | 27,464 | 0.3% | 0.6% |
| | Manure Management | 11,926 | 0.1% | 0.3% |
| Natural & Working Lands | Carbon Sequestration | (2,831,780.73) | | |
| | All Sectors & Subsectors | 9,518,023 | 100% | |

| Total Emissions (MT CO2e) | Stationary Energy | Transportation | Electricity | Waste | Agriculture | Forest Carbon | Percentage |
|---|---|---|---|---|---|---|---|
| Residential Buildings | 2.1 | | | | | | 22% |
| Non-residential Stationary | 2.0 | | | | | | 21% |
| Construction | 0.2 | | | | | | 2% |
| Residential Electricity | | | 0.53 | | | | 6% |
| C&I Electricity | | | 0.72 | | | | 7% |
| Passenger Vehicles | | 3.02 | | | | | 32% |
| Commercial Vehicles | | 0.58 | | | | | 6% |
| Rail | | 0.10 | | | | | 1% |
| Municipal Vehicles | | 0.04 | | | | | 1% |
| Wastewater | | | | 0.15 | | | 0.5% |
| Solid Waste | | | | 0.05 | | | 1.5% |
| Agriculture | | | | | 0.05 | | 1% |
| | | | | | | | |
| | | | | | | | |
| Forest Carbon Sequestration | | | | | | (2,831,780.73) | 9.3 |



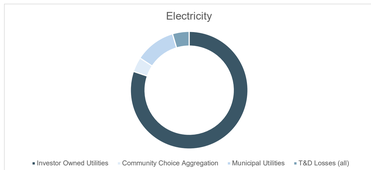
Sector

## Stationary Energy: Community-wide Energy & Emissions Summary

**Stationary Energy & Electricity Table 1: Summary of Energy Emissions from Residential Buildings, Commercial & Institutional Buildings and Manufacturing Industries & Construction Subsectors**

| Subsector | Energy Category | Natural Gas (Therms) | Natural Gas CO2 (MT CO2) | Natural Gas CH4 Emissions (MT CH4) | Natural Gas N2O Emissions (MT N2O) | Electricity Consumption (kWh) | Electricity Consumption CO2 Emissions (MT CO2) | Electricity Consumption CH4 Emissions (MT CH4) | Electricity Consumption N2O Emissions (MT N2O) | Electricity T&D Losses (kWh) | Electricity T&D Losses CO2 Emissions (MT CO2) | Electricity T&D Losses CH4 Emissions (MT CH4) | Electricity T&D Losses N2O Emissions (MT N2O) | Fuel Oil (gal) | Fuel Oil CO2 Emissions (MT CO2) | Fuel Oil CH4 Emissions (MT CH4) | Fuel Oil N2O Emissions (MT N2O) | Propane (gal) | Propane CO2 Emissions (MT CO2) | Propane CH4 Emissions (MT CH4) | Propane N2O Emissions (MT N2O) | Off-road CO2 Emissions- Various Fuels (MT CO2) | Off-road CH4 Emissions Various Fuels (MT CH4) | Total CO2 Emissions (MT CO2) | Total CH4 Emissions (MT CH4) | Total N2O Emissions (MT N2O) | Total CO2 Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Residential Buildings | IOU Residential | 97,161,517 | 515,436 | 9.71 | 0.97 | 2,241,426,444.90 | 404,320.72 | 37.54 | 5.05 | | | | | | | | | | | | | | | 919,756.62 | 47.25 | 5.05 | 922,416.71 |
| | CCA Residential | | | | | 286,951,725.00 | 25,677.00 | 2.04 | 0.29 | | | | | | | | | | | | | | | 25,677.00 | 2.04 | 0.29 | 25,809.85 |
| | Muni Residential | | | | | 440,054,157.66 | 77,819.24 | 6.20 | 0.86 | | | | | | | | | | | | | | | 77,819.24 | 6.20 | 0.86 | 78,221.88 |
| | All Res. T&D Losses | 2,429,038 | 48.12 | 4,494.34 | | | | | | 143,179,707.60 | 25,228.84 | 2.20 | 0.30 | | | | | | | | | | | 25,276.96 | 4,496.54 | 0.30 | 151,259.47 |
| | Fuel Oil | | | | | | | | | | | | | 104,705,210.92 | 1,068,671.64 | 43.35 | 8.67 | | | | | | | 1,068,671.64 | 43.35 | 8.67 | 1,072,182.83 |
| | Propane | | | | | | | | | | | | | | | | | 67,069,996.37 | 383,718.85 | 18.31 | 3.66 | | | 383,718.85 | 18.31 | 3.66 | 385,201.97 |
| | EV Adjustment | | | | | (15,743,706) | (3,167) | (0.34) | (0.04) | | | | | | | | | | | | | | | (3,166.56) | (0.34) | (0.04) | (3,187.73) |
| | ***Res. Buildings Total*** | **99,590,555** | **515,484** | **4,504** | **1** | **2,952,688,621.62** | **504,650.39** | **45.44** | **6.15** | **143,179,707.60** | **25,228.84** | **2.20** | **0.30** | **104,705,210.92** | **1,068,671.64** | **43.35** | **8.67** | **67,069,996.37** | **383,718.85** | **18.31** | **3.66** | **-** | **-** | **2,497,753.74** | **4,613.35** | **18.78** | 2,631,904.98 |
| Commercial & Institutional Buildings & Manufacturing Industries | IOU Non-Residential | 198,848,513 | 1,054,879 | 20 | 2 | 3,450,835,095.10 | 604,531.49 | 53.35 | 7.26 | | | | | | | | | | | | | | | 1,659,410.69 | 73.23 | 9.24 | 1,663,910.86 |
| | CCA Non-Residential | | | | | - | - | - | - | | | | | | | | | | | | | | | - | - | - | - |
| | Muni Non-Residential | | | | | 354,558,161.34 | 62,453.17 | 4.97 | 0.69 | | | | | | | | | | | | | | | 62,453.17 | 4.97 | 0.69 | 62,776.31 |
| | All C&I T&D Losses | 4,971,213 | 98.48 | 9,198.01 | | | | | | 182,441,325.07 | 31,625.45 | 2.70 | 0.371 | | | | | | | | | | | 31,723.93 | 9,200.71 | 0.37 | 289,442.02 |
| | Fuel Oil | | | | | | | | | | | | | 13,820,015.02 | 141,053.71 | 5.72 | 1.14 | | | | | | | 141,053.71 | 5.72 | 1.14 | 141,517.15 |
| | Propane | | | | | | | | | | | | | | | | | 17,827,599.28 | 101,991.76 | 4.87 | 0.97 | | | 101,991.76 | 4.87 | 0.97 | 102,385.97 |
| | EV Adjustment | | | | | -287,925 | -49 | -0.0039 | -0.0005 | | | | | | | | | | | | | | | (48.63) | (0.00) | (0.00) | (48.88) |
| | Off-road | | | | | | | | | | | | | | | | | | | | | 215,333.02 | 93.46 | 215,333.02 | 93.46 | - | 217,949.95 |
| | ***C&I Buildings Total*** | **203,819,726** | **1,054,978** | **9,218** | **2** | **3,805,105,331** | **666,936** | **58** | **8** | **182,441,325** | **31,625** | **3** | **0** | **13,820,015** | **141,054** | **6** | **1** | **17,827,599** | **101,992** | **5** | **1** | **215,333** | **93** | **2,211,918** | **9,383** | **12** | **2,477,933.38** |
| Construction | Off-road | | | | | | | | | | | | | | | | | | | | | 166,581.99 | 5.18 | 166,581.99 | 5.18 | | 166,727.05 |
| | ***Construction Total*** | | | | | | | | | | | | | | | | | | | | | **166,581.99** | **5.18** | **166,581.99** | **5.18** | | 166,727.05 |
| **All Stationary Energy Subsectors** | | **303,410,281.6** | **1,570,461.7** | **13,721.9** | **3.0** | **6,757,793,952.7** | **1,171,586.4** | **103.8** | **14.1** | **325,621,032.7** | **56,854.3** | **4.9** | **0.7** | **118,525,225.9** | **1,209,725.3** | **49.1** | **9.8** | **84,897,595.6** | **485,710.6** | **23.2** | **4.6** | **166,582.0** | **5.2** | **4,709,671.4** | **13,996.3** | **31.2** | **5,109,838.4** |

| Type | kWh | Percent |
|---|---|---|
| Investor Owned Utilities | 5,692,261,540 | 80% |
| Community Choice Aggregation | 286,951,725 | 4% |
| Municipal Utilities | 794,612,319 | 11% |
| T&D Losses (all) | 325,621,033 | 5% |



**Natural Gas:**
2022 natural gas consumption was sourced from Mass Save Data to determine the Commercial & Industrial and Residential annual natural gas use for each town in the MSA. The towns without data do not appear to be served by a natural gas utility.
https://www.masssavedata.com/Public/GeographicSavings?view=U

| Towns | County | State | Est. Annual Loss Rates from Natural Gas from Transmission, Distribution and End Use (%) | Residential Natural Gas Consumption (Therms) | Natural Gas Emissions _RESID (MT CO2) | Natural Gas Emissions _RESID (MT CH4) | Natural Gas Emissions _RESID (MT N2O) | Natural Gas Emissions _RESID (MT CO2e) | RESIDENTIAL Total Nat. Gas Distribution Losses (Therms) | RESIDENTIAL Natural Gas Distribution Losses CO2 Emissions (MT CO2) | RESIDENTIAL Natural Gas Distribution Losses CH4 Emissions (MT CH4) | RESIDENTIAL Natural Gas Distribution Losses N2O Emissions (MT CH4) | RESIDENTIAL Natural Gas Distribution Losses (MTCO2e) | Commercial & Industrial Natural Gas Consumption (Therms) | Natural Gas Emissions _C&I (MT CO2) | Natural Gas Emissions _C&I (MT CH4) | Natural Gas Emissions _C&I (MT N2O) | Natural Gas Emissions _C&I (MTCO2e | C&I Total Nat. Gas Distribution Losses (Therms) | C&I Natural Gas Distribution Losses CO2 Emissions (MT CO2) | C&I Natural Gas Distribution Losses CH4 Emissions (MT CH4) | C&I Natural Gas Distribution Losses Emissions (MTCO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **All Towns** | | ***Totals*** | **2.5%** | **97,161,517** | **515,436** | **10** | **1** | **515,965** | **2,429,038** | **48** | **4,494** | **4,494** | **125,890** | **198,848,513** | **1,054,879** | **20** | **2** | **1,055,963** | **4,971,213** | **98** | **9,198** | **257,643** |
| *Ashburnham* | Worcester | MA | 2.5% | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Ashby* | Middlesex | MA | 2.5% | 121,817 | 646 | 0 | 0 | 647 | 3045 | 0 | 6 | 6 | 158 | 77,87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Athol* | Worcester | MA | 2.5% | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Auburn* | Worcester | MA | 2.5% | 824,035 | 4371 | 0 | 0 | 4376 | 20601 | 0 | 38 | 38 | 1068 | 1878232 | 9964 | 0 | 0 | 9974 | 46956 | 1 | 87 | 2434 |
| *Ayer* | Middlesex | MA | 2.5% | 1,255,380 | 6660 | 0 | 0 | 6667 | 31385 | 1 | 58 | 58 | 1627 | 3655579 | 19393 | 0 | 0 | 19413 | 91389 | 2 | 169 | 4736 |
| *Barre* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Berlin* | Worcester | MA | 2.5% | 197,819 | 1049 | 0 | 0 | 1050 | 4945 | 0 | 9 | 9 | 256 | 155727 | 826 | 0 | 0 | 827 | 3893 | 0 | 7 | 202 |
| *Blackstone* | Worcester | MA | 2.5% | 934,404 | 4957 | 0 | 0 | 4962 | 23360 | 0 | 43 | 43 | 1211 | 330906 | 1755 | 0 | 0 | 1757 | 8273 | 0 | 15 | 429 |
| *Bolton* | Worcester | MA | 2.5% | 642,917 | 3411 | 0 | 0 | 3414 | 16073 | 0 | 30 | 30 | 833 | 626321 | 3323 | 0 | 0 | 3326 | 15658 | 0 | 29 | 812 |
| *Boylston* | Worcester | MA | 2.5% | 207,005 | 1098 | 0 | 0 | 1099 | 5175 | 0 | 10 | 10 | 268 | 328966 | 1745 | 0 | 0 | 1747 | 8224 | 0 | 15 | 426 |
| *Brookfield* | Worcester | MA | 2.5% | 136,416 | 724 | 0 | 0 | 724 | 3410 | 0 | 6 | 6 | 177 | 116347 | 617 | 0 | 0 | 618 | 2909 | 0 | 5 | 151 |
| *Charlton* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Clinton* | Worcester | MA | 2.5% | 271,091 | 1438 | 0 | 0 | 1440 | 6777 | 0 | 13 | 13 | 351 | 1073941 | 5697 | 0 | 0 | 5703 | 26849 | 1 | 50 | 1391 |
| *Douglas* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Dudley* | Worcester | MA | 2.5% | 564,227 | 2993 | 0 | 0 | 2996 | 14106 | 0 | 26 | 26 | 731 | 615349 | 3264 | 0 | 0 | 3268 | 15384 | 0 | 28 | 797 |
| *East Brookfield* | Worcester | MA | 2.5% | 126,432 | 671 | 0 | 0 | 671 | 3161 | 0 | 6 | 6 | 164 | 122654 | 651 | 0 | 0 | 651 | 3066 | 0 | 6 | 159 |
| *Fitchburg* | Worcester | MA | 2.5% | 7,325,099 | 38859 | 1 | 0 | 38899 | 183127 | 4 | 339 | 339 | 9491 | 13557073 | 71919 | 1 | 0 | 71993 | 338927 | 7 | 627 | 17566 |
| *Gardner* | Worcester | MA | 2.5% | 913,020 | 4844 | 0 | 0 | 4848 | 22826 | 0 | 42 | 42 | 1183 | 3937325 | 20887 | 0 | 0 | 20909 | 98433 | 2 | 182 | 5101 |
| *Grafton* | Worcester | MA | 2.5% | 3,415,436 | 18119 | 0 | 0 | 18137 | 85386 | 2 | 158 | 158 | 4425 | 7065667 | 37483 | 1 | 0 | 37521 | 176642 | 3 | 327 | 9155 |
| *Groton* | Middlesex | MA | 2.5% | 1,053,427 | 5588 | 0 | 0 | 5594 | 26336 | 1 | 49 | 49 | 1365 | 6178424 | 32776 | 1 | 0 | 32810 | 154461 | 3 | 286 | 8005 |
| *Hardwick* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Harvard* | Worcester | MA | 2.5% | 307,648 | 1632 | 0 | 0 | 1634 | 7691 | 0 | 14 | 14 | 399 | 228062 | 1210 | 0 | 0 | 1211 | 5702 | 0 | 11 | 295 |
| *Holden* | Worcester | MA | 2.5% | 1,253,640 | 6650 | 0 | 0 | 6657 | 31341 | 1 | 58 | 58 | 1624 | 1847958 | 9803 | 0 | 0 | 9813 | 46199 | 1 | 85 | 2394 |
| *Hopedale* | Worcester | MA | 2.5% | 397,770 | 2110 | 0 | 0 | 2112 | 9944 | 0 | 18 | 18 | 515 | 221716 | 1176 | 0 | 0 | 1177 | 5543 | 0 | 10 | 287 |
| *Hubbardston* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Lancaster* | Worcester | MA | 2.5% | 239,177 | 1269 | 0 | 0 | 1270 | 5979 | 0 | 11 | 11 | 310 | 262556 | 1393 | 0 | 0 | 1394 | 6564 | 0 | 12 | 340 |
| *Leicester* | Worcester | MA | 2.5% | 126,808 | 673 | 0 | 0 | 673 | 3170 | 0 | 6 | 6 | 164 | 275880 | 1464 | 0 | 0 | 1465 | 6897 | 0 | 13 | 357 |
| *Leominster* | Worcester | MA | 2.5% | 4,778,435 | 25349 | 0 | 0 | 25375 | 119461 | 2 | 221 | 221 | 6191 | 9054593 | 48034 | 1 | 0 | 48083 | 226365 | 4 | 419 | 11732 |
| *Lunenburg* | Worcester | MA | 2.5% | 615,991 | 3268 | 0 | 0 | 3271 | 15400 | 0 | 28 | 28 | 798 | 2051735 | 10884 | 0 | 0 | 10896 | 51293 | 1 | 95 | 2658 |
| *Mendon* | Worcester | MA | 2.5% | 1,689,981 | 8965 | 0 | 0 | 8974 | 42250 | 1 | 78 | 78 | 2190 | 300803 | 1596 | 0 | 0 | 1597 | 7520 | 0 | 14 | 390 |
| *Millbury* | Worcester | MA | 2.5% | 1,463,646 | 7765 | 0 | 0 | 7773 | 36591 | 1 | 68 | 68 | 1896 | 4203145 | 22297 | 0 | 0 | 22320 | 105079 | 2 | 194 | 5446 |
| *Millville* | Worcester | MA | 2.5% | 276,750 | 1468 | 0 | 0 | 1470 | 6919 | 0 | 13 | 13 | 359 | 73887 | 392 | 0 | 0 | 392 | 1847 | 0 | 3 | 96 |
| *New Braintree* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *North Brookfield* | Worcester | MA | 2.5% | 442,352 | 2347 | 0 | 0 | 2349 | 11059 | 0 | 20 | 20 | 573 | 267508 | 1419 | 0 | 0 | 1421 | 6688 | 0 | 12 | 347 |
| *Northborough* | Worcester | MA | 2.5% | 2,030,448 | 10771 | 0 | 0 | 10782 | 50761 | 1 | 94 | 94 | 2631 | 4950021 | 26260 | 0 | 0 | 26287 | 123751 | 2 | 229 | 6414 |
| *Northbridge* | Worcester | MA | 2.5% | 1,583,340 | 8400 | 0 | 0 | 8408 | 39584 | 1 | 73 | 73 | 2051 | 3223081 | 17098 | 0 | 0 | 17116 | 80577 | 2 | 149 | 4176 |
| *Oakham* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Oxford* | Worcester | MA | 2.5% | 65,688 | 348 | 0 | 0 | 349 | 1642 | 0 | 3 | 3 | 85 | 2519846 | 13368 | 0 | 0 | 13381 | 62996 | 1 | 117 | 3265 |
| *Paxton* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Petersham* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Phillipston* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Princeton* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Royalston* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Rutland* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Shirley* | Middlesex | MA | 2.5% | 410,768 | 2179 | 0 | 0 | 2181 | 10269 | 0 | 19 | 19 | 532 | 1857465 | 9854 | 0 | 0 | 9864 | 46437 | 1 | 86 | 2407 |
| *Shrewsbury* | Worcester | MA | 2.5% | 7,450,795 | 39526 | 1 | 0 | 39567 | 186270 | 4 | 345 | 345 | 9654 | 6030681 | 31992 | 1 | 0 | 32025 | 150767 | 3 | 279 | 7814 |
| *Southbridge* | Worcester | MA | 2.5% | 2,263,119 | 12006 | 0 | 0 | 12018 | 56578 | 1 | 105 | 105 | 2932 | 3242900 | 17203 | 0 | 0 | 17221 | 81073 | 2 | 150 | 4202 |
| *Spencer* | Worcester | MA | 2.5% | 982,133 | 5210 | 0 | 0 | 5216 | 24553 | 0 | 45 | 45 | 1273 | 2714307 | 14399 | 0 | 0 | 14414 | 67858 | 1 | 126 | 3517 |
| *Sterling* | Worcester | MA | 2.5% | 1,183,561 | 6279 | 0 | 0 | 6285 | 29589 | 1 | 55 | 55 | 1534 | 2220730 | 11781 | 0 | 0 | 11793 | 55518 | 1 | 103 | 2877 |
| *Sturbridge* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Sutton* | Worcester | MA | 2.5% | 271,091 | 1438 | 0 | 0 | 1440 | 6777 | 0 | 13 | 13 | 351 | 1073941 | 5697 | 0 | 0 | 5703 | 26849 | 1 | 50 | 1391 |
| *Templeton* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Townsend* | Middlesex | MA | 2.5% | 1,231,994 | 6536 | 0 | 0 | 6542 | 30800 | 1 | 57 | 57 | 1596 | 728560 | 3865 | 0 | 0 | 3869 | 18214 | 0 | 34 | 944 |
| *Upton* | Worcester | MA | 2.5% | 740,787 | 3930 | 0 | 0 | 3934 | 18520 | 0 | 34 | 34 | 960 | 693701 | 3680 | 0 | 0 | 3684 | 17343 | 0 | 32 | 899 |
| *Uxbridge* | Worcester | MA | 2.5% | 1,513,480 | 8029 | 0 | 0 | 8037 | 37837 | 1 | 70 | 70 | 1961 | 2126520 | 11281 | 0 | 0 | 11293 | 53163 | 1 | 98 | 2755 |
| *Warren* | Worcester | MA | 2.5% | 331,679 | 1760 | 0 | 0 | 1761 | 8292 | 0 | 15 | 15 | 430 | 92723 | 492 | 0 | 0 | 492 | 2318 | 0 | 4 | 120 |
| *Webster* | Worcester | MA | 2.5% | 1,548,975 | 8217 | 0 | 0 | 8226 | 38724 | 1 | 72 | 72 | 2007 | 1616491 | 8575 | 0 | 0 | 8584 | 40412 | 1 | 75 | 2094 |
| *West Boylston* | Worcester | MA | 2.5% | 971,593 | 5154 | 0 | 0 | 5160 | 24290 | 0 | 45 | 45 | 1259 | 1667337 | 8845 | 0 | 0 | 8854 | 41683 | 1 | 77 | 2160 |
| *West Brookfield* | Worcester | MA | 2.5% | 312,528 | 1658 | 0 | 0 | 1660 | 7813 | 0 | 14 | 14 | 405 | 498104 | 2642 | 0 | 0 | 2645 | 12453 | 0 | 23 | 645 |
| *Westborough* | Worcester | MA | 2.5% | 3,714,069 | 19703 | 0 | 0 | 19723 | 92852 | 2 | 172 | 172 | 4812 | 6089829 | 32306 | 1 | 0 | 32339 | 152246 | 3 | 282 | 7890 |
| *Westminster* | Worcester | MA | 2.5% | 321,416 | 1705 | 0 | 0 | 1707 | 8035 | 0 | 15 | 15 | 416 | 979655 | 5197 | 0 | 0 | 5202 | 24491 | 0 | 45 | 1269 |
| *Winchendon* | Worcester | MA | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Worcester* | Worcester | MA | 2.5% | 37,037,786 | 196483 | 4 | 0 | 196685 | 925945 | 18 | 1713 | 1713 | 47989 | 75896855 | 402628 | 8 | 1 | 403042 | 1897421 | 38 | 3511 | 98338 |
| *Ashford* | *Windham* | *CT* | 2.5% | 63 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Brooklyn* | *Windham* | *CT* | 2.5% | 161,037 | 854 | 0 | 0 | 855 | 4026 | 0 | 7 | 7 | 209 | 222990 | 1183 | 0 | 0 | 1184 | 5575 | 0 | 10 | 289 |
| *Canterbury* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Chaplin* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Eastford* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hampton* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Killingly* | *Windham* | *CT* | 2.5% | 650,305 | 3450 | 0 | 0 | 3453 | 16258 | 0 | 30 | 30 | 843 | 11059515 | 58670 | 1 | 0 | 58730 | 276488 | 5 | 512 | 14330 |
| *Plainfield* | *Windham* | *CT* | 2.5% | 205,470 | 1090 | 0 | 0 | 1091 | 5137 | 0 | 10 | 10 | 266 | 2744230 | 14558 | 0 | 0 | 14573 | 68606 | 1 | 127 | 3556 |
| *Pomfret* | *Windham* | *CT* | 2.5% | 43,931 | 233 | 0 | 0 | 233 | 1098 | 0 | 2 | 2 | 57 | 497814 | 2641 | 0 | 0 | 2644 | 12445 | 0 | 23 | 645 |
| *Putnam* | *Windham* | *CT* | 2.5% | 630,331 | 3344 | 0 | 0 | 3347 | 15758 | 0 | 29 | 29 | 817 | 3304718 | 17531 | 0 | 0 | 17549 | 82618 | 2 | 153 | 4282 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Scotland* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Sterling* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Thompson* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Union* | *Tolland* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Voluntown* | *New London* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Windham* | *Windham* | *CT* | 2.5% | 1,924,406 | 10209 | 0 | 0 | 10219 | 48110 | 1 | 89 | 89 | 2493 | 4366145 | 23162 | 0 | 0 | 23186 | 109154 | 2 | 202 | 5657 |
| *Woodstock* | *Windham* | *CT* | 2.5% | No gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | No Gas | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Electricity:
2012 electricity consumption was sourced from Mosa Grue Data to determine the Commercial & Industrial and Residential annual electricity use for each town in the MUA. Electricity associated with electric vehicles has been subtracted (above if production exceeded the residential/commercial/industrial sector).
Mosa Grue data, KPI Hub - https://www.kpihub.com/metrics/electricity-generation-per-grid-reporting-program-data-2012/c/

| Town | County | State | Annual_Residential (MWh) | Annual_Commercial&Industrial (MWh) | Electric Utility | % Of Sales Reported to MA DEP as Non-emitting MWh* | CA_Share_2030 (Tons) | Electricity Residential (MWh) (Residential/Total) | Electricity Commercial (MWh) (Commercial/Total) | Municipal Utility - Total 2012 Residential Sales (MWh)(excluding Sales) | Municipal Utility - Total 2012 CA Usage (MWh) (all losses) | CA Adjusted CA (MWh) | CO2 Emissions Factor (MT CO2/MWh) | CO2 Emissions Residential (MT CO2) | CO2 Emissions Commercial (MT CO2) | CO2 Emissions Municipal (MT CO2) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ALL TOWNS** | | | | | | | 2,237,008 | **1,633,266.6** | **1,604,341.3** | **1,003,796.93** | **1,010,796.93** | | | | | |
| Attleboro | Worcester | MA | Municipal | Municipal | MUNICIPAL | | - | 29,868.0 | 29,868.0 | 29,868.0 | 15,548.0147 | - | 0.000 | 11,945.20 | 11,945.20 | - |
| Ashby | Middlesex | MA | 3,797 | 2,138 | Unsl | 43.2% | 0 | 3,797.000 | 2,138.000 | - | - | (6,847) | 0.000000 | 2,131.160 | 0.000000 | 0.000000 |
| Ashland | MA | MA | 31,160 | 30,716 | NGRID | 42.7% | 0 | 31,160.000 | 30,716.000 | - | - | (12,978) | 0.000000 | 30,700.000 | 0.000000 | 0.000000 |
| Auburn | Worcester | MA | 55,264 | 77,978 | NGRID | 42.7% | 0 | 55,264.000 | 77,978.000 | - | - | (32,969) | 0.000000 | 77,948.010 | 0.000000 | 0.000000 |
| Avon | Norfolk | MA | 10,000 | 10,000 | NGRID | 42.7% | 0 | 10,000.000 | 10,000.000 | - | - | (4,166) | 0.000000 | 10,000.000 | 0.000000 | 0.000000 |
| Ayer | MA | MA | 10,247 | 10,247 | NGRID | 42.7% | 0 | 10,247.000 | 10,247.000 | - | - | (4,268) | 0.000000 | 10,247.000 | 0.000000 | 0.000000 |
| Berlin | Worcester | MA | 12,398 | 11,339 | NGRID | 42.7% | 0 | 12,398.000 | 11,339.000 | - | - | (5,216) | 0.000000 | 11,315.000 | 0.000000 | 0.000000 |
| Blackstone | Worcester | MA | 24,676 | 8,260 | NGRID | 42.7% | 0 | 24,676.000 | 8,260.000 | - | - | (10,758) | 0.000000 | 8,250.000 | 0.000000 | 0.000000 |
| Bolton | Worcester | MA | 22,551 | 10,556 | NGRID | 42.7% | 0 | 22,551.000 | 10,556.000 | - | - | (9,633) | 10.035,377 | 10,546.000 | 0.000000 | 0.000000 |
| Boylston | Worcester | MA | Municipal | Municipal | MUNICIPAL | | - | 23,737.397 | 23,737.397 | - | 11,602,480.37 | (9,455) | 11,602.480 | 0.000 | 0.000 | 11,602.480 |
| Brookfield | Worcester | MA | 12,272 | 2,879 | NGRID | 42.7% | 0 | 12,272.000 | 2,879.000 | - | - | (4,969) | 2,873.136 | 0.000000 | 0.000000 | 0.000000 |
| Charlton | Worcester | MA | 32,000 | 32,000 | NGRID | 42.7% | 0 | 32,000.000 | 32,000.000 | - | - | (12,958) | 32,000.000 | 0.000000 | 0.000000 | 0.000000 |
| Clinton | Worcester | MA | 46,010 | 40,007 | NGRID | 42.7% | 0 | 46,010.000 | 40,007.000 | - | - | (18,629) | 0.000000 | 39,967.000 | 0.000000 | 0.000000 |
| Douglas | Worcester | MA | 31,878 | 13,340 | NGRID | 42.7% | 0 | 31,878.000 | 13,340.000 | - | - | (12,910) | 13,324.878 | 0.000000 | 0.000000 | 0.000000 |
| Dudley | Worcester | MA | 37,260 | 37,847 | NGRID | 42.7% | 0 | 37,260.000 | 37,847.000 | - | - | (15,088) | 37,820.260 | 0.000000 | 0.000000 | 0.000000 |
| East Brookfield | Worcester | MA | 1,799 | 2,882 | NGRID | 42.7% | 0 | 1,799.000 | 2,882.000 | - | - | (2,466) | 2,879.027 | 0.000000 | 0.000000 | 0.000000 |
| Fitchburg | Worcester | MA | 150,286 | 201,782 | Unsl | 43.2% | 0 | 150,286.000 | 201,782.000 | - | - | (59,320) | 201,782.000 | 0.000000 | 0.000000 | 0.000000 |
| Gardner | Worcester | MA | 16,321 | 75,783 | NGRID | 42.7% | 0 | 16,321.000 | 75,783.000 | - | - | (18,169) | 75,784.310 | 0.000000 | 0.000000 | 0.000000 |
| Grafton | Worcester | MA | 50,000 | 50,000 | NGRID | 42.7% | 0 | 50,000.000 | 50,000.000 | - | - | (20,795) | 50,000.000 | 0.000000 | 0.000000 | 0.000000 |
| Groton | Middlesex | MA | Municipal | Municipal | MUNICIPAL | | - | 48,880.000 | 48,880.000 | - | 27,038,176.10 | (19,707) | 27,038.176 | 0.000 | 0.000 | 27,038.176 |
| Hardwick | Worcester | MA | 6,537 | 7,268 | NGRID | 42.7% | 0 | 6,537.000 | 7,268.000 | - | - | (2,267) | 7,262.731 | 0.000000 | 0.000000 | 0.000000 |
| Hopkinton | Worcester | MA | 22,461 | 5,882 | NGRID | 42.7% | 0 | 22,461.000 | 5,882.000 | - | - | (9,399) | 5,873.414 | 0.000000 | 0.000000 | 0.000000 |
| Hubbardston | Worcester | MA | Municipal | Municipal | MUNICIPAL | | - | 12,081.000 | 12,081.000 | - | 6,114,285.02 | (5,028) | 6,114.285 | 0.000 | 0.000 | 6,114.285 |
| Hopedale | Worcester | MA | 20,206 | 20,206 | NGRID | 42.7% | 0 | 20,206.000 | 20,206.000 | - | - | (8,386) | 20,206.000 | 0.000000 | 0.000000 | 0.000000 |
| Hubbardston | Worcester | MA | 14,007 | 5,234 | NGRID | 42.7% | 0 | 14,007.000 | 5,234.000 | - | - | (10,991) | 5,231.910 | 0.000000 | 0.000000 | 0.000000 |
| Lancaster | Worcester | MA | 23,796 | 19,573 | NGRID | 42.7% | 0 | 23,796.000 | 19,573.000 | - | - | (9,955) | 19,562.167 | 0.000000 | 0.000000 | 0.000000 |
| Leominster | Worcester | MA | 52,612 | 27,191 | NGRID | 42.7% | 0 | 52,612.000 | 27,191.000 | - | - | (17,516) | 27,175.484 | 0.000000 | 0.000000 | 0.000000 |
| Lexington | Middlesex | MA | 39,000 | 39,000 | NGRID | 42.7% | 0 | 39,000.000 | 39,000.000 | - | - | (16,173) | 38,984.000 | 0.000000 | 0.000000 | 0.000000 |
| Lunenburg | Worcester | MA | 34,812 | 19,994 | Unsl | 43.2% | 0 | 34,812.000 | 19,994.000 | - | - | (10,328) | 19,932.866 | 0.000000 | 0.000000 | 0.000000 |
| Mendon | Worcester | MA | 23,177 | 9,171 | NGRID | 42.7% | 0 | 23,177.000 | 9,171.000 | - | - | (9,478) | 9,162.324 | 0.000000 | 0.000000 | 0.000000 |
| Milford | Worcester | MA | 45,126 | 73,461 | NGRID | 42.7% | (3,330) | 45,126.000 | 73,461.000 | - | - | (20,258) | 73,434.772 | 0.000000 | 0.000000 | 0.000000 |
| Millville | Worcester | MA | 5,728 | 1,377 | NGRID | 42.7% | 0 | 5,728.000 | 1,377.000 | - | - | (3,030) | 1,371.976 | 0.000000 | 0.000000 | 0.000000 |
| New Braintree | Worcester | MA | 5,176 | 2,973 | NGRID | 42.7% | 0 | 5,176.000 | 2,973.000 | - | - | (1,964) | 2,970.116 | 0.000000 | 0.000000 | 0.000000 |
| North Brookfield | Worcester | MA | 16,120 | 20,024 | NGRID | 42.7% | 0 | 16,120.000 | 20,024.000 | - | - | (7,210) | 20,016.787 | 0.000000 | 0.000000 | 0.000000 |
| Northbridge | Worcester | MA | 37,000 | 37,000 | NGRID | 42.7% | 0 | 37,000.000 | 37,000.000 | - | - | (16,000) | 36,987.000 | 0.000000 | 0.000000 | 0.000000 |
| Northborough | Worcester | MA | 51,556 | 40,218 | NGRID | 42.7% | 0 | 51,556.000 | 40,218.000 | - | - | (23,734) | 40,187.276 | 0.000000 | 0.000000 | 0.000000 |
| Oakham | Worcester | MA | 1,632 | 1,025 | NGRID | 42.7% | 0 | 1,632.000 | 1,025.000 | - | - | (1,104) | 1,023.246 | 0.000000 | 0.000000 | 0.000000 |
| Oxford | Worcester | MA | 47,231 | 26,924 | NGRID | 42.7% | 0 | 47,231.000 | 26,924.000 | - | - | (20,468) | 26,903.231 | 0.000000 | 0.000000 | 0.000000 |
| Paxton | Worcester | MA | Municipal | Municipal | MUNICIPAL | | - | 16,542,085.84 | (79,097) | 17,963,995 | 8,944,995.31 | (19,774) | 8,934.995 | 0.000 | 0.000 | 8,944.995 |
| Petersham | Worcester | MA | 1,498 | 1,637 | NGRID | 42.7% | 0 | 1,498.000 | 1,637.000 | - | - | (2,403) | 1,636.000 | 0.000000 | 0.000000 | 0.000000 |
| Phillipston | Worcester | MA | 5,043 | 1,016 | NGRID | 42.7% | 0 | 5,043.000 | 1,016.000 | - | - | (2,907) | 1,014.370 | 0.000000 | 0.000000 | 0.000000 |
| Princeton | Worcester | MA | Municipal | Municipal | MUNICIPAL | | - | 12,638,136.36 | 12,638,136.36 | - | 5,350,475.02 | (15,197) | 5,350.475 | 0.000 | 0.000 | 5,350.475 |
| Royalston | Worcester | MA | 771 | 1,000 | NGRID | 42.7% | 0 | 771.000 | 1,000.000 | - | - | (1,458) | 999.000 | 0.000000 | 0.000000 | 0.000000 |
| Rutland | Worcester | MA | 27,388 | 5,611 | NGRID | 42.7% | 0 | 27,388.000 | 5,611.000 | - | - | (22,412) | 5,595.106 | 0.000000 | 0.000000 | 0.000000 |
| Sterling | Middlesex | MA | 21,765 | 36,837 | NGRID | 42.7% | 0 | 21,765.000 | 36,837.000 | - | - | (19,070) | 27,897.000 | 0.000000 | 0.000000 | 0.000000 |
| Stoneham | Middlesex | MA | Municipal | Municipal | MUNICIPAL | | - | 140,261,538.62 | 2,072,101 | 140,268,400 | - | (20,037) | 140,741.300 | 0.000 | 0.000 | 140,993.938.38 |
| Sturbridge | Worcester | MA | 32,000 | 27,000 | NGRID | 42.7% | 0 | 32,000.000 | 27,000.000 | - | - | (26,146) | 26,973.000 | 0.000000 | 0.000000 | 0.000000 |
| Spencer | Worcester | MA | 40,108 | 35,962 | NGRID | 42.7% | 0 | 40,108.000 | 35,962.000 | - | - | (27,050) | 35,934.387 | 0.000000 | 0.000000 | 0.000000 |
| Sutton | Worcester | MA | 34,000 | 34,000 | NGRID | 42.7% | 0 | 34,000.000 | 34,000.000 | - | - | (28,000) | 33,987.000 | 0.000000 | 0.000000 | 0.000000 |
| Shrewsbury | Worcester | MA | 48,000 | 48,000 | NGRID | 42.7% | 0 | 48,000.000 | 48,000.000 | - | - | (48,000) | 48,000.000 | 0.000000 | 0.000000 | 0.000000 |
| Sutton | Worcester | MA | 36,274 | 36,320 | NGRID | 42.7% | 354,180 | 36,369.000 | 36,465.200 | - | - | (48,108) | 36,415.980 | 0.000000 | 0.000000 | 0.000000 |
| Templeton | Worcester | MA | Municipal | Municipal | MUNICIPAL | | - | 29,490,203.30 | 87,880 | 29,637,000 | 38,753,511.08 | (19,968) | 38,753,511.08 | 0.000 | 0.000 | 38,753,511.08 |
| Tyngsboro | Middlesex | MA | 25,998 | 42,038 | Unsl | 43.2% | 0 | 25,998.000 | 42,038.000 | - | - | (8,114) | 42,026.586 | 0.000000 | 0.000000 | 0.000000 |
| Upton | Worcester | MA | 27,969 | 11,104 | NGRID | 42.7% | 0 | 27,969.000 | 11,104.000 | - | - | (26,921) | 11,075.896 | 0.000000 | 0.000000 | 0.000000 |
| Uxbridge | Worcester | MA | 47,914 | 44,764 | NGRID | 42.7% | 0 | 47,914.000 | 44,764.000 | - | - | (28,109) | 44,736.890 | 0.000000 | 0.000000 | 0.000000 |
| Westborough | Worcester | MA | 72,013 | 7,841 | NGRID | 42.7% | 0 | 72,013.000 | 7,841.000 | - | - | (3,168) | 7,273.000 | 0.000000 | 0.000000 | 0.000000 |
| Westminster | Worcester | MA | 50,000 | 50,000 | NGRID | 42.7% | 0 | 50,000.000 | 50,000.000 | - | - | (30,468) | 50,000.000 | 0.000000 | 0.000000 | 0.000000 |
| West Boylston | Worcester | MA | Municipal | Municipal | MUNICIPAL | | - | 28,675,109.20 | 34,468,174.92 | - | 12,425,358.91 | (19,707) | 12,425.359 | 0.000 | 0.000 | 12,425.359 |
| West Brookfield | Worcester | MA | 11,267 | 8,604 | NGRID | 42.7% | 0 | 11,267.000 | 8,604.000 | - | - | (8,789) | 8,591.000 | 0.000000 | 0.000000 | 0.000000 |
| Westborough | Worcester | MA | 44,531 | 44,531 | 13,117,000 | 0 | (816,880) | 58,384,140 | 224,473,000 | - | - | (140,997) | 224,723.217 | 0.000000 | 0.000000 | 0.000000 |
| Westminster | Worcester | MA | 27,366 | 35,788 | NGRID | 42.7% | 0 | 27,366.000 | 35,788.000 | - | - | (26,852) | 35,756.345 | 0.000000 | 0.000000 | 0.000000 |
| Winchendon | Worcester | MA | 31,105 | 15,574 | NGRID | 42.7% | 0 | 31,105.000 | 15,574.000 | - | - | (24,177) | 31,270.820 | 0.000000 | 0.000000 | 0.000000 |
| Worcester | Worcester | MA | 243,575 | 337,547 | 243,575,000 | 100 | (349,546) | 426,315,400 | 637,014,000 | - | - | (224,411) | 637,089,382 | 0.000000 | 0.000000 | 0.000000 |

| Town | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | Electricity CO2 Emissions Per Capita (MT CO2/MWh) | % Of Sales Reported to MA DEP as Non-emitting MWh* | MGMC Emissions Ratio (MT CO2/MWh) | MGMC Emissions Ratio (MT CO2/MWh) | MGMC Emissions Ratio (MT MCO2/MWh) | Overall MGMC Emissions Ratio (MT CO2/MWh) | Overall MGMC Emissions Ratio (MT CO2/MWh) | Electricity CO2 Emissions (MT CO2) (Residential/MGMC) | Electricity CO2 Emissions (MT CO2) (Commercial/MGMC) | Electricity CO2 Emissions (MT CO2) (Municipal/MGMC) | Electricity CO2 Emissions (MT CO2) (Residential/Overall MGMC) | Electricity CO2 Emissions (MT CO2) (Commercial/Overall MGMC) | Electricity CO2 Emissions (MT CO2) (Municipal/Overall MGMC) | Residential CO2 Emissions (MT/Year) | Residential CO2 Emissions (MT/Year) | Commercial CO2 Emissions (MT/Year) | Commercial CO2 Emissions (MT/Year) | Municipal CO2 Emissions (MT/Year) | Municipal CO2 Emissions (MT/Year) | Electricity CO2 REDUCTION Emissions (MT CO2) | Electricity CO2 REDUCTION Emissions (MT CO2) | Electricity NO REDUCTION Emissions (MT NO2) | Electricity NO REDUCTION Emissions (MT NO2) | Electricity CH4 REDUCTION Emissions (MT CO2) | Electricity CH4 REDUCTION Emissions (MT CO2) | Electricity N2O REDUCTION Emissions (MT N2O) | Electricity N2O REDUCTION Emissions (MT N2O) | RESIDENTIAL Carbon Dioxide Equivalent Emissions (MT CO2e) | CA Carbon Dioxide Equivalent Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ALL TOWNS** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Attleboro | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 33% | 0.000014 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Ashby | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Ashland | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Auburn | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Avon | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Ayer | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Berlin | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Blackstone | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Bolton | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Boylston | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 38% | 0.000758 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Brookfield | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Charlton | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Clinton | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Douglas | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Dudley | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| East Brookfield | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Fitchburg | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Gardner | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Grafton | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Groton | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Hardwick | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Hopkinton | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Hubbardston | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Hopedale | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Hopkinton | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 52% | 0.000184 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Lancaster | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Leominster | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Lexington | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Lunenburg | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Mendon | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Milford | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Millville | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| New Braintree | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| North Brookfield | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 | 0.000000 |
| Northb

**Transmission & Distribution Losses:**
Emissions associated with transmission and distribution (T&D) losses are calculated as a percentage of the total electricity. The T&D Loss factor is sourced by the EIA and applied separately by state (CT and MA). The losses for municipal utilities were obtained from DPU annual reports.

https://www.eia.gov/electricity/state/archive/2022

| Town | County | State | T&D Loss Factor (%) | RESIDENTIAL Total Electricity Consumption (kWh) | RESIDENTIAL Total Elec Grid Loss (kWh) | RESIDENTIAL_WAvg Emissions Rate (MT CO2/kWh) | RESIDENTIAL_WAvg Emissions Rate (MT CH4/kWh) | RESIDENTIAL_WAvg Emissions Rate (MT N2O/kWh) | RESIDENTIAL Electricity T&D CO2 Emissions (MT CO2) | RESIDENTIAL Electricity T&D CH4 Emissions (MT CH4) | RESIDENTIAL Electricity T&D N2O Emissions (MT N2O) | C&I Total Electricity Consumption (kWh) | C&I Total Elec Grid Loss (kWh) | C&I_WAvg Emissions Rate (MT CO2/kWh) | C&I_WAvg Emissions Rate (MT CH4/kWh) | C&I_WAvg Emissions Rate (MT N2O/kWh) | C&I Electricity T&D CO2 Emissions (MT CO2) | C&I Electricity T&D CH4 Emissions (MT CH4) | C&I Electricity T&D N2O Emissions (MT N2O) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ALL TOWNS** | | | | **2,553,796,621** | **128,748,410** | | | | **21,697.97** | **1.73** | **0.24** | **3,323,296,515.449** | **168,367,216.48** | | | | **28,181.97** | **2.24** | **0.313** |
| Ashburnham | Worcester | MA | 4.23% | 25,533,744 | 1,080,077 | 0.0001914422 | 0.0000000152 | 0.0000000021 | 206.8 | 0.02 | 0.002 | 11,550,477 | 488,585 | 0 | 0 | 0 | 94 | 0 | 0 |
| Ashby | Middlesex | MA | 5.14% | 9,769,612 | 502,196 | 0.0001633667 | 0.0000000130 | 0.0000000018 | 82.0 | 0.01 | 0.001 | 2,131,153 | 109,549 | 0 | 0 | 0 | 18 | 0 | 0 |
| Athol | Worcester | MA | 5.14% | 38,440,103 | 1,975,969 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 329.0 | 0.03 | 0.004 | 35,705,026 | 1,835,375 | 0 | 0 | 0 | 306 | 0 | 0 |
| Auburn | Worcester | MA | 5.14% | 55,133,660 | 2,834,082 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 471.8 | 0.04 | 0.005 | 77,945,415 | 4,006,694 | 0 | 0 | 0 | 667 | 0 | 0 |
| Ayer | Middlesex | MA | 5.14% | 24,756,782 | 1,272,594 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 211.9 | 0.02 | 0.002 | 101,220,235 | 5,203,109 | 0 | 0 | 0 | 866 | 0 | 0 |
| Barre | Worcester | MA | 5.14% | 16,840,455 | 865,664 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 144.1 | 0.01 | 0.002 | 10,511,114 | 540,312 | 0 | 0 | 0 | 90 | 0 | 0 |
| Berlin | Worcester | MA | 5.14% | 12,453,123 | 640,138 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 106.6 | 0.01 | 0.001 | 11,310,781 | 581,418 | 0 | 0 | 0 | 97 | 0 | 0 |
| Blackstone | Worcester | MA | 5.14% | 26,625,043 | 1,368,629 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 227.9 | 0.02 | 0.003 | 8,252,261 | 424,198 | 0 | 0 | 0 | 71 | 0 | 0 |
| Bolton | Worcester | MA | 5.14% | 21,796,509 | 1,120,424 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 186.5 | 0.01 | 0.002 | 10,635,377 | 546,699 | 0 | 0 | 0 | 91 | 0 | 0 |
| Boylston | Worcester | MA | 4.59% | 23,609,406 | 1,083,672 | 0.0001787944 | 0.0000000142 | 0.0000000020 | 193.8 | 0.02 | 0.002 | 11,902,998 | 546,348 | 0 | 0 | 0 | 98 | 0 | 0 |
| Brookfield | Worcester | MA | 5.14% | 12,240,112 | 629,189 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 104.7 | 0.01 | 0.001 | 2,873,134 | 147,690 | 0 | 0 | 0 | 25 | 0 | 0 |
| Charlton | Worcester | MA | 5.14% | 48,093,120 | 2,472,171 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 411.6 | 0.03 | 0.005 | 50,497,307 | 2,595,756 | 0 | 0 | 0 | 432 | 0 | 0 |
| Clinton | Worcester | MA | 5.14% | 43,462,065 | 2,234,117 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 371.9 | 0.03 | 0.004 | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| Douglas | Worcester | MA | 5.14% | 31,616,713 | 1,625,221 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 270.6 | 0.02 | 0.003 | 13,324,678 | 684,940 | 0 | 0 | 0 | 114 | 0 | 0 |
| Dudley | Worcester | MA | 5.14% | 37,195,368 | 1,911,985 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 318.3 | 0.03 | 0.004 | 37,825,092 | 1,944,355 | 0 | 0 | 0 | 324 | 0 | 0 |
| East Brookfield | Worcester | MA | 5.14% | 7,759,124 | 398,849 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 66.4 | 0.01 | 0.001 | 2,679,531 | 137,738 | 0 | 0 | 0 | 23 | 0 | 0 |
| Fitchburg | Worcester | MA | 5.14% | 100,148,400 | 5,148,012 | 0.0001633667 | 0.0000000130 | 0.0000000018 | 841.0 | 0.07 | 0.009 | 221,752,680 | 11,398,940 | 0 | 0 | 0 | 1862 | 0 | 0 |
| Gardner | Worcester | MA | 5.14% | 55,245,603 | 2,839,836 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 472.8 | 0.04 | 0.005 | 73,764,817 | 3,791,795 | 0 | 0 | 0 | 631 | 0 | 0 |
| Grafton | Worcester | MA | 5.14% | 62,376,950 | 3,206,415 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 533.8 | 0.04 | 0.006 | 82,073,237 | 4,218,880 | 0 | 0 | 0 | 702 | 0 | 0 |
| Groton | Middlesex | MA | 4.82% | 48,919,148 | 2,357,903 | 0.0002124262 | 0.0000000169 | 0.0000000024 | 500.9 | 0.04 | 0.006 | 26,937,833 | 1,298,404 | 0 | 0 | 0 | 276 | 0 | 0 |
| Hardwick | Worcester | MA | 5.14% | 9,515,524 | 489,134 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 81.4 | 0.01 | 0.001 | 7,262,718 | 373,332 | 0 | 0 | 0 | 62 | 0 | 0 |
| Harvard | Worcester | MA | 5.14% | 22,098,569 | 1,135,951 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 189.1 | 0.02 | 0.002 | 6,573,414 | 337,899 | 0 | 0 | 0 | 56 | 0 | 0 |
| Holden | Worcester | MA | 4.12% | 71,814,589 | 2,958,761 | 0.0001382638 | 0.0000000110 | 0.0000000015 | 409.1 | 0.03 | 0.005 | 39,047,165 | 1,608,743 | 0 | 0 | 0 | 222 | 0 | 0 |
| Hopedale | Worcester | MA | 5.14% | 19,918,604 | 1,023,893 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 170.5 | 0.01 | 0.002 | 13,109,651 | 673,886 | 0 | 0 | 0 | 112 | 0 | 0 |
| Hubbardston | Worcester | MA | 5.14% | 13,958,653 | 717,528 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 119.5 | 0.01 | 0.001 | 3,221,913 | 165,619 | 0 | 0 | 0 | 28 | 0 | 0 |
| Lancaster | Worcester | MA | 5.14% | 23,674,222 | 1,216,946 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 202.6 | 0.02 | 0.002 | 19,542,167 | 1,004,542 | 0 | 0 | 0 | 167 | 0 | 0 |
| Leicester | Worcester | MA | 5.14% | 36,544,959 | 1,878,551 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 312.7 | 0.02 | 0.003 | 27,173,490 | 1,396,822 | 0 | 0 | 0 | 233 | 0 | 0 |
| Leominster | Worcester | MA | 5.14% | 122,355,219 | 6,289,528 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 1,047.1 | 0.08 | 0.012 | 289,836,866 | 14,898,728 | 0 | 0 | 0 | 2480 | 0 | 0 |
| Lunenburg | Worcester | MA | 5.14% | 36,851,472 | 1,894,307 | 0.0001633667 | 0.0000000130 | 0.0000000018 | 309.5 | 0.02 | 0.003 | 19,833,868 | 1,019,537 | 0 | 0 | 0 | 167 | 0 | 0 |
| Mendon | Worcester | MA | 5.14% | 23,062,608 | 1,185,507 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 197.4 | 0.02 | 0.002 | 9,142,524 | 469,961 | 0 | 0 | 0 | 78 | 0 | 0 |
| Millbury | Worcester | MA | 5.14% | 46,026,827 | 2,365,956 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 393.9 | 0.03 | 0.004 | 73,434,772 | 3,774,829 | 0 | 0 | 0 | 628 | 0 | 0 |
| Millville | Worcester | MA | 5.14% | 9,705,900 | 498,921 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 83.1 | 0.01 | 0.001 | 1,371,975 | 70,525 | 0 | 0 | 0 | 12 | 0 | 0 |
| New Braintree | Worcester | MA | 5.14% | 3,765,266 | 193,549 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 32.2 | 0.00 | 0.000 | 2,970,316 | 152,686 | 0 | 0 | 0 | 25 | 0 | 0 |
| North Brookfield | Worcester | MA | 5.14% | 16,100,149 | 827,610 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 137.8 | 0.01 | 0.002 | 22,016,787 | 1,131,747 | 0 | 0 | 0 | 188 | 0 | 0 |
| Northborough | Worcester | MA | 5.14% | 51,200,593 | 2,631,907 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 438.2 | 0.03 | 0.005 | 93,900,961 | 4,826,870 | 0 | 0 | 0 | 804 | 0 | 0 |
| Northbridge | Worcester | MA | 5.14% | 50,943,279 | 2,618,680 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 436.0 | 0.03 | 0.005 | 43,197,276 | 2,220,506 | 0 | 0 | 0 | 370 | 0 | 0 |
| Oakham | Worcester | MA | 5.14% | 7,624,983 | 391,953 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 65.3 | 0.01 | 0.001 | 1,073,246 | 55,169 | 0 | 0 | 0 | 9 | 0 | 0 |
| Oxford | Worcester | MA | 5.14% | 47,548,127 | 2,444,156 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 406.9 | 0.03 | 0.005 | 65,493,032 | 3,366,593 | 0 | 0 | 0 | 560 | 0 | 0 |
| Paxton | Worcester | MA | 4.62% | 17,963,589 | 829,918 | 0.0001339521 | 0.0000000107 | 0.0000000015 | 111.2 | 0.01 | 0.001 | 6,824,915 | 315,311 | 0 | 0 | 0 | 42 | 0 | 0 |
| Petersham | Worcester | MA | 5.14% | 4,470,230 | 229,787 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 38.3 | 0.00 | 0.000 | 1,530,557 | 78,677 | 0 | 0 | 0 | 13 | 0 | 0 |
| Phillipston | Worcester | MA | 5.14% | 6,627,291 | 340,668 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 56.7 | 0.00 | 0.001 | 1,314,073 | 67,548 | 0 | 0 | 0 | 11 | 0 | 0 |
| Princeton | Worcester | MA | 9.20% | 13,763,355 | 1,266,229 | 0.0002635924 | 0.0000000210 | 0.0000000029 | 333.8 | 0.03 | 0.004 | 5,039,098 | 463,597 | 0 | 0 | 0 | 122 | 0 | 0 |
| Royalston | Worcester | MA | 5.14% | 4,471,489 | 229,852 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 38.3 | 0.00 | 0.000 | 569,372 | 29,268 | 0 | 0 | 0 | 5 | 0 | 0 |
| Rutland | Worcester | MA | 5.14% | 27,305,753 | 1,403,621 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 233.7 | 0.02 | 0.003 | 6,590,188 | 338,761 | 0 | 0 | 0 | 56 | 0 | 0 |
| Shirley | Middlesex | MA | 5.14% | 21,687,927 | 1,114,843 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 185.6 | 0.01 | 0.002 | 36,918,232 | 1,897,739 | 0 | 0 | 0 | 316 | 0 | 0 |
| Shrewsbury | Worcester | MA | 4.57% | 143,268,457 | 6,547,369 | 0.0001888552 | 0.0000000150 | 0.0000000021 | 1,236.5 | 0.10 | 0.014 | 145,741,902 | 6,660,405 | 0 | 0 | 0 | 1258 | 0 | 0 |
| Southbridge | Worcester | MA | 5.14% | 54,522,851 | 2,802,684 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 466.6 | 0.04 | 0.005 | 67,673,191 | 3,478,662 | 0 | 0 | 0 | 579 | 0 | 0 |
| Spencer | Worcester | MA | 5.14% | 40,053,895 | 2,058,924 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 342.8 | 0.03 | 0.004 | 35,934,907 | 1,847,192 | 0 | 0 | 0 | 308 | 0 | 0 |
| Sterling | Worcester | MA | 5.57% | 34,352,046 | 1,913,409 | 0.0001701709 | 0.0000000136 | 0.0000000019 | 325.6 | 0.03 | 0.004 | 35,787,762 | 1,993,378 | 0 | 0 | 0 | 339 | 0 | 0 |
| Sturbridge | Worcester | MA | 5.14% | 38,418,860 | 1,974,877 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 328.8 | 0.03 | 0.004 | 65,519,194 | 3,367,938 | 0 | 0 | 0 | 561 | 0 | 0 |
| Sutton | Worcester | MA | 5.14% | 36,469,254 | 1,874,660 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 312.1 | 0.02 | 0.003 | 38,473,892 | 1,977,706 | 0 | 0 | 0 | 329 | 0 | 0 |
| Templeton | Worcester | MA | 3.32% | 29,827,219 | 990,264 | 0.0001635595 | 0.0000000130 | 0.0000000018 | 162.0 | 0.01 | 0.002 | 38,776,515 | 1,287,380 | 0 | 0 | 0 | 211 | 0 | 0 |
| Townsend | Middlesex | MA | 5.14% | 25,958,745 | 1,334,379 | 0.0001633667 | 0.0000000130 | 0.0000000018 | 218.0 | 0.02 | 0.002 | 42,028,686 | 2,160,436 | 0 | 0 | 0 | 353 | 0 | 0 |
| Upton | Worcester | MA | 5.14% | 27,814,997 | 1,429,798 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 238.0 | 0.02 | 0.003 | 11,070,499 | 569,066 | 0 | 0 | 0 | 95 | 0 | 0 |
| Uxbridge | Worcester | MA | 5.14% | 47,783,077 | 2,456,234 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 408.9 | 0.03 | 0.005 | 44,739,891 | 2,299,802 | 0 | 0 | 0 | 383 | 0 | 0 |
| Warren | Worcester | MA | 5.14% | 17,976,565 | 924,065 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 153.8 | 0.01 | 0.002 | 7,373,891 | 379,046 | 0 | 0 | 0 | 63 | 0 | 0 |
| Webster | Worcester | MA | 5.14% | 58,988,727 | 3,032,247 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 504.8 | 0.04 | 0.006 | 65,496,512 | 3,366,772 | 0 | 0 | 0 | 561 | 0 | 0 |
| West Boylston | Worcester | MA | 3.31% | 28,809,572 | 953,597 | 0.0001448752 | 0.0000000115 | 0.0000000016 | 138.2 | 0.01 | 0.002 | 32,409,625 | 1,072,759 | 0 | 0 | 0 | 155 | 0 | 0 |
| West Brookfield | Worcester | MA | 5.14% | 13,260,132 | 681,622 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 113.5 | 0.01 | 0.001 | 6,817,283 | 350,435 | 0 | 0 | 0 | 58 | 0 | 0 |
| Westborough | Worcester | MA | 5.14% | 58,584,140 | 3,011,450 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 501.4 | 0.04 | 0.006 | 224,723,313 | 11,551,642 | 0 | 0 | 0 | 1923 | 0 | 0 |
| Westminster | Worcester | MA | 5.14% | 27,249,591 | 1,400,734 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 233.2 | 0.02 | 0.003 | 33,758,148 | 1,735,298 | 0 | 0 | 0 | 289 | 0 | 0 |
| Winchendon | Worcester | MA | 5.14% | 31,070,823 | 1,597,160 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 265.9 | 0.02 | 0.003 | - | - | 0 | 0 | 0 | 0 | 0 | 0 |
| Worcester | Worcester | MA | 5.14% | 428,373,452 | 22,020,041 | 0.0001664838 | 0.0000000133 | 0.0000000018 | 3,666.0 | 0.29 | 0.041 | 837,089,583 | 43,029,620 | 0 | 0 | 0 | 7164 | 1 | 0 |

**Municipal Light Plants:**
For communities which are served by municipal light plants, data was sourced from 2022 Department of Public Utilities (DPU) reports which include the electricity consumption for both commercial & Industrial and Residential customers. The percent of sales reported to the Massachusetts DEP as "non-emitting MWh" were used to calculate an emissions factor for each utility.

https://www.mass.gov/info-details/find-an-mlp-annual-return

## Municipal Light Plants

**Table 1: Participating MA Towns Total Residential and Commercial Consumption (kWh)**

| Town | State | Total 2022 Residential Usage (kWh)(including T&D losses) | Total 2022 Commercial Usage (kWh) (including T&D) | T&D losses | % Of Sales Reported to MA DEP as "Non-emitting MWh" |
|---|---|---|---|---|---|
| Ashburnham | MA | 25,568,014 | 11,556,814 | 4.23% | **33%** |
| Boylston | MA | 23,727,368 | 11,932,488 | 4.59% | **38%** |
| Groton | MA | 49,280,512 | 27,028,174 | 4.82% | **26%** |
| Holden | MA | 72,091,070 | 39,116,285 | 4.12% | **52%** |
| Paxton | MA | 18,042,686 | 6,844,689 | 4.62% | **53%** |
| Princeton | MA | 13,808,862 | 5,050,475 | 9.20% | **8%** |
| Shrewsbury | MA | 144,281,559 | 145,993,939 | 4.57% | **34%** |
| Sterling | MA | 34,480,174 | 35,814,877 | 5.57% | **41%** |
| Templeton | MA | 29,895,204 | 38,793,511 | 3.32% | **43%** |
| West Boylston | MA | 28878709.2 | 32426908.81 | 3.31% | **50%** |

**Table 2: Municipal Utilities and Non-emitting MWh**

| Municipal Utility | 2021 % Of Sales Reported to MA DEP as "Non-emitting MWh" |
|---|---|
| **Ashburnham Muni. Light Dept.** | **33%** |
| Belmont Municipal Light Department | 39% |
| **Boylston Municipal Light Dept.** | **38%** |
| Braintree Electric Light Dept. | 55% |
| Chester Municipal Electric Light Dept. | 12% |
| Chicopee Electric Light Dept. | 7% |
| Concord Municipal Light Plant | 84% |
| Danvers Electric Division | 49% |
| Georgetown Municipal Light Department | 35% |
| **Groton Electric Light Dept.** | **26%** |
| Groveland Municipal Light Dept. | 15% |
| Hingham Municipal Lighting Plant | 51% |
| **Holden Municipal Light Dept.** | **52%** |
| Holyoke Gas & Electric Dept. | 89% |
| Hudson Light & Power Dept. | 82% |
| Hull Municipal Lighting Plant | 49% |
| Ipswich Municipal Light Department | 30% |
| Littleton Electric Light & Water | 10% |
| Mansfield Municipal Electric Dept. | 47% |
| Marblehead Municipal Light Dept. | 35% |
| Merrimac Municipal Light & Water Dept. | 22% |
| Middleborough Gas & Electric Dept. | 67% |
| Middleton Municipal Electric Dept. | 43% |
| North Attleboro Electric Dept. | 30% |
| Norwood Municipal Light Dept. | 13% |
| **Paxton Municipal Light Dept.** | **53%** |
| Peabody Municipal Light Plant | 34% |
| **Princeton Municipal Light Dept.** | **8%** |
| Reading Municipal Light Dept. | 23% |
| Rowley Municipal Lighting Plant | 31% |
| Russell Municipal Light Department | 8% |
| **Shrewsbury Electric & Cable Ops.** | **34%** |
| South Hadley Electric Light Dept. | 89% |
| **Sterling Municipal Light Dept.** | **41%** |
| Taunton Municipal Lighting Plant | 19% |
| **Templeton Municipal Light & Water** | 43% |
| Wakefield Municipal Gas & Light Dept. | 40% |
| Wellesley Municipal Light Plant | 51% |
| **West Boylston Municipal Lighting Plant** | **50%** |
| Westfield Gas & Electric | 45% |

*Retail electricity providers and IOUs can voluntarily report the percent of sales*

*reported as "non-emitting MWh" to DEP. This data for reporting municipal utilities is*

**Electricity:**
2022 electricity consumption was sourced from the CT Municipal Energy Dashboard from EnergizeCT to determine the Commercial & Industrial and Residential annual electricity use for each town in the MSA. Electricity associated with electric vehicles has been subtracted (column K) and accounted for in the transportation sector.

**Residential and Commercial & Industrial Electricity**

| Town | County | State | Utility | RESIDENTIAL Elec Grid Loss % (HRS) | Residential Use (kWh) |
|---|---|---|---|---|---|
| | | | Totals | | 465,441,170 |
| Ashford | Windham | CT | Eversource | 3.56% | 16,136,073 |
| Brooklyn | Windham | CT | Eversource | 3.56% | 27,215,709 |
| Canterbury | Windham | CT | Eversource | 3.56% | 8,664,800 |
| Chaplin | Windham | CT | Eversource | 3.56% | 9,804,200 |
| Eastford | Windham | CT | Eversource | 3.56% | 6,488,968 |
| Hampton | Windham | CT | Eversource | 3.56% | 7,330,346 |
| Killingly | Windham | CT | Eversource | 3.56% | 58,642,338 |
| Plainfield | Windham | CT | Eversource | 3.56% | 50,364,468 |
| Pomfret | Windham | CT | Eversource | 3.56% | 14,860,199 |
| Putnam | Windham | CT | Eversource | 3.56% | 26,153,000 |
| Scotland | Windham | CT | Eversource | 3.56% | 5,060,403 |
| Sterling | Windham | CT | Eversource | 3.56% | 14,249,658 |
| Thompson | Windham | CT | Eversource | 3.56% | 34,895,278 |
| Union | Tolland | CT | Eversource | 3.56% | 3,332,982 |
| Windham | New London | CT | Eversource | 3.56% | 8,158,000 |
| Woodstock | Windham | CT | Eversource | 3.56% | 30,585,191 |
| Woodstock | Windham | CT | Eversource | 3.56% | 34,813,632 |

**Residential**

| Town | Residential Emissions (MTCO2) | Residential Emissions (MTCH4) | Residential Emissions (MTN2O) | Residential Emissions (MTCO2e) | EV Residential Consumption (kWh) | Adjusted Residential Electricity Usage (kWh) | Adjusted Residential Emissions (MTCO2) | Adjusted Residential Emissions (MTCH4) | Adjusted Residential Emissions (MTN2O) | Adjusted Residential Emissions (MTCO2e) | Adjusted RESIDENTIAL Total Grid Loss (kWh) | Adjusted Residential T&D Emissions (MTCO2) | Adjusted Residential T&D Emissions (MTCH4) | Adjusted Residential T&D Emissions (MTN2O) | Adjusted Residential T&D Emissions (MTCO2e) | RESIDENTIAL Total Elec Grid Loss (kWh) | RESIDENTIAL Electricity T&D CO2 Emissions (MT CO2) | RESIDENTIAL Electricity T&D CH4 Emissions (MT CH4) | RESIDENTIAL Electricity T&D N2O Emissions (MT N2O) | RESIDENTIAL Electricity T&D CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 99,188 | 13 | 2 | 100,308 | (5,549,106) | 411,390,339 | 100,801 | 13 | 2 | 101,622 | 14,864,499 | 3,268 | 0 | 0 | 3,817 | 14,431,298 | 3,531 | 0 | 0 | 3,531 |
| Ashford | 3,960.21 | 0.53 | 0.1 | 3,993 | (282,335) | 16,468,901 | 4,025.41 | 0.54 | 0.1 | 4,062 | 595,150 | 143.52 | 0.02 | 0.0 | 145 | 574,148 | 140.99 | 0.02 | 0.0 | 141 |
| Brooklyn | 6,658.80 | 0.89 | 0.1 | 6,713 | (367,577) | 27,583,286 | 6,748.73 | 0.90 | 0.1 | 6,804 | 981,801 | 240.21 | 0.03 | 0.0 | 242 | 968,718 | 237.51 | 0.03 | 0.004 | 237 |
| Canterbury | 2,114.27 | 0.28 | 0.0 | 2,149 | (92,931) | 18,850,416 | 4,611.86 | 0.62 | 0.1 | 4,649 | 673,814 | 164.88 | 0.02 | 0.0 | 166 | 665,078 | 162.74 | 0.02 | 0.003 | 164 |
| Chaplin | 2,397.60 | 0.32 | 0.0 | 2,438 | (103,000) | 9,804,200 | 2,398.00 | 0.32 | 0.0 | 2,417 | 353,000 | 86.38 | 0.01 | 0.0 | 87 | 348,000 | 85.16 | 0.01 | 0.001 | 86 |
| Eastford | 1,586.98 | 0.21 | 0.0 | 1,600 | (77,259) | 6,526,207 | 1,596.75 | 0.21 | 0.0 | 1,610 | 232,294 | 56.83 | 0.01 | 0.0 | 57 | 230,247 | 56.33 | 0.01 | 0.001 | 57 |
| Hampton | 1,793.50 | 0.24 | 0.0 | 1,808 | (55,256) | 7,425,602 | 1,816.60 | 0.24 | 0.0 | 1,832 | 264,307 | 64.67 | 0.01 | 0.0 | 65 | 260,917 | 63.84 | 0.01 | 0.001 | 64 |
| Killingly | 14,347.88 | 1.92 | -0.2 | 14,465 | (1,496,237) | 60,138,575 | 14,713.96 | 1.96 | 0.2 | 14,834 | 2,140,576 | 523.73 | 0.07 | 0.0 | 528 | 2,087,319 | 510.70 | 0.07 | 0.009 | 511 |
| Plainfield | 12,322.55 | 1.64 | -0.2 | 12,423 | (1,523,350) | 51,887,818 | 12,695.26 | 1.69 | 0.2 | 12,799 | 1,845,888 | 451.66 | 0.06 | 0.0 | 456 | 1,792,678 | 438.61 | 0.06 | 0.007 | 439 |
| Pomfret | 3,635.61 | 0.49 | 0.1 | 3,665 | (264,002) | 15,144,201 | 3,705.29 | 0.49 | 0.1 | 3,736 | 539,044 | 131.89 | 0.02 | 0.0 | 133 | 528,935 | 129.41 | 0.02 | 0.002 | 129 |
| Putnam | 6,396.00 | 0.85 | 0.1 | 6,449 | (453,000) | 26,153,000 | 6,396.00 | 0.85 | 0.1 | 6,449 | 930,000 | 227.58 | 0.03 | 0.0 | 230 | 912,000 | 223.16 | 0.03 | 0.003 | 225 |
| Scotland | 1,392.98 | 0.19 | 0.0 | 1,404 | (68,888) | 5,792,241 | 1,418.63 | 0.19 | 0.0 | 1,431 | 205,152 | 50.18 | 0.01 | 0.0 | 51 | 202,650 | 49.58 | 0.01 | 0.001 | 50 |
| Sterling | 3,486.43 | 0.47 | 0.1 | 3,515 | (38,242) | 14,287,901 | 3,495.79 | 0.47 | 0.1 | 3,524 | 508,564 | 124.43 | 0.02 | 0.0 | 125 | 507,203 | 124.10 | 0.02 | 0.002 | 124 |
| Thompson | 8,537.74 | 1.16 | 0.1 | 8,607 | (588,362) | 35,483,641 | 8,681.69 | 1.18 | 0.1 | 8,753 | 1,263,007 | 309.02 | 0.04 | 0.0 | 312 | 1,242,085 | 303.89 | 0.04 | 0.005 | 304 |
| Union | 815.03 | 0.11 | 0.0 | 820 | (390,963) | 3,713,944 | 908.68 | 0.12 | 0.0 | 916 | 132,194 | 32.34 | 0.00 | 0.0 | 33 | 118,278 | 28.94 | 0.00 | 0.000 | 29 |
| Windham | 2,000.00 | 0.27 | 0.0 | 2,016 | (77,000) | 8,158,000 | 1,996.00 | 0.27 | 0.0 | 2,012 | 290,000 | 70.96 | 0.01 | 0.0 | 71 | 288,000 | 70.47 | 0.01 | 0.000 | 70 |
| Woodstock | 7,500.00 | 1.00 | 0.1 | 7,561 | (463,979) | 32,064,189 | 7,841.42 | 1.05 | 0.1 | 7,905 | 1,209,000 | 295.77 | 0.07 | 0.0 | 298 | 1,192,267 | 291.67 | 0.07 | 0.009 | 294 |
| Woodstock | 8,517.77 | 1.14 | 0.1 | 8,587 | (276,446) | 35,096,381 | 8,585.40 | 1.15 | 0.1 | 8,655 | 1,248,998 | 305.50 | 0.04 | 0.0 | 308 | 1,208,159 | 303.18 | 0.04 | 0.005 | 303 |

**Commercial & Industrial**

| Town | Commercial & Industrial Use (kWh) | C&I Emissions (MTCO2) | C&I Emissions (MTCH4) | C&I Emissions (MTN2O) | Commercial & Industrial Emissions (MTCO2e) | EV Commercial & Industrial Consumption | C&I Electricity Usage Adjusted (kWh) | Adjusted C&I Emissions (MTCO2) | Adjusted C&I Emissions (MTCH4) | Adjusted C&I Emissions (MTN2O) | Adjusted C&I Emissions (MTCO2e) | Adjusted C&I Total Grid Loss (kWh) | Adjusted Residential T&D Emissions (MTCO2) | Adjusted C&I T&D Emissions (MTCH4) | Adjusted C&I T&D Emissions (MTN2O) | Adjusted C&I T&D Emissions (MTCO2e) | C&I Total Elec Grid Loss (kWh) | C&I Electricity T&D CO2 Emissions (MT CO2) | C&I Electricity T&D CH4 Emissions (MT CH4) | C&I Electricity T&D N2O Emissions (MT N2O) | C&I Electricity T&D CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 390,406,098 | 96,743 | 13 | 2 | 96,758 | 223,215 | 390,626,318 | 96,798 | 13 | 2 | 96,816 | 14,034,109 | 3,443 | 0.46 | 0.06 | 3,445 | 14,034,109 | 3,443 | 0.46 | 0.06 | 3,445 |
| Ashford | 5,413,573 | 1,447.41 | 0.19 | 0.024 | 1,447 | 11,462 | 5,427,461 | 1,450.25 | 0.19 | 0.024 | 1,450 | 210,982 | 51.82 | 0.01 | 0.001 | 52 | 210,374 | 51.72 | 0.01 | 0.001 | 52 |
| Brooklyn | 13,850,598 | 3,388.79 | 0.45 | 0.057 | 3,389 | 33,577 | 13,884,175 | 3,397.01 | 0.45 | 0.057 | 3,397 | 494,194 | 120.91 | 0.02 | 0.002 | 121 | 492,999 | 120.62 | 0.02 | 0.002 | 121 |
| Canterbury | 3,556,078 | 939.24 | 0.12 | 0.015 | 939 | 7,691 | 3,563,769 | 938.25 | 0.12 | 0.015 | 938 | 126,925 | 31.20 | 0.00 | 0.000 | 31 | 126,495 | 31.10 | 0.00 | 0.000 | 31 |
| Chaplin | 1,359,000 | 358.77 | 0.05 | 0.006 | 359 | - | 1,359,000 | 358.77 | 0.05 | 0.006 | 359 | 48,000 | 11.75 | 0.00 | 0.000 | 12 | 47,850 | 11.76 | 0.00 | 0.000 | 12 |
| Eastford | 6,197,572 | 1,635.94 | 0.20 | 0.025 | 1,636 | - | 6,197,572 | 1,635.94 | 0.20 | 0.025 | 1,636 | 212,000 | 52.97 | 0.01 | 0.001 | 54 | 220,587 | 53.97 | 0.01 | 0.001 | 54 |
| Hampton | 1,251,342 | 306.18 | 0.04 | 0.005 | 306 | - | 1,251,342 | 306.18 | 0.04 | 0.005 | 306 | 44,040 | 10.90 | 0.00 | 0.000 | 11 | 44,040 | 10.90 | 0.00 | 0.000 | 11 |
| Killingly | 99,145,474 | 24,257.68 | 3.24 | 0.405 | 24,258 | 49,911 | 99,195,385 | 24,269.89 | 3.24 | 0.405 | 24,273 | 3,530,767 | 863.86 | 0.12 | 0.014 | 864 | 3,526,990 | 863.43 | 0.12 | 0.014 | 863 |
| Plainfield | 53,788,880 | 13,160.39 | 1.76 | 0.220 | 13,160 | 30,489 | 53,819,349 | 13,167.85 | 1.76 | 0.220 | 13,168 | 1,913,649 | 469.70 | 0.06 | 0.008 | 469 | 1,914,564 | 468.43 | 0.06 | 0.008 | 468 |
| Pomfret | 18,010,957 | 4,406.70 | 0.59 | 0.074 | 4,407 | 17,790 | 18,028,106 | 4,411.04 | 0.59 | 0.074 | 4,411 | 641,715 | 157.01 | 0.02 | 0.003 | 157 | 641,063 | 156.85 | 0.02 | 0.003 | 157 |
| Putnam | 31,153,000 | 7,622.49 | 1.02 | 0.127 | 7,624 | 77,000 | 31,230,000 | 7,641.27 | 1.02 | 0.127 | 7,643 | 1,108,000 | 271.11 | 0.04 | 0.004 | 271 | 1,086,000 | 265.73 | 0.04 | 0.004 | 266 |
| Scotland | 1,136,804 | 278.27 | 0.04 | 0.005 | 278 | 5,454 | 1,142,258 | 280.01 | 0.04 | 0.005 | 280 | 40,764 | 9.97 | 0.00 | 0.000 | 10 | 40,370 | 9.88 | 0.00 | 0.000 | 10 |
| Sterling | 2,457,219 | 601.20 | 0.08 | 0.010 | 601 | - | 2,457,219 | 601.20 | 0.08 | 0.010 | 601 | 87,462 | 21.40 | 0.00 | 0.000 | 21 | 87,462 | 21.40 | 0.00 | 0.000 | 21 |
| Thompson | 11,817,205 | 2,891.50 | 0.39 | 0.048 | 2,891 | 9,104 | 11,826,308 | 2,893.53 | 0.39 | 0.048 | 2,894 | 420,948 | 102.99 | 0.01 | 0.002 | 103 | 420,624 | 102.91 | 0.01 | 0.002 | 103 |
| Union | 967,923 | 236.82 | 0.03 | 0.004 | 237 | - | 967,923 | 236.82 | 0.03 | 0.004 | 237 | 34,452 | 8.43 | 0.00 | 0.000 | 8 | 34,452 | 8.43 | 0.00 | 0.000 | 8 |
| Windham | 2,600,000 | 636.00 | 0.08 | 0.010 | 636 | - | 2,600,000 | 636.00 | 0.08 | 0.010 | 636 | 92,560 | 22.64 | 0.00 | 0.000 | 23 | 92,560 | 22.64 | 0.00 | 0.000 | 23 |
| Woodstock | 85,851,959 | 21,000.99 | 2.80 | 0.351 | 21,014 | 18,328 | 85,869,812 | 21,014.48 | 2.81 | 0.351 | 21,014 | 3,057,172 | 747.99 | 0.10 | 0.012 | 748 | 3,056,019 | 747.83 | 0.10 | 0.012 | 748 |
| Woodstock | 14,758,548 | 3,610.94 | 0.48 | 0.060 | 3,611 | 21,598 | 14,780,145 | 3,616.22 | 0.48 | 0.060 | 3,616 | 526,085 | 128.72 | 0.02 | 0.002 | 129 | 525,317 | 128.53 | 0.02 | 0.002 | 129 |

**Electric Vehicles**

| Town | Residential EV CO2 Emissions (MTCO2) | Residential EV CH4 Emissions (MTCH4) | Residential EV N2O Emissions (MTN2O) | Residential EV TOTAL Emissions (MTCO2e) | Commercial EV CO2 Emissions (MTCO2) | Commercial EV CH4 Emissions (MTCH4) | Commercial EV N2O Emissions (MTN2O) | Commercial EV TOTAL Emissions (MTCO2e) |
|---|---|---|---|---|---|---|---|---|
| | (1,862) | (0.214) | (0.027) | (1,862) | 38 | 0 | 0 | 38 |
| Ashford | (89.09) | (0.0092) | (0.0012) | (89.38) | 1.94 | 0.00005 | 0.00002 | 1.94 |
| Brooklyn | (89.93) | (0.0120) | (0.0015) | (89.93) | 5.68 | 0.00045 | 0.00006 | 5.68 |
| Canterbury | (29.16) | (0.0032) | (0.0003) | (29.16) | - | - | - | - |
| Chaplin | (32.35) | (0.0033) | (0.0003) | (32.35) | 1.30 | 0.00010 | 0.00001 | 1.30 |
| Eastford | (14.36) | (0.0020) | (0.0002) | (14.36) | - | - | - | - |
| Hampton | (23.31) | (0.0012) | (0.0004) | (23.31) | - | - | - | - |
| Killingly | (366.08) | (0.0489) | (0.0061) | (366.08) | 8.44 | 0.00067 | 0.00009 | 8.44 |
| Plainfield | (372.71) | (0.0466) | (0.0062) | (372.71) | 5.16 | 0.00041 | 0.00006 | 5.16 |
| Pomfret | (89.49) | (0.0093) | (0.0012) | (89.49) | 3.00 | 0.00024 | 0.00003 | 3.00 |
| Putnam | (154.85) | (0.0202) | (0.0020) | (154.85) | 0.92 | 0.00007 | 0.00001 | 0.92 |
| Scotland | (18.85) | (0.0022) | (0.0003) | (18.85) | 0.92 | 0.00007 | 0.00001 | 0.92 |
| Sterling | (9.36) | (0.0012) | (0.0002) | (9.36) | - | - | - | - |
| Thompson | (143.95) | (0.0192) | (0.0024) | (143.95) | 1.54 | 0.00012 | 0.00002 | 1.54 |
| Union | (35.95) | (0.0128) | (0.0016) | (35.95) | - | - | - | - |
| Windham | (27.00) | (0.0036) | (0.0004) | (27.00) | - | - | - | - |
| Woodstock | (113.52) | (0.0152) | (0.0016) | (113.52) | 3.10 | 0.00025 | 0.00003 | 3.10 |
| Woodstock | (87.64) | (0.0092) | (0.0012) | (87.64) | 3.65 | 0.00029 | 0.00004 | 3.65 |

**MA Investor-Owned Utilities - Electricity:**
MA IOU Electricity was sourced from MassSave, see sheet "Electricity_MA" for more calculation details and methodology.

| Town | Residential Electricity Use (MWh) | Commercial & Industrial Electricity Use (MWh) |
|---|---|---|
| Ashburnham | Municipal | Municipal |
| Ashby | 9,797 | 2,138 |
| Athol | 38,492 | 35,718 |
| Auburn | 55,264 | 77,978 |
| Ayer | 24,907 | 101,257 |
| Barre | 16,880 | 10,521 |
| Berlin | 12,566 | 11,339 |
| Blackstone | 26,676 | 8,265 |
| Bolton | 22,051 | 10,699 |
| Boylston | Municipal | Municipal |
| Brookfield | 12,272 | 2,878 |
| Charlton | 48,234 | 50,531 |
| Clinton | 43,557 | 68,915 |
| Douglas | 31,678 | 13,340 |
| Dudley | 37,283 | 37,847 |
| East Brookfield | 7,769 | 2,682 |
| Fitchburg | 100,266 | 221,782 |
| Gardner | 55,321 | 73,783 |
| Grafton | 62,888 | 82,201 |
| Groton | Municipal | Municipal |
| Hardwick | 9,537 | 7,268 |
| Harvard | 22,481 | 6,662 |
| Holden | Municipal | Municipal |
| Hopedale | 20,008 | 13,132 |
| Hubbardston | 14,007 | 3,234 |
| Lancaster | 23,796 | 19,572 |
| Leicester | 36,615 | 27,191 |
| Leominster | 122,617 | 289,900 |
| Lunenburg | 36,972 | 19,864 |
| Mendon | 23,177 | 9,171 |
| Millbury | 46,138 | 73,461 |
| Millville | 9,726 | 1,377 |
| New Braintree | 3,776 | 2,973 |
| North Brookfield | 16,129 | 22,024 |
| Northborough | 51,633 | 94,009 |
| Northbridge | 51,099 | 43,230 |
| Oakham | 7,632 | 1,075 |
| Oxford | 47,612 | 65,509 |
| Paxton | Municipal | Municipal |
| Petersham | 4,496 | 1,537 |
| Phillipston | 6,643 | 1,318 |

| | | |
|---|---|---|
| Princeton | Municipal | Municipal |
| Royalston | 4,478 | 571 |
| Rutland | 27,389 | 6,611 |
| Shirley | 21,763 | 36,937 |
| Shrewsbury | Municipal | Municipal |
| Southbridge | 54,587 | 67,689 |
| Spencer | 40,168 | 35,962 |
| Sterling | Municipal | Municipal |
| Sturbridge | 38,611 | 65,565 |
| Sutton | 36,674 | 38,523 |
| Templeton | Municipal | Municipal |
| Townsend | 25,996 | 42,038 |
| Upton | 27,969 | 11,109 |
| Uxbridge | 47,914 | 44,764 |
| Warren | 18,013 | 7,383 |
| Webster | 59,099 | 65,523 |
| West Boylston | Municipal | Municipal |
| West Brookfield | 13,287 | 6,824 |
| Westborough | 59,201 | 224,873 |
| Westminster | 27,369 | 33,788 |
| Winchendon | 31,105 | 15,574 |
| Worcester | 429,319 | 837,314 |

**MA Community Choice Aggregation:**
Massachusetts Municipal Aggregation Plans and reported electricity consumption were sourced from EOEEA.

https://eeaonline.eea.state.ma.us/dpu/fileroom/#/dashboard

| Town | Residential or C/I | Electricity Rate (Name) | Total Annual Electricity Consumption (kWh / Year) (data gaps filled) | % of Voluntary RECs | Combined % of Sales from "Non-emitting MWh" | Emissions Rate (MT CO2/kWh) | Emissions Rate (MT CH4/kWh) | Emissions Rate (MT N2O/kWh) | Overall Emission Factor (MT of CO2e/kWh) | Emissions (MT CO2) | Emissions (MT CH4) | Emissions (MT N2O) | Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SUM** | | | **439,731,577** | | | | | | | **39,402** | **3.1** | **0.4** | **39,606** |
| Douglas | Residential | Green 50% | 13,024 | 50% | 99% | 0.000004 | 0.00000000030 | 0.00000000004 | 0.000004 | 0 | 0.0000 | 0.0000 | 0.049 |
| Douglas | Residential | Green 100% | 16,218 | 100% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |
| Grafton | Residential | Green Option | 297,466 | 20% | 69% | 0.000090 | 0.00000000716 | 0.00000000100 | 0.000090 | 27 | 0.0021 | 0.0003 | 26.894 |
| Grafton | C/I | Green Option | 71,264 | 20% | 69% | 0.000090 | 0.00000000716 | 0.00000000100 | 0.000090 | 6 | 0.0005 | 0.0001 | 6.443 |
| Millbury | Residential | 100% RECs option | 23,305 | 100% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |
| Northbridge | Residential | 50% RECs option | 24,368 | 50% | 99% | 0.000004 | 0.00000000030 | 0.00000000004 | 0.000004 | 0 | 0.0000 | 0.0000 | 0.091 |
| Northbridge | C/I | 50% RECs option | 7,042 | 50% | 99% | 0.000004 | 0.00000000030 | 0.00000000004 | 0.000004 | 0 | 0.0000 | 0.0000 | 0.026 |
| Northbridge | Residential | 100% RECs option | 32,160 | 100% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |
| Oxford | Residential | 100% RECs option | 32,505 | 100% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |
| Sutton | Residential | Green Option | 304,180 | 20% | 69% | 0.000090 | 0.00000000716 | 0.00000000100 | 0.000090 | 27 | 0.0022 | 0.0003 | 27.501 |
| Westborough | Residential | Standard Default | 43,235,881 | 20% | 69% | 0.000090 | 0.00000000716 | 0.00000000100 | 0.000090 | 3889 | 0.3097 | 0.0432 | 3908.901 |
| Westborough | Residential | Green Option | 787,260 | 84% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |
| Westborough | C/I | Standard Default | 39,530,295 | 20% | 69% | 0.000090 | 0.00000000716 | 0.00000000100 | 0.000090 | 3555 | 0.2831 | 0.0395 | 3573.884 |
| Westborough | C/I | Green Option | 74,299 | 84% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |
| Worcester | Residential | Standard Default | 241,642,106 | 20% | 69% | 0.000090 | 0.00000000716 | 0.00000000100 | 0.000090 | 21734 | 1.7307 | 0.2415 | 21846.557 |
| Worcester | Residential | Green Option | 629,022 | 80% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |
| Worcester | C/I | Standard Default | 112,995,524 | 20% | 69% | 0.000090 | 0.00000000716 | 0.00000000100 | 0.000090 | 10163 | 0.8093 | 0.1129 | 10215.782 |
| Worcester | C/I | Green Option | 15,658 | 80% | 100% | 0.000000 | 0.00000000000 | 0.00000000000 | 0.000000 | 0 | 0.0000 | 0.0000 | 0.000 |

**Fuel Oil & Propane:**
Summary table for the following building subsectors and calculated annual fuel oil consumption.

| Subsector | Annual Fuel Oil Use (gal) | Annual Fuel Oil Use (MMBtu) | Fuel Oil CO2 Emissions (MT CO2) | Fuel Oil CH4 Emissions (MT CH4) | Fuel Oil N2O Emissions (MT N2O) | Fuel Oil CO2e Emissions (MT CO2e) | Annual Propane Use (gal) | Annual Propane Use (MMBtu) | Propane CO2 Emissions (MT CO2) | Propane CH4 Emissions (MT CH4) | Propane N2O Emissions (MT N2O) | Propane CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Residential Buildings* | 104,705,211 | 14,449,319 | 1,068,672 | 43.3 | 8.7 | 1,072,183 | 67,069,996 | 6,103,370 | 383,719 | 18 | 4 | 130,900 |
| *Commercial Buildings* | 11,793,559 | 1,627,511 | 120,371 | 4.9 | 1.0 | 120,766 | 17,537,980 | 1,595,909 | 100,335 | 5 | 1 | 100,723 |
| *Manufacturing Industries & Construction* | 1,011,783 | 139,626 | 10,327 | 0.4 | 0.1 | 10,361 | | | | | | |
| *Municipal Buildings* | 1,014,673 | 140,025 | 10,356 | 0.4 | 0.1 | 10,390 | 289,619 | 26,355 | 1,657 | 0.08 | 0.02 | 1,663 |
| ***All Building Subsectors:*** | **118,525,226** | **16,356,481** | **1,209,725** | **49.1** | **9.8** | **1,213,700** | **84,897,596** | **7,725,634** | **485,711** | **23.18** | **4.64** | **233,286** |

**Residential Fuel Oil By Program**

Residential Fuel Oil By Program data was calculated from the Census Table B25009(5). Census by Units in Structure 2010. ACS 5-year estimate). The Census Table B25127 (Tenure by Heating Fuel was used to select the Fuel Oil/Kerosene Heating Units and Housing Units with Heating Fuel Other Than Fuel Oil/Kerosene. Data was aggregated at the census tract level. Data was then aggregated to the Program level.

https://data.census.gov/cedsci/table?q=B25127&tid=ACSDP5Y2010.B25127&hidePreview=false&viewPublishedTable=true&tp=true&g=0400000US04,06,08,09,10,11,12,13,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,44,45,46,47,48,49,50,51,53,54,55,56,72,78,0500000US01001,01003,01005,01007,01009,01011,01013,01015,01017,01019,01021,01023,01025,01027,01029,01031,01033,01035,01037,01039,01041,01043,01045,01047,01049,01051,01053,01055,01057,01059,01061,01063,01065,01067,01069,01071,01073,01075,01077,01079,01081,01083,01085,01087,01089,01091,01093,01095,01097,01099,01101,01103,01105,01107,01109,01111,01113,01115,01117,01119,01121,01123,01125,01127,01129,01131,01133&d=DP5&cv&mode=table

https://data.census.gov/table?q=B25127+Q+ACS+Y+Y+Y

**Municipal Fuel Oil & Propane:**
Fuel oil and propane usage by municipality was obtained from Mass Energy Insight (MEI). CT data was estimated based on MA municipal usage averages for communities without utility gas. For those with utility gas, it was assumed there was no fuel oil or propane usage, based on MA data where a portion of the communities do not use these fuels.

| Town | State | Oil (gal) | Annual Fuel Oil Use (MMBtu) | Fuel Oil CO2 Emissions (MT CO2) | Fuel Oil CH4 Emissions (MT CH4) | Fuel Oil N2O Emissions (MT N2O) | Fuel Oil CO2e Emissions (MT CO2e) | Propane (gal) | Annual Propane Use (MMBtu) | Propane CO2 Emissions (MT CO2) | Propane CH4 Emissions (MT CH4) | Propane N2O Emissions (MT N2O) | Propane CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **SUM** | **1,014,673** | **140,025** | **10,356** | **0.4** | **0.1** | **10,390** | **289,619** | **26,355** | **1,657** | **0.08** | **0.02** | **1,663** |
| Ashburnham | MA | 12845 | 1773 | 131 | 0.005 | 0.001 | 132 | 1421.0 | 129.3 | 8.1 | 0.000 | 0.000 | 8.2 |
| Ashby | MA | 3311 | 457 | 34 | 0.001 | 0.000 | 34 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Athol | MA | 28304 | 3906 | 289 | 0.012 | 0.002 | 290 | 8425.0 | 766.7 | 48.2 | 0.002 | 0.000 | 48.4 |
| Auburn | MA | 14311 | 1975 | 146 | 0.006 | 0.001 | 147 | 19903.0 | 1811.2 | 113.9 | 0.005 | 0.001 | 114.3 |
| Ayer | MA | 8011 | 1106 | 82 | 0.003 | 0.001 | 82 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Barre | MA | 19556 | 2699 | 200 | 0.008 | 0.002 | 200 | 792.0 | 72.1 | 4.5 | 0.000 | 0.000 | 4.5 |
| Berlin | MA | 27915 | 3852 | 285 | 0.012 | 0.002 | 286 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Blackstone | MA | 1650 | 228 | 17 | 0.001 | 0.000 | 17 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Bolton | MA | 7277 | 1004 | 74 | 0.003 | 0.001 | 75 | 7092.0 | 645.4 | 40.6 | 0.002 | 0.000 | 40.7 |
| Boylston | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Brookfield | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Charlton | MA | 26821 | 3701 | 274 | 0.011 | 0.002 | 275 | 5521.0 | 502.4 | 31.6 | 0.002 | 0.000 | 31.7 |
| Clinton | MA | 773 | 107 | 8 | 0.000 | 0.000 | 8 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Douglas | MA | 97753 | 13490 | 998 | 0.040 | 0.008 | 1001 | 10523.0 | 957.6 | 60.2 | 0.003 | 0.001 | 60.4 |
| Dudley | MA | 911 | 126 | 9 | 0.000 | 0.000 | 9 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| East Brookfield | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Fitchburg | MA | 85730 | 11831 | 875 | 0.035 | 0.007 | 878 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Gardner | MA | 223 | 31 | 2 | 0.000 | 0.000 | 2 | 4424.0 | 402.6 | 25.3 | 0.001 | 0.000 | 25.4 |
| Grafton | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 30200.0 | 2748.2 | 172.8 | 0.008 | 0.002 | 173.4 |
| Groton | MA | 1766 | 244 | 18 | 0.001 | 0.000 | 18 | 10543.0 | 959.4 | 60.3 | 0.003 | 0.001 | 60.6 |
| Hardwick | MA | 14700 | 2029 | 150 | 0.006 | 0.001 | 151 | 2887.0 | 262.7 | 16.5 | 0.001 | 0.000 | 16.6 |
| Harvard | MA | 2384 | 329 | 24 | 0.001 | 0.000 | 24 | 952.0 | 86.6 | 5.4 | 0.000 | 0.000 | 5.5 |
| Holden | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Hopedale | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Hubbardston | MA | 6032 | 832 | 62 | 0.002 | 0.000 | 62 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Lancaster | MA | 10739 | 1482 | 110 | 0.004 | 0.001 | 110 | 9986.0 | 908.7 | 57.1 | 0.003 | 0.001 | 57.4 |
| Leicester | MA | 79636 | 10990 | 813 | 0.033 | 0.007 | 815 | 5924.0 | 539.1 | 33.9 | 0.002 | 0.000 | 34.0 |
| Leominster | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Lunenburg | MA | 11989 | 1654 | 122 | 0.005 | 0.001 | 123 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Mendon | MA | 8674 | 1197 | 89 | 0.004 | 0.001 | 89 | 9097.0 | 827.8 | 52.0 | 0.002 | 0.000 | 52.2 |
| Millbury | MA | 16413 | 2265 | 168 | 0.007 | 0.001 | 168 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Millville | MA | 2507 | 346 | 26 | 0.001 | 0.000 | 26 | 12405.0 | 1128.9 | 71.0 | 0.003 | 0.001 | 71.2 |
| New Braintree | MA | 4046 | 558 | 41 | 0.002 | 0.000 | 41 | 1315.0 | 119.7 | 7.5 | 0.000 | 0.000 | 7.6 |
| North Brookfield | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Northborough | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Northbridge | MA | 17841 | 2462 | 182 | 0.007 | 0.001 | 183 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Oakham | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Oxford | MA | 4126 | 569 | 42 | 0.002 | 0.000 | 42 | 45930.0 | 4179.6 | 262.8 | 0.013 | 0.003 | 263.8 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paxton | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Petersham | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Phillipston | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Princeton | MA | 5777 | 797 | 59 | 0.002 | 0.000 | 59 | 10095.0 | 918.6 | 57.8 | 0.003 | 0.001 | 58.0 |
| Royalston | MA | 7624 | 1052 | 78 | 0.003 | 0.001 | 78 | 9.0 | 0.8 | 0.1 | 0.000 | 0.000 | 0.1 |
| Rutland | MA | 25138 | 3469 | 257 | 0.010 | 0.002 | 257 | 12991.0 | 1182.2 | 74.3 | 0.004 | 0.001 | 74.6 |
| Shirley | MA | 188 | 26 | 2 | 0.000 | 0.000 | 2 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Shrewsbury | MA | 1948 | 269 | 20 | 0.001 | 0.000 | 20 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Southbridge | MA | 153141 | 21133 | 1563 | 0.063 | 0.013 | 1568 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Spencer | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 2952.0 | 268.6 | 16.9 | 0.001 | 0.000 | 17.0 |
| Sterling | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Sturbridge | MA | 67340 | 9293 | 687 | 0.028 | 0.006 | 690 | 6407.0 | 583.0 | 36.7 | 0.002 | 0.000 | 36.8 |
| Sutton | MA | 83463 | 11518 | 852 | 0.035 | 0.007 | 855 | 11621.0 | 1057.5 | 66.5 | 0.003 | 0.001 | 66.7 |
| Templeton | MA | 20753 | 2864 | 212 | 0.009 | 0.002 | 213 | 1381.0 | 125.7 | 7.9 | 0.000 | 0.000 | 7.9 |
| Townsend | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Upton | MA | 2998 | 414 | 31 | 0.001 | 0.000 | 31 | 978.0 | 89.0 | 5.6 | 0.000 | 0.000 | 5.6 |
| Uxbridge | MA | 9965 | 1375 | 102 | 0.004 | 0.001 | 102 | 382.0 | 34.8 | 2.2 | 0.000 | 0.000 | 2.2 |
| Warren | MA | 11554 | 1594 | 118 | 0.005 | 0.001 | 118 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Webster | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| West Boylston | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 158.0 | 14.4 | 0.9 | 0.000 | 0.000 | 0.9 |
| West Brookfield | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Westborough | MA | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 387.0 | 35.2 | 2.2 | 0.000 | 0.000 | 2.2 |
| Westminster | MA | 2802 | 387 | 29 | 0.001 | 0.000 | 29 | 592.0 | 53.9 | 3.4 | 0.000 | 0.000 | 3.4 |
| Winchendon | MA | 76907 | 10613 | 785 | 0.032 | 0.006 | 788 | 49823.0 | 4533.9 | 285.0 | 0.014 | 0.003 | 286.1 |
| Worcester | MA | 28831 | 3979 | 294 | 0.012 | 0.002 | 295 | 4503.0 | 409.8 | 25.8 | 0.001 | 0.000 | 25.9 |
| Ashford | CT | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Brooklyn | CT | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Canterbury | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Chaplin | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Eastford | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Hampton | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Killingly | CT | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Plainfield | CT | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Pomfret | CT | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Putnam | CT | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Scotland | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Sterling | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Thompson | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Union | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Voluntown | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |
| Windham | CT | 0 | 0 | 0 | 0.000 | 0.000 | 0 | 0.0 | 0.0 | 0.0 | 0.000 | 0.000 | 0.0 |
| Woodstock | CT | 23597 | 3256 | 241 | 0.010 | 0.002 | 242 | 9648.4 | 878.0 | 55.2 | 0.003 | 0.001 | 55.4 |

**Commercial Fuel Oil:**
Data was obtained from the Bureau of Labor Statistics to determine annual fuel oil consumption in the commercial industry by using building activity types, average employment, number of employers, and average fuel usage.

| County | Primary Building Activity Category | Primary Building Activity | Average Monthly Employment | Number of Employer Establishments Within the Primary Building Activity | Average Monthly Employment Per Employer Establishment (Employees/ Employer Establishment) | Fuel Oil Consumption Per Employer Establishment (Gallons/ Employer Establishment / Year) | Fuel Oil Consumption Per Employee (Gallons/ Employee / Year) | Percent of Buildings in Community Using Fuel Oil as Heating Fuel (%) | Annual Fuel Oil Consumption (Gallons/Year) | Annual Fuel Oil Use (MMBtu) | Fuel Oil CO2 Emissions (MT CO2) | Fuel Oil CH4 Emissions (MT CH4) | Fuel Oil N2O Emissions (MT N2O) | Fuel Oil CO2e Emissions (MT CO2e) | Fuel Oil Consumption Per Employee (MMBTU/ Employee / Year) | Percent of Buildings in Community Using Propane as Heating Fuel (%) | Annual Propane Use (MMBtu/year) | Annual Propane Use (gal/year) | Propane CO2 Emissions (MT CO2) | Propane CH4 Emissions (MT CH4) | Propane N2O Emissions (MT N2O) | Propane CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SUM** | | | | | | | | | **11,793,559.18** | **1,627,511.17** | **120,370.73** | **4.88** | **0.98** | **120,766** | **4,345.297** | **29** | **1,595,909** | **17,537,980** | **100,335** | **5** | **1** | **100,723** |
| *Middlesex* | *Education* | Education | 1,054 | 14 | 75 | *6,322* | 84 | 37.45% | 33,150 | 4,575 | 338.35 | 0.01 | 0.00 | 339 | 12,214 | 37% | 4,486 | 49,296 | 282 | 0.013 | 0.003 | 283 |
| *Middlesex* | *Food Sales* | Food Sales | 10 | 3 | 3 | *909* | 273 | 37.45% | 1,022 | 141 | 10.43 | 0.00 | 0.00 | 10 | 377 | 37% | 138 | 1,520 | 9 | 0.000 | 0.000 | 9 |
| *Middlesex* | *Food Service* | Food Service | 1,125 | 68 | 17 | *1,280* | 77 | 37.45% | 32,590 | 4,497 | 332.63 | 0.01 | 0.00 | 334 | 12,008 | 37% | 4,410 | 48,463 | 277 | 0.013 | 0.003 | 278 |
| *Middlesex* | *Inpatient Health Care* | Health Care Inpatient | | | | *7,315* | | 37.45% | | | | | | | | 37% | | 378 | | | | |
| *Middlesex* | *Outpatient Health Care* | Health Care Outpatient | 246 | 36 | 7 | *222* | 32 | 37.45% | 2,993 | 413 | 30.55 | 0.00 | 0.00 | 31 | 1,103 | 37% | 405 | 4,451 | 25 | 0.001 | 0.000 | 26 |
| *Middlesex* | *Lodging* | Lodging | 8 | 3 | 3 | *1,421* | 533 | 37.45% | 1,597 | 220 | 16.30 | 0.00 | 0.00 | 16 | 588 | 37% | 216 | 2,374 | 14 | 0.001 | 0.000 | 14 |
| *Middlesex* | *Retail (non-mall)* | Mercantile Retail (other than mall) | 64 | 3 | 21 | *1,022* | 48 | 37.45% | 1,148 | 158 | 11.72 | 0.00 | 0.00 | 12 | 423 | 37% | 155 | 1,708 | 10 | 0.000 | 0.000 | 10 |
| *Middlesex* | *Retail (mall)* | Mercantile Enclosed and Strip Malls | | | | *2,719* | | 37.45% | | | | | | | | 37% | | 141 | | | | |
| *Middlesex* | *Office* | Office | 1,382 | 365 | 4 | *824* | 218 | 37.45% | 112,648 | 15,545 | 1,149.74 | 0.05 | 0.01 | 1,154 | 41,505 | 37% | 15,244 | 167,512 | 958 | 0.046 | 0.009 | 962 |
| *Middlesex* | *Public Assembly* | Public Assembly | 54 | 8 | 7 | *1,095* | 162 | 37.45% | 3,281 | 453 | 33.49 | 0.00 | 0.00 | 34 | 1,209 | 37% | 444 | 4,879 | 28 | 0.001 | 0.000 | 28 |
| *Middlesex* | *Public Order/ Safety* | Public Order And Safety | 93 | 9 | 10 | *1,475* | 143 | 37.45% | 4,973 | 686 | 50.76 | 0.00 | 0.00 | 51 | 1,832 | 37% | 673 | 7,396 | 42 | 0.002 | 0.000 | 42 |
| *Middlesex* | *Religious Worship* | Religious Worship | 30 | 8 | 4 | *1,388* | 370 | 37.45% | 4,159 | 574 | 42.45 | 0.00 | 0.00 | 43 | 1,532 | 37% | 563 | 6,185 | 35 | 0.002 | 0.000 | 36 |
| *Middlesex* | *Service* | Service | 392 | 76 | 5 | *692* | 134 | 37.45% | 19,698 | 2,718 | 201.05 | 0.01 | 0.00 | 202 | 7,258 | 37% | 2,666 | 29,292 | 168 | 0.008 | 0.002 | 168 |
| *Middlesex* | *Warehouse/ Storage* | Warehouse And Storage | 696 | 40 | 17 | *651* | 37 | 37.45% | 9,759 | 1,347 | 99.60 | 0.00 | 0.00 | 100 | 3,596 | 37% | 1,321 | 14,512 | 83 | 0.004 | 0.001 | 83 |
| ***Middlesex*** | ***Other*** | **Other Activity** | 8 | **3** | 3 | ***1,839*** | 690 | 37.45% | 2,066 | 285 | 21.09 | 0.00 | 0.00 | 21 | 761 | 37% | 280 | 3,073 | 18 | 0.001 | 0.000 | 18 |
| ***Middlesex*** | ***Other*** | **Other** | **730** | **173** | 4 | ***1,839*** | 436 | 37.45% | 119,161 | 16,444 | 1,216.21 | 0.05 | 0.01 | 1,220 | 43,904 | 37% | 16,125 | 177,196 | 1,014 | 0.048 | 0.010 | 1,018 |
| *Worcester* | *Education* | Education | 39,173 | 445 | 88 | *6,322* | 72 | 37.45% | 1,053,705 | 145,411 | 10,754.62 | 0.44 | 0.09 | 10,790 | 388,234 | 37% | 142,588 | 1,566,899 | 8,964 | 0.428 | 0.086 | 8,999 |
| *Worcester* | *Food Sales* | Food Sales | 9,664 | 486 | 20 | *909* | 46 | 37.45% | 165,542 | 22,845 | 1,689.60 | 0.07 | 0.01 | 1,695 | 60,993 | 37% | 22,401 | 246,167 | 1,408 | 0.067 | 0.013 | 1,414 |
| *Worcester* | *Food Service* | Food Service | 22,613 | 1,524 | 15 | *1,280* | 86 | 37.45% | 730,406 | 100,796 | 7,454.88 | 0.30 | 0.06 | 7,479 | 269,116 | 37% | 98,839 | 1,086,142 | 6,214 | 0.297 | 0.059 | 6,238 |
| *Worcester* | *Inpatient Health Care* | Health Care Inpatient | 19,839 | 54 | 367 | *7,315* | 20 | 37.45% | 147,949 | 20,417 | 1,510.04 | 0.06 | 0.01 | 1,515 | 54,511 | 37% | 20,021 | 220,006 | 1,259 | 0.060 | 0.012 | 1,264 |
| *Worcester* | *Outpatient Health Care* | Health Care Outpatient | 17,930 | 1,114 | 16 | *222* | 14 | 37.45% | 92,628 | 12,783 | 945.41 | 0.04 | 0.01 | 949 | 34,129 | 37% | 12,534 | 137,741 | 788 | 0.038 | 0.008 | 791 |
| *Worcester* | *Lodging* | Lodging | 15,071 | 432 | 35 | *1,421* | 41 | 37.45% | 229,923 | 31,729 | 2,346.70 | 0.10 | 0.02 | 2,354 | 84,714 | 37% | 31,113 | 341,904 | 1,956 | 0.093 | 0.019 | 1,964 |
| *Worcester* | *Retail (non-mall)* | Mercantile Retail (other than mall) | 9,179 | 610 | 15 | *1,022* | 68 | 37.45% | 233,499 | 32,223 | 2,383.20 | 0.10 | 0.02 | 2,391 | 86,032 | 37% | 31,597 | 347,222 | 1,987 | 0.095 | 0.019 | 1,994 |
| *Worcester* | *Retail (mall)* | Mercantile Enclosed and Strip Malls | | | | *2,719* | | 37.45% | | | | | | | | 37% | | | | | | |
| *Worcester* | *Office* | Office | 73,854 | 13,649 | 5 | *824* | 152 | 37.45% | 4,212,429 | 581,315 | 42,994.07 | 1.74 | 0.35 | 43,135 | 1,552,055 | 37% | 570,028 | 6,264,039 | 35,838 | 1.710 | 0.342 | 35,976 |
| *Worcester* | *Public Assembly* | Public Assembly | 7,540 | 465 | 16 | *1,095* | 68 | 37.45% | 190,709 | 26,318 | 1,946.47 | 0.08 | 0.02 | 1,953 | 70,266 | 37% | 25,807 | 283,592 | 1,622 | 0.077 | 0.015 | 1,629 |
| *Worcester* | *Public Order/ Safety* | Public Order And Safety | 7,327 | 208 | 35 | *1,475* | 42 | 37.45% | 114,939 | 15,862 | 1,173.13 | 0.05 | 0.01 | 1,177 | 42,349 | 37% | 15,554 | 170,919 | 978 | 0.047 | 0.009 | 982 |
| *Worcester* | *Religious Worship* | Religious Worship | 2,522 | 311 | 8 | *1,388* | 171 | 37.45% | 161,679 | 22,312 | 1,650.18 | 0.07 | 0.01 | 1,656 | 59,570 | 37% | 21,879 | 240,423 | 1,376 | 0.066 | 0.013 | 1,381 |
| *Worcester* | *Service* | Service | 14,380 | 1,687 | 9 | *692* | 81 | 37.45% | 437,246 | 60,340 | 4,462.74 | 0.18 | 0.04 | 4,477 | 161,102 | 37% | 59,168 | 650,201 | 3,720 | 0.178 | 0.036 | 3,734 |
| *Worcester* | *Warehouse/ Storage* | Warehouse And Storage | 12,377 | 853 | 15 | *651* | 45 | 37.45% | 208,104 | 28,718 | 2,124.01 | 0.09 | 0.02 | 2,131 | 76,675 | 37% | 28,161 | 309,459 | 1,770 | 0.084 | 0.017 | 1,777 |
| ***Worcester*** | ***Other*** | **Other Activity** | 2,012 | 143 | 14 | ***1,839*** | 131 | 37.45% | 98,497 | 13,593 | 1,005.31 | 0.04 | 0.01 | 1,009 | 36,291 | 37% | 13,329 | 146,468 | 838 | 0.040 | 0.008 | 841 |
| ***Worcester*** | ***Other*** | **Other** | **23,244** | **3,100** | 7 | ***1,839*** | 245 | 37.45% | 2,135,246 | 294,664 | 21,793.35 | 0.88 | 0.18 | 21,865 | 786,724 | 37% | 288,942 | 3,175,191 | 18,166 | 0.867 | 0.173 | 18,236 |
| *Windham* | *Education* | Education | 5,110 | 70 | 73 | *6,322* | 87 | 37.45% | 165,751 | 22,874 | 1,691.74 | 0.07 | 0.01 | 1,697 | 61,071 | 37% | 22,430 | 246,478 | 1,410 | 0.067 | 0.013 | 1,416 |
| *Windham* | *Food Sales* | Food Sales | 1,106 | 80 | 14 | *909* | 66 | 37.45% | 27,250 | 3,760 | 278.12 | 0.01 | 0.00 | 279 | 10,040 | 37% | 3,687 | 40,521 | 232 | 0.011 | 0.002 | 233 |
| *Windham* | *Food Service* | Food Service | 3,164 | 239 | 13 | *1,280* | 97 | 37.45% | 114,545 | 15,807 | 1,169.11 | 0.05 | 0.01 | 1,173 | 42,204 | 37% | 15,500 | 170,333 | 975 | 0.047 | 0.009 | 978 |
| *Windham* | *Inpatient Health Care* | Health Care Inpatient | 1,373 | 11 | 125 | *7,315* | 59 | 37.45% | 30,138 | 4,159 | 307.60 | 0.01 | 0.00 | 309 | 11,104 | 37% | 4,078 | 44,816 | 256 | 0.012 | 0.002 | 257 |
| *Windham* | *Outpatient Health Care* | Health Care Outpatient | 1,682 | 165 | 10 | *222* | 22 | 37.45% | 13,720 | 1,893 | 140.03 | 0.01 | 0.00 | 140 | 5,055 | 37% | 1,857 | 20,402 | 117 | 0.006 | 0.001 | 117 |
| *Windham* | *Lodging* | Lodging | 2,147 | 90 | 24 | *1,421* | 60 | 37.45% | 47,901 | 6,610 | 488.90 | 0.02 | 0.00 | 491 | 17,649 | 37% | 6,482 | 71,230 | 408 | 0.019 | 0.004 | 409 |
| *Windham* | *Retail (non-mall)* | Mercantile Retail (other than mall) | 1,338 | 89 | 15 | *1,022* | 68 | 37.45% | 34,068 | 4,701 | 347.71 | 0.01 | 0.00 | 349 | 12,552 | 37% | 4,610 | 50,660 | 290 | 0.014 | 0.003 | 291 |
| *Windham* | *Retail (mall)* | Mercantile Enclosed and Strip Malls | | | | *2,719* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *Windham* | *Office* | Office | 4,708 | 981 | 5 | *824* | 172 | 37.45% | 302,762 | 41,781 | 3,090.13 | 0.13 | 0.03 | 3,100 | 111,551 | 37% | 40,970 | 450,218 | 2,576 | 0.123 | 0.025 | 2,586 |
| *Windham* | *Public Assembly* | Public Assembly | 523 | 48 | 11 | *1,095* | 100 | 37.45% | 19,686 | 2,717 | 200.93 | 0.01 | 0.00 | 202 | 7,253 | 37% | 2,664 | 29,274 | 167 | 0.008 | 0.002 | 168 |
| *Windham* | *Public Order/ Safety* | Public Order And Safety | 534 | 35 | 15 | *1,475* | 97 | 37.45% | 19,341 | 2,669 | 197.40 | 0.01 | 0.00 | 198 | 7,126 | 37% | 2,617 | 28,760 | 165 | 0.008 | 0.002 | 165 |
| *Windham* | *Religious Worship* | Religious Worship | 282 | 44 | 6 | *1,388* | 217 | 37.45% | 22,874 | 3,157 | 233.47 | 0.01 | 0.00 | 234 | 8,428 | 37% | 3,095 | 34,015 | 195 | 0.009 | 0.002 | 195 |
| *Windham* | *Service* | Service | 865 | 189 | 5 | *692* | 151 | 37.45% | 48,986 | 6,760 | 499.98 | 0.02 | 0.00 | 502 | 18,049 | 37% | 6,629 | 72,844 | 417 | 0.020 | 0.004 | 418 |
| *Windham* | *Warehouse/ Storage* | Warehouse And Storage | 2,253 | 188 | 12 | *651* | 54 | 37.45% | 45,866 | 6,329 | 468.13 | 0.02 | 0.00 | 470 | 16,899 | 37% | 6,207 | 68,204 | 390 | 0.019 | 0.004 | 392 |
| ***Windham*** | ***Other*** | **Other Activity** | 10 | 4 | 3 | ***1,839*** | 736 | 37.45% | 2,755 | 380 | 28.12 | 0.00 | 0.00 | 28 | 1,015 | 37% | 373 | 4,097 | 23 | 0.001 | 0.000 | 24 |
| ***Windham*** | ***Other*** | **Other Subsector** | **1,693** | **450** | 4 | ***1,839*** | 489 | 37.45% | 309,955 | 42,774 | 3,163.55 | 0.13 | 0.03 | 3,174 | 114,202 | 37% | 41,943 | 460,915 | 2,637 | 0.126 | 0.025 | 2,647 |
| *Tolland* | *Education* | Education | | | | *6,322* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *Tolland* | *Food Sales* | Food Sales | 20 | 1 | 16 | *909* | 58 | 37.45% | 445 | 61 | 4.55 | 0.00 | 0.00 | 5 | 164 | 37% | 60 | 662 | 4 | 0.000 | 0.000 | 4 |
| *Tolland* | *Food Service* | Food Service | 15 | 1 | 15 | *1,280* | 83 | 37.45% | 455 | 63 | 4.65 | 0.00 | 0.00 | 5 | 168 | 37% | 62 | 677 | 4 | 0.000 | 0.000 | 4 |
| *Tolland* | *Inpatient Health Care* | Health Care Inpatient | | | | *7,315* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *Tolland* | *Outpatient Health Care* | Health Care Outpatient | 3 | 0 | 8 | *222* | 28 | 37.45% | 32 | 4 | 0.32 | 0.00 | 0.00 | 0 | 12 | 37% | 4 | 47 | 0 | 0.000 | 0.000 | 0 |
| *Tolland* | *Lodging* | Lodging | 3 | 0 | 17 | *1,421* | 83 | 37.45% | 80 | 11 | 0.82 | 0.00 | 0.00 | 1 | 30 | 37% | 11 | 120 | 1 | 0.000 | 0.000 | 1 |
| *Tolland* | *Retail (non-mall)* | Mercantile Retail (other than mall) | 19 | 1 | 14 | *1,022* | 71 | 37.45% | 512 | 71 | 5.23 | 0.00 | 0.00 | 5 | 189 | 37% | 69 | 762 | 4 | 0.000 | 0.000 | 4 |
| *Tolland* | *Retail (mall)* | Mercantile Enclosed and Strip Malls | | | | *2,719* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *Tolland* | *Office* | Office | 6 | 2 | 3 | *824* | 276 | 37.45% | 617 | 85 | 6.30 | 0.00 | 0.00 | 6 | 227 | 37% | 84 | 918 | 5 | 0.000 | 0.000 | 5 |
| *Tolland* | *Public Assembly* | Public Assembly | 9 | 0 | 30 | *1,095* | 36 | 37.45% | 125 | 17 | 1.27 | 0.00 | 0.00 | 1 | 46 | 37% | 17 | 185 | 1 | 0.000 | 0.000 | 1 |
| *Tolland* | *Public Order/ Safety* | Public Order And Safety | | | | *1,475* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *Tolland* | *Religious Worship* | Religious Worship | 3 | 0 | 6 | *1,388* | 216 | 37.45% | 211 | 29 | 2.15 | 0.00 | 0.00 | 2 | 78 | 37% | 29 | 314 | 2 | 0.000 | 0.000 | 2 |
| *Tolland* | *Service* | Service | 8 | 2 | 4 | *692* | 166 | 37.45% | 498 | 69 | 5.08 | 0.00 | 0.00 | 5 | 184 | 37% | 67 | 741 | 4 | 0.000 | 0.000 | 4 |
| *Tolland* | *Warehouse/ Storage* | Warehouse And Storage | 2 | 1 | 3 | *651* | 218 | 37.45% | 178 | 24 | 1.81 | 0.00 | 0.00 | 2 | 65 | 37% | 24 | 264 | 2 | 0.000 | 0.000 | 2 |
| ***Tolland*** | ***Other*** | **Other Activity** | | | | ***1,839*** | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| ***Tolland*** | ***Other*** | **Other Subsector** | **18** | **2** | 7 | ***1,839*** | 246 | 37.45% | 1,686 | 233 | 17.21 | 0.00 | 0.00 | 17 | 621 | 37% | 228 | 2,507 | 14 | 0.001 | 0.000 | 14 |
| *New London* | *Education* | Education | | | | *6,322* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *New London* | *Food Sales* | Food Sales | 16 | 2 | 8 | *909* | 119 | 37.45% | 715 | 99 | 7.30 | 0.00 | 0.00 | 7 | 264 | 37% | 97 | 1,064 | 6 | 0.000 | 0.000 | 6 |
| *New London* | *Food Service* | Food Service | 67 | 7 | 10 | *1,280* | 134 | 37.45% | 3,393 | 468 | 34.63 | 0.00 | 0.00 | 35 | 1,250 | 37% | 459 | 5,045 | 29 | 0.001 | 0.000 | 29 |
| *New London* | *Inpatient Health Care* | Health Care Inpatient | 11 | 0 | 173 | *7,315* | 42 | 37.45% | 174 | 24 | 1.78 | 0.00 | 0.00 | 2 | 64 | 37% | 24 | 259 | 1 | 0.000 | 0.000 | 1 |
| *New London* | *Outpatient Health Care* | Health Care Outpatient | 15 | 1 | 12 | *222* | 19 | 37.45% | 110 | 15 | 1.12 | 0.00 | 0.00 | 1 | 40 | 37% | 15 | 163 | 1 | 0.000 | 0.000 | 1 |
| *New London* | *Lodging* | Lodging | 20 | 1 | 15 | *1,421* | 97 | 37.45% | 711 | 98 | 7.25 | 0.00 | 0.00 | 7 | 262 | 37% | 96 | 1,057 | 6 | 0.000 | 0.000 | 6 |
| *New London* | *Retail (non-mall)* | Mercantile Retail (other than mall) | 16 | 2 | 8 | *1,022* | 128 | 37.45% | 767 | 106 | 7.83 | 0.00 | 0.00 | 8 | 283 | 37% | 104 | 1,141 | 7 | 0.000 | 0.000 | 7 |
| *New London* | *Retail (mall)* | Mercantile Enclosed and Strip Malls | | | | *2,719* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *New London* | *Office* | Office | 59 | 14 | 4 | *824* | 204 | 37.45% | 4,470 | 617 | 45.62 | 0.00 | 0.00 | 46 | 1,647 | 37% | 605 | 6,647 | 38 | 0.002 | 0.000 | 38 |
| *New London* | *Public Assembly* | Public Assembly | 20 | 1 | 14 | *1,095* | 80 | 37.45% | 612 | 84 | 6.25 | 0.00 | 0.00 | 6 | 226 | 37% | 83 | 910 | 5 | 0.000 | 0.000 | 5 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *New London* | *Public Order/ Safety* | Public Order And Safety | | | | *1,475* | | 37.45% | | | | | | | | 37% | | | - | - | - | - |
| *New London* | *Religious Worship* | Religious Worship | 3 | 1 | 3 | *1,388* | 485 | 37.45% | 610 | 84 | 6.23 | 0.00 | 0.00 | 6 | 225 | 37% | 83 | 907 | 5 | 0.000 | 0.000 | 5 |
| *New London* | *Service* | Service | 18 | 3 | 5 | *692* | 130 | 37.45% | 858 | 118 | 8.76 | 0.00 | 0.00 | 9 | 316 | 37% | 116 | 1,276 | 7 | 0.000 | 0.000 | 7 |
| *New London* | *Warehouse/ Storage* | Warehouse And Storage | 4 | 4 | 1 | *651* | 695 | 37.45% | 974 | 134 | 9.94 | 0.00 | 0.00 | 10 | 359 | 37% | 132 | 1,449 | 8 | 0.000 | 0.000 | 8 |
| ***New London*** | ***Other*** | **Other Activity** | 1 | 0 | 4 | ***1,839*** | 485 | 37.45% | 195 | 27 | 1.99 | 0.00 | 0.00 | 2 | 72 | 37% | 26 | 290 | 2 | 0.000 | 0.000 | 2 |
| ***New London*** | ***Other*** | **Other Subsector** | **73** | **13** | 6 | ***1,839*** | 320 | 37.45% | 8,785 | 1,212 | 89.66 | 0.00 | 0.00 | 90 | 3,237 | 37% | 1,189 | 13,063 | 75 | 0.004 | 0.001 | 75 |

**Fuel Oil Data:**
This sheet summarized data pertaining to North American Industry Classification System (NAICS) codes and associated employment for fuel oil and propane emissions calculations.

| *County* | NAICS | # of Establishment | Avg Monthly Employmen | EIA Principal Business Activity | Sub Sector |
|---|---|---|---|---|---|
| *Middlesex* | 236 | 52 | 229 | Construction of buildings | Other |
| *Middlesex* | 238 | 97 | 457 | Specialty trade contractors | Other |
| *Middlesex* | 311 | 7 | 412 | Food | Industrial |
| *Middlesex* | 323 | 3 | 104 | Printing and Related Support | Industrial |
| *Middlesex* | 332 | 3 | 36 | Fabricated Metal Products | Industrial |
| *Middlesex* | 333 | 4 | 251 | Machinery | Industrial |
| *Middlesex* | 334 | 11 | 344 | Computer and Electronic Products | Industrial |
| *Middlesex* | 423 | 23 | 365 | Warehouse/ Storage | Commercial |
| *Middlesex* | 424 | 10 | 79 | Warehouse/ Storage | Commercial |
| *Middlesex* | 425 | 8 | 23 | Electronic markets and agents and brokers | Other |
| *Middlesex* | 444 | 3 | 64 | Retail (non-mall) | Commercial |
| *Middlesex* | 445 | 3 | 10 | Food Sales | Commercial |
| *Middlesex* | 484 | 16 | 163 | Service | Commercial |
| *Middlesex* | 488 | 3 | 3 | Service | Commercial |
| *Middlesex* | 491 | 6 | 62 | Service | Commercial |
| *Middlesex* | 493 | 7 | 252 | Warehouse/ Storage | Commercial |
| *Middlesex* | 517 | 5 | 16 | Office | Commercial |
| *Middlesex* | 518 | 2 | 5 | Office | Commercial |
| *Middlesex* | 522 | 13 | 83 | Office | Commercial |
| *Middlesex* | 531 | 22 | 53 | Office | Commercial |
| *Middlesex* | 541 | 151 | 472 | Office | Commercial |
| *Middlesex* | 551 | 3 | 46 | Office | Commercial |
| *Middlesex* | 561 | 64 | 354 | Office | Commercial |
| *Middlesex* | 562 | 3 | 8 | Other | Commercial |
| *Middlesex* | 611 | 14 | 1,054 | Education | Commercial |
| *Middlesex* | 621 | 36 | 246 | Outpatient Health Care | Commercial |
| *Middlesex* | 624 | 105 | 353 | Office | Commercial |
| *Middlesex* | 713 | 8 | 54 | Public Assembly | Commercial |

| | | | | | |
|---|---|---|---|---|---|
| *Middlesex* | 721 | 3 | 8 | Lodging | Commercial |
| *Middlesex* | 722 | 68 | 1,125 | Food Service | Commercial |
| *Middlesex* | 811 | 39 | 117 | Service | Commercial |
| *Middlesex* | 812 | 12 | 47 | Service | Commercial |
| *Middlesex* | 813 | 8 | 30 | Religious Worship | Commercial |
| *Middlesex* | 814 | 16 | 21 | Private Households | Other |
| *Middlesex* | 922 | 9 | 93 | Public Order/ Safety | Commercial |
| *Worcester* | 111 | 51 | 1,243 | Crop production | Other |
| *Worcester* | 112 | 18 | 166 | Animal production and aquaculture | Other |
| *Worcester* | 113 | 14 | 35 | Forestry and logging | Other |
| *Worcester* | 115 | 21 | 104 | Agriculture and forestry support activities | Other |
| *Worcester* | 212 | 13 | 222 | Mining, except oil and gas | Other |
| *Worcester* | 213 | 4 | 18 | Support activities for mining | Other |
| *Worcester* | 221 | 92 | 4,139 | Utilities | Other |
| *Worcester* | 236 | 632 | 2,491 | Construction of buildings | Other |
| *Worcester* | 237 | 164 | 2,801 | Heavy and civil engineering construction | Other |
| *Worcester* | 238 | 1,685 | 11,078 | Specialty trade contractors | Other |
| *Worcester* | 311 | 56 | 1,422 | Food | Industrial |
| *Worcester* | 312 | 31 | 1,589 | Beverage and Tobacco Products | Industrial |
| *Worcester* | 313 | 17 | 291 | Textile Mills | Industrial |
| *Worcester* | 314 | 9 | 29 | Textile Product Mills | Industrial |
| *Worcester* | 321 | 26 | 656 | Wood Products | Industrial |
| *Worcester* | 322 | 30 | 2,148 | Paper | Industrial |
| *Worcester* | 323 | 58 | 634 | Printing and Related Support | Industrial |
| *Worcester* | 324 | 8 | 39 | Petroleum and Coal Products | Industrial |
| *Worcester* | 325 | 43 | 3,087 | Chemicals | Industrial |
| *Worcester* | 326 | 71 | 4,356 | Plastics and Rubber Products | Industrial |
| *Worcester* | 327 | 48 | 2,076 | Nonmetallic Mineral Products | Industrial |
| *Worcester* | 331 | 13 | 174 | Primary Metals | Industrial |
| *Worcester* | 332 | 189 | 4,708 | Fabricated Metal Products | Industrial |
| *Worcester* | 333 | 82 | 3,646 | Machinery | Industrial |
| *Worcester* | 334 | 57 | 4,391 | Computer and Electronic Products | Industrial |
| *Worcester* | 335 | 31 | 1,232 | Electrical Equip., Appliances, and Components | Industrial |
| *Worcester* | 336 | 8 | 79 | Transportation Equipment | Industrial |

| | | | | | |
|---|---|---|---|---|---|
| *Worcester* | 337 | 39 | 1,316 | Furniture and Related Products | Industrial |
| *Worcester* | 339 | 54 | 931 | Miscellaneous | Industrial |
| *Worcester* | 423 | 571 | 6,130 | Warehouse/ Storage | Commercial |
| *Worcester* | 424 | 249 | 3,530 | Warehouse/ Storage | Commercial |
| *Worcester* | 425 | 188 | 714 | Electronic markets and agents and brokers | Other |
| *Worcester* | 441 | 303 | 4,899 | Retail (non-mall) | Commercial |
| *Worcester* | 444 | 187 | 3,317 | Retail (non-mall) | Commercial |
| *Worcester* | 445 | 486 | 9,664 | Food Sales | Commercial |
| *Worcester* | 484 | 287 | 3,139 | Service | Commercial |
| *Worcester* | 485 | 95 | 2,146 | Public Assembly | Commercial |
| *Worcester* | 488 | 74 | 569 | Service | Commercial |
| *Worcester* | 491 | 79 | 1,765 | Service | Commercial |
| *Worcester* | 492 | 38 | 2,540 | Service | Commercial |
| *Worcester* | 493 | 33 | 2,717 | Warehouse/ Storage | Commercial |
| *Worcester* | 512 | 38 | 393 | Public Assembly | Commercial |
| *Worcester* | 516 | 35 | 176 | Office | Commercial |
| *Worcester* | 517 | 93 | 1,202 | Office | Commercial |
| *Worcester* | 518 | 49 | 385 | Office | Commercial |
| *Worcester* | 519 | 85 | 740 | Office | Commercial |
| *Worcester* | 522 | 369 | 3,719 | Office | Commercial |
| *Worcester* | 523 | 190 | 705 | Office | Commercial |
| *Worcester* | 524 | 294 | 7,180 | Office | Commercial |
| *Worcester* | 531 | 504 | 1,671 | Office | Commercial |
| *Worcester* | 532 | 120 | 963 | Retail (non-mall) | Commercial |
| *Worcester* | 541 | 2,346 | 16,942 | Office | Commercial |
| *Worcester* | 551 | 109 | 3,768 | Office | Commercial |
| *Worcester* | 561 | 1,100 | 16,120 | Office | Commercial |
| *Worcester* | 562 | 142 | 2,006 | Other | Commercial |
| *Worcester* | 611 | 445 | 39,173 | Education | Commercial |
| *Worcester* | 621 | 1,114 | 17,930 | Outpatient Health Care | Commercial |
| *Worcester* | 622 | 54 | 19,839 | Inpatient Health Care | Commercial |
| *Worcester* | 623 | 362 | 13,142 | Lodging | Commercial |
| *Worcester* | 624 | 8,142 | 17,012 | Office | Commercial |
| *Worcester* | 711 | 71 | 832 | Public Assembly | Commercial |

| | | | | | |
|---|---|---|---|---|---|
| *Worcester* | 712 | 16 | 759 | Public Assembly | Commercial |
| *Worcester* | 713 | 245 | 3,410 | Public Assembly | Commercial |
| *Worcester* | 721 | 70 | 1,929 | Lodging | Commercial |
| *Worcester* | 722 | 1,524 | 22,613 | Food Service | Commercial |
| *Worcester* | 811 | 665 | 3,373 | Service | Commercial |
| *Worcester* | 812 | 544 | 2,994 | Service | Commercial |
| *Worcester* | 813 | 311 | 2,522 | Religious Worship | Commercial |
| *Worcester* | 814 | 218 | 233 | Private Households | Other |
| *Worcester* | 921 | 205 | 2,691 | Office | Commercial |
| *Worcester* | 922 | 208 | 7,327 | Public Order/ Safety | Commercial |
| *Worcester* | 924 | 50 | 559 | Office | Commercial |
| *Worcester* | 925 | 47 | 521 | Office | Commercial |
| *Worcester* | 926 | 22 | 273 | Office | Commercial |
| *Worcester* | 927 | 1 | 6 | Other | Commercial |
| *Worcester* | 928 | 9 | 190 | Office | Commercial |
| *Windham* | 111 | 15 | 131 | Crop production | Other |
| *Windham* | 112 | 17 | 44 | Animal production and aquaculture | Other |
| *Windham* | 212 | 9 | 70 | Mining, except oil and gas | Other |
| *Windham* | 221 | 4 | 29 | Utilities | Other |
| *Windham* | 236 | 66 | 182 | Construction of buildings | Other |
| *Windham* | 237 | 29 | 254 | Heavy and civil engineering construction | Other |
| *Windham* | 238 | 209 | 818 | Specialty trade contractors | Other |
| *Windham* | 312 | 7 | 52 | Beverage and Tobacco Products | Industrial |
| *Windham* | 313 | 5 | 124 | Textile Mills | Industrial |
| *Windham* | 321 | 7 | 122 | Wood Products | Industrial |
| *Windham* | 322 | 6 | 286 | Paper | Industrial |
| *Windham* | 323 | 7 | 30 | Printing and Related Support | Industrial |
| *Windham* | 324 | 3 | 26 | Petroleum and Coal Products | Industrial |
| *Windham* | 325 | 12 | 263 | Chemicals | Industrial |
| *Windham* | 326 | 15 | 1,110 | Plastics and Rubber Products | Industrial |
| *Windham* | 327 | 12 | 383 | Nonmetallic Mineral Products | Industrial |
| *Windham* | 332 | 42 | 641 | Fabricated Metal Products | Industrial |
| *Windham* | 334 | 7 | 92 | Computer and Electronic Products | Industrial |
| *Windham* | 335 | 9 | 682 | Electrical Equip., Appliances, and Components | Industrial |

| | | | | | |
|---|---|---|---|---|---|
| *Windham* | 339 | 8 | 132 | Miscellaneous | Industrial |
| *Windham* | 423 | 124 | 509 | Warehouse/ Storage | Commercial |
| *Windham* | 424 | 58 | 671 | Warehouse/ Storage | Commercial |
| *Windham* | 425 | 36 | 51 | Electronic markets and agents and brokers | Other |
| *Windham* | 441 | 52 | 676 | Retail (non-mall) | Commercial |
| *Windham* | 444 | 37 | 662 | Retail (non-mall) | Commercial |
| *Windham* | 445 | 80 | 1,106 | Food Sales | Commercial |
| *Windham* | 449 | 21 | 129 | Furniture, Home Furnishings, Electronics, and Ap | Commercial |
| *Windham* | 455 | 33 | 1,597 | General Merchandise Retailers | Commercial |
| *Windham* | 456 | 33 | 275 | Health and Personal Care Retailers | Commercial |
| *Windham* | 457 | 56 | 406 | Gasoline Stations and Fuel Dealers | Commercial |
| *Windham* | 458 | 9 | 100 | Clothing, Clothing Accessories, Shoe, and Jewelr | Commercial |
| *Windham* | 459 | 43 | 261 | Sporting Goods, Hobby, Musical Instrument, Boo | Commercial |
| *Windham* | 484 | 45 | 342 | Service | Commercial |
| *Windham* | 485 | 15 | 212 | Public Assembly | Commercial |
| *Windham* | 493 | 6 | 1,073 | Warehouse/ Storage | Commercial |
| *Windham* | 517 | 12 | 114 | Office | Commercial |
| *Windham* | 518 | 17 | 18 | Office | Commercial |
| *Windham* | 519 | 18 | 92 | Office | Commercial |
| *Windham* | 522 | 56 | 331 | Office | Commercial |
| *Windham* | 523 | 14 | 32 | Office | Commercial |
| *Windham* | 524 | 46 | 209 | Office | Commercial |
| *Windham* | 531 | 53 | 171 | Office | Commercial |
| *Windham* | 541 | 286 | 868 | Office | Commercial |
| *Windham* | 551 | 21 | 271 | Office | Commercial |
| *Windham* | 561 | 2 | 13 | Office | Commercial |
| *Windham* | 562 | 4 | 10 | Other | Commercial |
| *Windham* | 611 | 70 | 5,110 | Education | Commercial |
| *Windham* | 621 | 165 | 1,682 | Outpatient Health Care | Commercial |
| *Windham* | 622 | 11 | 1,373 | Inpatient Health Care | Commercial |
| *Windham* | 623 | 67 | 1,905 | Lodging | Commercial |
| *Windham* | 624 | 395 | 2,309 | Office | Commercial |
| *Windham* | 712 | 1 | 10 | Public Assembly | Commercial |
| *Windham* | 713 | 32 | 301 | Public Assembly | Commercial |

| | | | | | |
|---|---|---|---|---|---|
| *Windham* | 721 | 23 | 242 | Lodging | Commercial |
| *Windham* | 722 | 239 | 3,164 | Food Service | Commercial |
| *Windham* | 811 | 73 | 268 | Service | Commercial |
| *Windham* | 812 | 71 | 255 | Service | Commercial |
| *Windham* | 813 | 44 | 282 | Religious Worship | Commercial |
| *Windham* | 814 | 65 | 114 | Private Households | Other |
| *Windham* | 921 | 35 | 37 | Office | Commercial |
| *Windham* | 922 | 35 | 534 | Public Order/ Safety | Commercial |
| *Windham* | 923 | 3 | 36 | Office | Commercial |
| *Windham* | 924 | 2 | 20 | Office | Commercial |
| *Windham* | 925 | 5 | 53 | Office | Commercial |
| *Windham* | 926 | 15 | 131 | Office | Commercial |
| *Windham* | 928 | 1 | 3 | Office | Commercial |
| *Tolland* | 111 | 0 | 7 | Crop production | Other |
| *Tolland* | 112 | 0 | 5 | Animal production and aquaculture | Other |
| *Tolland* | 236 | 0 | 1 | Construction of buildings | Other |
| *Tolland* | 237 | 0 | 0 | Heavy and civil engineering construction | Other |
| *Tolland* | 238 | 1 | 4 | Specialty trade contractors | Other |
| *Tolland* | 423 | 1 | 2 | Warehouse/ Storage | Commercial |
| *Tolland* | 424 | 0 | 0 | Warehouse/ Storage | Commercial |
| *Tolland* | 425 | 0 | 0 | Electronic markets and agents and brokers | Other |
| *Tolland* | 441 | 1 | 14 | Retail (non-mall) | Commercial |
| *Tolland* | 444 | 0 | 6 | Retail (non-mall) | Commercial |
| *Tolland* | 445 | 1 | 20 | Food Sales | Commercial |
| *Tolland* | 449 | 0 | 4 | Furniture, Home Furnishings, Electronics, and Ap | Commercial |
| *Tolland* | 484 | 1 | 2 | Service | Commercial |
| *Tolland* | 485 | 0 | 9 | Public Assembly | Commercial |
| *Tolland* | 541 | 2 | 6 | Office | Commercial |
| *Tolland* | 621 | 0 | 3 | Outpatient Health Care | Commercial |
| *Tolland* | 623 | 0 | 2 | Lodging | Commercial |
| *Tolland* | 721 | 0 | 0 | Lodging | Commercial |
| *Tolland* | 722 | 1 | 15 | Food Service | Commercial |
| *Tolland* | 811 | 1 | 3 | Service | Commercial |
| *Tolland* | 812 | 1 | 3 | Service | Commercial |

| | | | | | |
|---|---|---|---|---|---|
| *Tolland* | 813 | 0 | 3 | Religious Worship | Commercial |
| *Tolland* | 814 | 0 | 1 | Private Households | Other |
| *New London* | 111 | 1 | 29 | Crop production | Other |
| *New London* | 112 | 2 | 26 | Animal production and aquaculture | Other |
| *New London* | 236 | 2 | 5 | Construction of buildings | Other |
| *New London* | 237 | 1 | 2 | Heavy and civil engineering construction | Other |
| *New London* | 238 | 5 | 10 | Specialty trade contractors | Other |
| *New London* | 423 | 3 | 2 | Warehouse/ Storage | Commercial |
| *New London* | 424 | 1 | 2 | Warehouse/ Storage | Commercial |
| *New London* | 425 | 1 | 0 | Electronic markets and agents and brokers | Other |
| *New London* | 441 | 1 | 9 | Retail (non-mall) | Commercial |
| *New London* | 444 | 1 | 7 | Retail (non-mall) | Commercial |
| *New London* | 445 | 2 | 16 | Food Sales | Commercial |
| *New London* | 449 | 1 | 3 | Furniture, Home Furnishings, Electronics, and Ap | Commercial |
| *New London* | 484 | 0 | 4 | Service | Commercial |
| *New London* | 485 | 0 | 7 | Public Assembly | Commercial |
| *New London* | 487 | 0 | 0 | Public Assembly | Commercial |
| *New London* | 488 | 0 | 1 | Service | Commercial |
| *New London* | 512 | 0 | 1 | Public Assembly | Commercial |
| *New London* | 513 | 0 | 3 | Publishing Industries | Commercial |
| *New London* | 516 | 0 | 1 | Office | Commercial |
| *New London* | 517 | 0 | 2 | Office | Commercial |
| *New London* | 518 | 0 | 0 | Office | Commercial |
| *New London* | 519 | 0 | 1 | Office | Commercial |
| *New London* | 531 | 1 | 3 | Office | Commercial |
| *New London* | 541 | 6 | 22 | Office | Commercial |
| *New London* | 551 | 1 | 11 | Office | Commercial |
| *New London* | 561 | 4 | 8 | Office | Commercial |
| *New London* | 562 | 0 | 1 | Other | Commercial |
| *New London* | 621 | 1 | 15 | Outpatient Health Care | Commercial |
| *New London* | 622 | 0 | 11 | Inpatient Health Care | Commercial |
| *New London* | 623 | 0 | 10 | Lodging | Commercial |
| *New London* | 624 | 2 | 12 | Office | Commercial |
| *New London* | 711 | 0 | 1 | Public Assembly | Commercial |

| | | | | | |
|---|---|---|---|---|---|
| *New London* | 712 | 0 | 4 | Public Assembly | Commercial |
| *New London* | 713 | 1 | 8 | Public Assembly | Commercial |
| *New London* | 721 | 1 | 10 | Lodging | Commercial |
| *New London* | 722 | 7 | 67 | Food Service | Commercial |
| *New London* | 811 | 1 | 5 | Service | Commercial |
| *New London* | 812 | 2 | 8 | Service | Commercial |
| *New London* | 813 | 1 | 3 | Religious Worship | Commercial |
| *New London* | 814 | 1 | 1 | Private Households | Other |

**Fuel Oil Industrial:**
The following building activity and number of employees, along with energy consumption per employee were sourced from the MA DER Employment and Wages (ES-202)
https://lmi.dua.eol.mass.gov/lmi/EmploymentAndWages

| County | Primary Building Activity Category | Principal Building Activity | Average Monthly Employment | Number of Employer Establishments Within the Primary Building Activity | Energy Consumption Per Employee - Northeast (MMBTU/ employee/ year) | Total Energy Consumption - United States (Trillion BTU / year) | Distillate Fuel Oil and Diesel Fuel Energy Consumption (Trillion Btu / year) | Percent of Total Energy Consumption from Fuel Oil and Diesel Fuel (%) | Distillate Fuel Oil Energy Consumption (Gallons / Year) | Annual Fuel Oil Use (MMBtu) | Fuel Oil CO2 Emissions (MT CO2) | Fuel Oil CH4 Emissions (MT CH4) | Fuel Oil N2O Emissions (MT N2O) | Fuel Oil CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ***TOTALS*** | **94,530.0** | **415.0** | **0.5** | **1,011,782.8** | **139,626.0** | **10,326.7** | **0.4** | **0.08** | **10,360.7** |
| *Middlesex* | *Food* | Food | 412 | 7 | 359.6 | 1161 | 14 | 1.21% | 12,945.9 | 1,786.5 | 132.13 | 0.01 | 0.00 | 132.6 |
| *Middlesex* | *Beverage and Tobacco Products* | Beverage and Tobacco Products | 0 | 0 | 410.9 | 118 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Textile Mills* | Textile Mills | 0 | 0 | 681.1 | 64 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Textile Product Mills* | Textile Product Mills | 0 | 0 | 219.4 | 22 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Apparel* | Apparel | 0 | 0 | 70.1 | 4 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Leather and Allied Products* | Leather and Allied Products | 0 | 0 | 111.1 | 2 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Wood Products* | Wood Products | 0 | 0 | 921.8 | 388 | 11 | 2.84% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Paper* | Paper | 0 | 0 | 3785.7 | 2041 | 4 | 0.20% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Printing and Related Support* | Printing and Related Support | 104 | 3 | 162.8 | 60 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Petroleum and Coal Products* | Petroleum and Coal Products | 0 | 0 | 13764.8 | 4245 | 14 | 0.33% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Chemicals* | Chemicals | 0 | 0 | 1005.8 | 7141 | 6 | 0.08% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Plastics and Rubber Products* | Plastics and Rubber Products | 0 | 0 | 316.3 | 257 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Nonmetallic Mineral Products* | Nonmetallic Mineral Products | 0 | 0 | 1316.8 | 846 | 20 | 2.36% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Primary Metals* | Primary Metals | 0 | 0 | 2054.7 | 1511 | 6 | 0.40% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Fabricated Metal Products* | Fabricated Metal Products | 36 | 3 | 132.1 | 257 | 2 | 0.78% | 268.2 | 37.0 | 2.74 | 0.00 | 0.00 | 2.7 |
| *Middlesex* | *Machinery* | Machinery | 251 | 4 | 71.3 | 148 | 2 | 1.35% | 1,752.5 | 241.8 | 17.89 | 0.00 | 0.00 | 17.9 |
| *Middlesex* | *Computer and Electronic Products* | Computer and Electronic Products | 344 | 11 | 115.6 | 110 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Electrical Equip., Appliances, and Co* | Electrical Equip., Appliances, and Components | 0 | 0 | 191.2 | 85 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Transportation Equipment* | Transportation Equipment | 0 | 0 | 266.5 | 348 | 4 | 1.15% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Furniture and Related Products* | Furniture and Related Products | 0 | 0 | 71.8 | 37 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Middlesex* | *Miscellaneous* | Miscellaneous | 0 | 0 | 97.2 | 61 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Food* | Food | 1422 | 56 | 359.6 | 1161 | 14 | 1.21% | 44,682.4 | 6,166.2 | 456.05 | 0.02 | 0.00 | 457.5 |
| *Worcester* | *Beverage and Tobacco Products* | Beverage and Tobacco Products | 1589 | 31 | 410.9 | 118 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Textile Mills* | Textile Mills | 291 | 17 | 681.1 | 64 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Textile Product Mills* | Textile Product Mills | 29 | 9 | 219.4 | 22 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Apparel* | Apparel | 0 | 0 | 70.1 | 4 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Leather and Allied Products* | Leather and Allied Products | 0 | 0 | 111.1 | 2 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Wood Products* | Wood Products | 656 | 26 | 921.8 | 388 | 11 | 2.84% | 124,228.8 | 17,143.6 | 1,267.94 | 0.05 | 0.01 | 1272.1 |
| *Worcester* | *Paper* | Paper | 2148 | 30 | 3785.7 | 2041 | 4 | 0.20% | 115,483.1 | 15,936.7 | 1,178.68 | 0.05 | 0.01 | 1182.5 |
| *Worcester* | *Printing and Related Support* | Printing and Related Support | 634 | 58 | 162.8 | 60 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Petroleum and Coal Products* | Petroleum and Coal Products | 39 | 8 | 13764.8 | 4245 | 14 | 0.33% | 12,829.4 | 1,770.5 | 130.94 | 0.01 | 0.00 | 131.4 |
| *Worcester* | *Chemicals* | Chemicals | 3087 | 43 | 1005.8 | 7141 | 6 | 0.08% | 18,904.3 | 2,608.8 | 192.95 | 0.01 | 0.00 | 193.6 |
| *Worcester* | *Plastics and Rubber Products* | Plastics and Rubber Products | 4356 | 71 | 316.3 | 257 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Nonmetallic Mineral Products* | Nonmetallic Mineral Products | 2076 | 48 | 1316.8 | 846 | 20 | 2.36% | 468,303.8 | 64,625.9 | 4,779.73 | 0.19 | 0.04 | 4795.4 |
| *Worcester* | *Primary Metals* | Primary Metals | 174 | 13 | 2054.7 | 1511 | 6 | 0.40% | 10,287.4 | 1,419.7 | 105.00 | 0.00 | 0.00 | 105.3 |
| *Worcester* | *Fabricated Metal Products* | Fabricated Metal Products | 4708 | 189 | 132.1 | 257 | 2 | 0.78% | 35,071.7 | 4,839.9 | 357.96 | 0.01 | 0.00 | 359.1 |
| *Worcester* | *Machinery* | Machinery | 3646 | 82 | 71.3 | 148 | 2 | 1.35% | 25,456.3 | 3,513.0 | 259.82 | 0.01 | 0.00 | 260.7 |
| *Worcester* | *Computer and Electronic Products* | Computer and Electronic Products | 4391 | 57 | 115.6 | 110 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Electrical Equip., Appliances, and Co* | Electrical Equip., Appliances, and Components | 1232 | 31 | 191.2 | 85 | 0 | 0.00% | - | - | - | - | - | 0.0 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Worcester* | *Transportation Equipment* | Transportation Equipment | 79 | 8 | 266.5 | 348 | 4 | 1.15% | 1,753.6 | 242.0 | 17.90 | 0.00 | 0.00 | 18.0 |
| *Worcester* | *Furniture and Related Products* | Furniture and Related Products | 1316 | 39 | 71.8 | 37 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Worcester* | *Miscellaneous* | Miscellaneous | 931 | 54 | 97.2 | 61 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Food* | Food | 0 | 0 | 359.6 | 1161 | 14 | 1.21% | - | - | - | - | - | 0.0 |
| *Windham* | *Beverage and Tobacco Products* | Beverage and Tobacco Products | 52 | 7 | 410.9 | 118 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Textile Mills* | Textile Mills | 124 | 5 | 681.1 | 64 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Textile Product Mills* | Textile Product Mills | 0 | 0 | 219.4 | 22 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Apparel* | Apparel | 0 | 0 | 70.1 | 4 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Leather and Allied Products* | Leather and Allied Products | 0 | 0 | 111.1 | 2 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Wood Products* | Wood Products | 122 | 7 | 921.8 | 388 | 11 | 2.84% | 23,103.5 | 3,188.3 | 235.81 | 0.01 | 0.00 | 236.6 |
| *Windham* | *Paper* | Paper | 286 | 6 | 3785.7 | 2041 | 4 | 0.20% | 15,376.2 | 2,121.9 | 156.94 | 0.01 | 0.00 | 157.5 |
| *Windham* | *Printing and Related Support* | Printing and Related Support | 30 | 7 | 162.8 | 60 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Petroleum and Coal Products* | Petroleum and Coal Products | 26 | 3 | 13764.8 | 4245 | 14 | 0.33% | 8,552.9 | 1,180.3 | 87.30 | 0.00 | 0.00 | 87.6 |
| *Windham* | *Chemicals* | Chemicals | 263 | 12 | 1005.8 | 7141 | 6 | 0.08% | 1,610.6 | 222.3 | 16.44 | 0.00 | 0.00 | 16.5 |
| *Windham* | *Plastics and Rubber Products* | Plastics and Rubber Products | 1110 | 15 | 316.3 | 257 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Nonmetallic Mineral Products* | Nonmetallic Mineral Products | 383 | 12 | 1316.8 | 846 | 20 | 2.36% | 86,397.1 | 11,922.8 | 881.81 | 0.04 | 0.01 | 884.7 |
| *Windham* | *Primary Metals* | Primary Metals | 0 | 0 | 2054.7 | 1511 | 6 | 0.40% | - | - | - | - | - | 0.0 |
| *Windham* | *Fabricated Metal Products* | Fabricated Metal Products | 641 | 42 | 132.1 | 257 | 2 | 0.78% | 4,775.1 | 659.0 | 48.74 | 0.00 | 0.00 | 48.9 |
| *Windham* | *Machinery* | Machinery | 0 | 0 | 71.3 | 148 | 2 | 1.35% | - | - | - | - | - | 0.0 |
| *Windham* | *Computer and Electronic Products* | Computer and Electronic Products | 92 | 7 | 115.6 | 110 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Electrical Equip., Appliances, and Co* | Electrical Equip., Appliances, and Components | 682 | 9 | 191.2 | 85 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Transportation Equipment* | Transportation Equipment | 0 | 0 | 266.5 | 348 | 4 | 1.15% | - | - | - | - | - | 0.0 |
| *Windham* | *Furniture and Related Products* | Furniture and Related Products | 0 | 0 | 71.8 | 37 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Windham* | *Miscellaneous* | Miscellaneous | 132 | 8 | 97.2 | 61 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Food* | Food | 0 | 0 | 359.6 | 1161 | 14 | 1.21% | - | - | - | - | - | 0.0 |
| *Tolland* | *Beverage and Tobacco Products* | Beverage and Tobacco Products | 0 | 0 | 410.9 | 118 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Textile Mills* | Textile Mills | 0 | 0 | 681.1 | 64 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Textile Product Mills* | Textile Product Mills | 0 | 0 | 219.4 | 22 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Apparel* | Apparel | 0 | 0 | 70.1 | 4 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Leather and Allied Products* | Leather and Allied Products | 0 | 0 | 111.1 | 2 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Wood Products* | Wood Products | 0 | 0 | 921.8 | 388 | 11 | 2.84% | - | - | - | - | - | 0.0 |
| *Tolland* | *Paper* | Paper | 0 | 0 | 3785.7 | 2041 | 4 | 0.20% | - | - | - | - | - | 0.0 |
| *Tolland* | *Printing and Related Support* | Printing and Related Support | 0 | 0 | 162.8 | 60 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Petroleum and Coal Products* | Petroleum and Coal Products | 0 | 0 | 13764.8 | 4245 | 14 | 0.33% | - | - | - | - | - | 0.0 |
| *Tolland* | *Chemicals* | Chemicals | 0 | 0 | 1005.8 | 7141 | 6 | 0.08% | - | - | - | - | - | 0.0 |
| *Tolland* | *Plastics and Rubber Products* | Plastics and Rubber Products | 0 | 0 | 316.3 | 257 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Nonmetallic Mineral Products* | Nonmetallic Mineral Products | 0 | 0 | 1316.8 | 846 | 20 | 2.36% | - | - | - | - | - | 0.0 |
| *Tolland* | *Primary Metals* | Primary Metals | 0 | 0 | 2054.7 | 1511 | 6 | 0.40% | - | - | - | - | - | 0.0 |
| *Tolland* | *Fabricated Metal Products* | Fabricated Metal Products | 0 | 0 | 132.1 | 257 | 2 | 0.78% | - | - | - | - | - | 0.0 |
| *Tolland* | *Machinery* | Machinery | 0 | 0 | 71.3 | 148 | 2 | 1.35% | - | - | - | - | - | 0.0 |
| *Tolland* | *Computer and Electronic Products* | Computer and Electronic Products | 0 | 0 | 115.6 | 110 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Electrical Equip., Appliances, and Co* | Electrical Equip., Appliances, and Components | 0 | 0 | 191.2 | 85 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Transportation Equipment* | Transportation Equipment | 0 | 0 | 266.5 | 348 | 4 | 1.15% | - | - | - | - | - | 0.0 |
| *Tolland* | *Furniture and Related Products* | Furniture and Related Products | 0 | 0 | 71.8 | 37 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *Tolland* | *Miscellaneous* | Miscellaneous | 0 | 0 | 97.2 | 61 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Food* | Food | 0 | 0 | 359.6 | 1161 | 14 | 1.21% | - | - | - | - | - | 0.0 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *New London* | *Beverage and Tobacco Products* | Beverage and Tobacco Products | 0 | 0 | 410.9 | 118 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Textile Mills* | Textile Mills | 0 | 0 | 681.1 | 64 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Textile Product Mills* | Textile Product Mills | 0 | 0 | 219.4 | 22 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Apparel* | Apparel | 0 | 0 | 70.1 | 4 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Leather and Allied Products* | Leather and Allied Products | 0 | 0 | 111.1 | 2 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Wood Products* | Wood Products | 0 | 0 | 921.8 | 388 | 11 | 2.84% | - | - | - | - | - | 0.0 |
| *New London* | *Paper* | Paper | 0 | 0 | 3785.7 | 2041 | 4 | 0.20% | - | - | - | - | - | 0.0 |
| *New London* | *Printing and Related Support* | Printing and Related Support | 0 | 0 | 162.8 | 60 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Petroleum and Coal Products* | Petroleum and Coal Products | 0 | 0 | 13764.8 | 4245 | 14 | 0.33% | - | - | - | - | - | 0.0 |
| *New London* | *Chemicals* | Chemicals | 0 | 0 | 1005.8 | 7141 | 6 | 0.08% | - | - | - | - | - | 0.0 |
| *New London* | *Plastics and Rubber Products* | Plastics and Rubber Products | 0 | 0 | 316.3 | 257 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Nonmetallic Mineral Products* | Nonmetallic Mineral Products | 0 | 0 | 1316.8 | 846 | 20 | 2.36% | - | - | - | - | - | 0.0 |
| *New London* | *Primary Metals* | Primary Metals | 0 | 0 | 2054.7 | 1511 | 6 | 0.40% | - | - | - | - | - | 0.0 |
| *New London* | *Fabricated Metal Products* | Fabricated Metal Products | 0 | 0 | 132.1 | 257 | 2 | 0.78% | - | - | - | - | - | 0.0 |
| *New London* | *Machinery* | Machinery | 0 | 0 | 71.3 | 148 | 2 | 1.35% | - | - | - | - | - | 0.0 |
| *New London* | *Computer and Electronic Products* | Computer and Electronic Products | 0 | 0 | 115.6 | 110 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Electrical Equip., Appliances, and Co* | Electrical Equip., Appliances, and Components | 0 | 0 | 191.2 | 85 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Transportation Equipment* | Transportation Equipment | 0 | 0 | 266.5 | 348 | 4 | 1.15% | - | - | - | - | - | 0.0 |
| *New London* | *Furniture and Related Products* | Furniture and Related Products | 0 | 0 | 71.8 | 37 | 0 | 0.00% | - | - | - | - | - | 0.0 |
| *New London* | *Miscellaneous* | Miscellaneous | 0 | 0 | 97.2 | 61 | 0 | 0.00% | - | - | - | - | - | 0.0 |

**Off Road Emissions:**
Off road data including emissions associated from Commercial, Construction, Lawn/Garden, and Industrial were analyzed by MAPC and sourced from EPA MOVES and Federal Highway Administration Data. MAPC's dataset is avlaible on the DataCommon https://datacommon.mapc.org/browser/datasets/410 Additional information can be found in "Off Road_Data".

| County | Emissions Source | Sum of Off-Road CO2 (lbs) | Sum of Off-Road CH4 (lbs) | Off-Road CO2 (kg) | Off-Road CH4 (kg) | Off-Road CO2 (MT) | Off-Road CH4 (MT) | Percent of COUNTY Allocation Category in MSA | MSA Off-road CO2 Emissions (MT CO2) | MSA Off-road CH4 Emissions (MT CH4) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,407,211,179.20 | 332,372.00 | 638,299,733.20 | 150,761.28 | 638,299.73 | 150.76 | | 381,915.01 | 98.64255457 |
| *Worcester* | Commercial | 89,893,220 | 59,384 | 40,774,845 | 26,936 | 40,775 | 27 | 95% | 38648 | 26 |
| *Worcester* | Construction | 365,683,573 | 11,008 | 165,871,143 | 4,993 | 165,871 | 5 | 82% | 135892 | 4 |
| *Worcester* | Industrial | 221,342,145 | 37,916 | 100,399,026 | 17,198 | 100,399 | 17 | 96% | 96423 | 17 |
| *Worcester* | Lawn/Garden | 125,237,550 | 93,902 | 56,806,751 | 42,593 | 56,807 | 43 | 97% | 55007 | 41 |
| *Middlesex* | Commercial | 16,311,110 | 11,007 | 7,398,589 | 4,993 | 7,399 | 5 | 2% | 159 | 0.11 |
| *Middlesex* | Construction | 63,656,405 | 2,258 | 28,874,036 | 1,024 | 28,874 | 1 | 0.01% | 3 | 0.00 |
| *Middlesex* | Industrial | 54,476,793 | 9,380 | 24,710,238 | 4,255 | 24,710 | 4 | 4% | 914 | 0.16 |
| *Middlesex* | Lawn/Garden | 27,747,426 | 20,835 | 12,586,010 | 9,451 | 12,586 | 9 | 7% | 915 | 1 |
| *Windham* | Commercial | 6,495,568 | 4,390 | 2,946,338 | 1,991 | 2,946 | 2 | 100% | 2946 | 2 |
| *Windham* | Construction | 67,654,908 | 2,403 | 30,687,725 | 1,090 | 30,688 | 1 | 100% | 30688 | 1 |
| *Windham* | Industrial | 29,818,629 | 4,990 | 13,525,492 | 2,263 | 13,525 | 2 | 100% | 13525 | 2 |
| *Windham* | Lawn/Garden | 13,021,597 | 9,911 | 5,906,492 | 4,495 | 5,906 | 4 | 100% | 5907 | 4 |
| *Tolland* | Commercial | 5,918,184 | 4,000 | 2,684,441 | 1,814 | 2,684 | 2 | 1% | 19 | 0.01 |
| *Tolland* | Construction | 55,572,416 | 1,974 | 25,207,203 | 895 | 25,207 | 1 | 0.0% | 0 | 0.00 |
| *Tolland* | Industrial | 20,926,285 | 3,105 | 9,491,996 | 1,409 | 9,492 | 1 | 1% | 54 | 0.01 |
| *Tolland* | Lawn/Garden | 16,259,397 | 12,346 | 7,375,132 | 5,600 | 7,375 | 6 | 3% | 204 | 0.15 |
| *New London* | Commercial | 14,434,605 | 9,739 | 6,547,421 | 4,417 | 6,547 | 4 | 1% | 75 | 0.05 |
| *New London* | Construction | 124,959,375 | 4,433 | 56,680,573 | 2,011 | 56,681 | 2 | 0% | 0 | 0.00 |
| *New London* | Industrial | 63,109,231 | 10,387 | 28,625,842 | 4,712 | 28,626 | 5 | 1% | 284 | 0.05 |
| *New London* | Lawn/Garden | 24,692,762 | 19,005 | 11,200,439 | 8,621 | 11,200 | 9 | 2% | 254 | 0.20 |

| Row Labels | Sum of MSA Off-road CO2 Emissions (MT CO2) | Sum of MSA Off-road CH4 Emissions (MT CH4) | Total Off Road Emissions (MTCO2e) |
|---|---|---|---|
| Commercial | 41,847 | 28 | 42,622 |
| Construction | 166,582 | 5 | 166,727 |
| Industrial | 111,200 | 19 | 111,731 |
| Lawn/Garden | 62,286 | 47 | 63,596 |

| Summary of O | MSA Off-road CO2 Emissions (MT CO2) | MSA Off-road CH4 Emissions (MT CH4) | Total Off Road Emissions (MTCO2e) |
|---|---|---|---|
| **Off-road Emiss** | 111,200 | 19 | 111,731 |
| **Off-road Emiss** | 104,134 | 74 | 106,219 |
| **Off-road Emiss** | 166,582 | 5 | 166,727 |
| **All Off-Road Ei** | **381,915** | **99** | **384,677** |

**Off Road Emissions Methods:**
The following data tables provide data which is used to calculate emissions of off-road vehicles

## Off Road - Data Methods

### Table 1: MSA Manufacturing Calculations

| COUNTY | STATE | MSA Civilian employed population 16 years and over | MSA Manufacturing | COUNTY Civilian employed population 16 years and over | COUNTY Manufacturing | PORTION OF MSA All Sectors Jobs Excl. Manufacturing | COUNTY All Sectors Jobs Excl. Manufacturing | Percent of COUNTY Allocation Category in MSA | Civilian Total Percent | Manufacturing Percent |
|---|---|---|---|---|---|---|---|---|---|---|
| Worcester | MA | 419,185 | 49,540 | 441,570 | 51,583 | 369,645 | 389,987 | 95% | 95% | 96% |
| Middlesex | MA | 20,660 | 3,429 | 896,385 | 92,717 | 17,231 | 803,668 | 2% | 2% | 4% |
| Windham | CT | 57,849 | 7,129 | 57,849 | 7,129 | 50,720 | 50,720 | 100% | 100% | 100% |
| Tolland | CT | 524 | 46 | 77,057 | 8,161 | 478 | 68,896 | 1% | 1% | 1% |
| New London | CT | 1,449 | 196 | 128,486 | 19,754 | 1,253 | 108,732 | 1% | 1% | 1% |

Sources: US Census Table S2405 Industry by Occupation for the Civilian Employed Population 16 Years and Over
https://data.census.gov/table/ACSST1Y2023.S2405?q=s2405

Massachusetts Department of Economic Research Employment and Wages Data
https://lmi.dua.eol.mass.gov/lmi/employmentandwages

### Table 2: MSA Open Space Calculations

| County | STATE | COUNTY Open Space (sq. ft) | MSA Open Space (sq. ft) | Percent of COUNTY Allocation Category in MSA |
|---|---|---|---|---|
| Middlesex | MA | 202,673,700 | 14,739,300 | 7% |
| Worcester | MA | 240,034,500 | 232,429,500 | 97% |
| New London | CT | 108,740,700 | 2,465,100 | 2% |
| Windham | CT | 72,332,100 | 72,333,000 | 100% |
| Tolland | CT | 81,642,600 | 2,255,400 | 3% |

Source: USGS National Land Cover Database https://www.usgs.gov/centers/eros/science/national-land-cover-database

### Table 3: MSA Construction Calculations

| County | STATE | Square Feet of Construction In County | Square Feet of Construction In Cities/Towns by County (for those within the MSA) | Percent of County Allocation in MSA |
|---|---|---|---|---|
| Worcester | MA | 9,167,964 | 7,510,947 | 81.93% |
| Middlesex | MA | 21,714,541 | 2,000 | 0.01% |
| Windham | MA | 26,127 | 26,127 | 100.00% |
| Tolland | MA | 11,000 | - | 0.00% |
| New London | MA | 1,038,345 | - | 0.00% |

Source: Provided by MAPC from the commercial real estate database, CoStar

# Transportation: MSA-wide Transportation Summary

**Transportation Summary Table 1: Summary of On-road and Rail Transit Emissions by Fuel Type**

| | | | | | MA | | | | CT | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subsector | Fuel Type | Fuel Consumption (gallons or GGE) | Electricity Consumption (kWh) | Electricity T&D Losses (kWh) | CO2 Emissions (MT CO2) | CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) | CO2e Emissions (MT CO2e) | CO2 Emissions (MT CO2) | CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) | CO2e Emissions (MT CO2e) | CO2 Emissions (MT CO2) | CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) | CO2e Emissions (MT CO2e) |
| On-road | CNG | 82,494 | | | 208 | 0 | 0 | 210 | 347 | 0.12 | 0.004 | 352 | **555** | **0** | **0** | **562** |
| | Diesel | 31,728,192 | | | 273,098 | 13 | 10 | 276,031 | 54,375 | 3 | 2 | 54,959 | **327,473** | **16** | **12** | **330,990** |
| | Electricity | | 20,860,417 | | 1,966 | 0 | 0 | 1,976 | 2,276 | 0.304 | 0.038 | 2,295 | **4,242** | **0** | **0** | **4,271** |
| | Electricity (T&D Losses) | | | 864,172 | 99 | 0 | 0 | 99 | 81 | 0.011 | 0.001 | 82 | **180** | **0** | **0** | **181** |
| | Gasoline | 371,357,217 | | | 2,893,554 | 143 | 102 | 2,924,624 | 370,860 | 18.3 | 13.1 | 374,843 | **3,264,414** | **161** | **115** | **3,299,466** |
| | Propane (LPG) | 180,871 | | | 53 | 0 | 0 | 53 | 904 | 0.002 | 0.001 | 905 | **958** | **0** | **0** | **958** |
| | | | | **All On-road Transportation:** | **3,168,978** | **157** | **112** | **3,202,994** | **428,844** | **21** | **15** | **433,434** | **3,597,822** | **178** | **127** | **3,636,428** |
| | | | | | **Total** | | | | | | | | | | | |
| Rail | Diesel | 9,658,565 | | | 98,580 | 4.9 | 3.5 | 99,638 | | | | | | | | |
| Air Travel | Various Fuels | | | | 16,705 | 0.03 | 0.2 | 16,758 | | | | | | | | |
| | | | | **All Transportation:** | **3,284,263** | **162** | **115** | **3,319,391** | | | | | | | | |

**Transportation Summary Table 2: Total CO2e Emissions by Type and State**

| Type | Description | CO2 Emissions (MT CO2) | CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) | CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|
| MA Vehicles | MA Passenger Vehicles | 2,698,635 | 133 | 95 | 2,727,601 |
| | MA Commercial Vehicles | 444,833 | 22 | 16 | 449,609 |
| | MA State & Municipal Vehicles | 25,510 | 1 | 1 | 25,784 |
| | **MA Portion Total** | **3,168,978** | **157** | **112** | **3,202,994** |
| CT Vehicles | CT Passenger Vehicles | 293,633 | 15 | 10 | 296,781 |
| | CT Commercial Vehicles | 125,817 | 6 | 4 | 127,157 |
| | CT Municipal Vehicles | 9,395 | 0.5 | 0.3 | 9,495 |
| | **CT Portion Total** | **419,449** | **21.0** | **15** | **433,434** |
| | **MSA Total** | **3,588,428** | **178** | **127** | **3,636,428** |

**Percentage Rank (all 50 States):**
Rank 1 = Highest Percentage; 50 = Lowest Percentage; 0 = Data not available or not applicable; Blank = Not applicable

| Year | Daily Vehicle Miles Traveled | Annual Vehicle Miles Traveled | Total Passenger Vehicles | Number of Motorcycles | Percent of Motorcycles | Percent of Passenger Vehicles | Percent of Motorcycles of Passenger Vehicles | Percentage Change Passenger Vehicles | Percentage Change Motorcycles | Percentage Change Passenger Vehicles | Vehicle Miles Traveled per Passenger Vehicle | Vehicle Miles Traveled per Motorcycle | Vehicle Miles Traveled per Motorcycle | Vehicle Miles Traveled per Passenger Vehic

| COMMERCIAL - COMMERCIAL - COMMERCIAL -

| ches) | | | | | | | TOTAL EMISSIONS BY FUEL TYPE COMMERCIAL (includes all commercial) | | | | | | |

Other Notes:
Vehicle Type: WRECKERS = Wreckers
Fuel Type: CNG = Compressed Natural Gas, DSL = Diesel, GAS = Gasoline, LPG = Liquefied Petroleum Gas
Emission Type: CO2 = Carbon Dioxide, CH4 = Methane, N2O = Nitrous Oxide, HFC = Hydrofluorocarbons, PFC = Perfluorocarbons, SF6 = Sulfur Hexafluoride, CO2e = Carbon Dioxide Equivalent

| Year | Vehicle Type | WRECKERS - WRECKERS - WRECKERS - WRECKERS - WRECKERS - WRECKERS - WRECKERS - WRECKERS | | |

all commercial, motorcycles are considered passenger and not included in these sums)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| | | 5.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 7.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 10.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 15.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 20.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 25.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 30.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 35.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 40.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 45.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |
| | | 50.0 | 0.0 | 0.0 | 0.0 | | | | | | | | | | | | |

**CT Vehicle Supplemental Information:**
To determine the fuel usage associated with registered vehicles and vehicle miles traveled which have been provided by CT DMV and DOT, respectively, average fuel efficiencies by vehicles type were identified from various sources.

**Table 1: Fuel Economy by Vehicle Type and Methodology**

| Type | Application | Fuel Efficiency Gasoline (miles/gallon) | Fuel Efficiency Diesel (miles/gallon) | Fuel Efficiency CNG (miles/gge) | Fuel Efficiency LPG (miles/gge) | Fuel Efficiency Hybrid (miles/gallon) | Fuel Efficiency Electric (kwh/ mi) | Sources |
|---|---|---|---|---|---|---|---|---|
| Passenger | Passenger Passenger, Commercial Passenger | 25.0 | 27.2 | 23.0 | | 38.2 | 0.27 | **Gasoline & Diesel:** Calculated using a weighted average from the vehicle year from the CT DMV 2021 Registered Vehicles and the fuel efficiency by year from the U.S. Department of Transportation, Federal Highway Administration, Highway Statistics Summary Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicles. https://www.bts.gov/content/average-fuel-efficiency-us-light-duty-vehicles **CNG**: FuelEconomy.gov CNG Vehicles for subcompact cars, compact cars, large cars https://www.fueleconomy.gov/feg/pdfs/guides/FEG2001_Part2.pdf **Hybrid:** FuelEconomy.gov average fuel efficiency from most common hybrids identified in CT DMV data. **Electric**: FuelEconomy.gov average kWh/mile for most common EVs in CT from DEEP EV Fact Sheet https://portal.ct.gov/-/media/deep/air/mobile/cheapr/ev-reg-fact-sheet.pdf?rev=2e90d04a907340779f1d3593829256ab&hash=B4629B8C8B798902B0CEC9343B4BC74A |
| Light-duty truck | Passenger truck | 22.2 | 30.0 | 13.0 | | 38.3 | | **Gas, Diesel, & Hybrid:** CT DMV 2021 Registered Vehicles top most common vehicles and average year with fuel efficiencies from FuelEconomy.gov **CNG**: Average from FuelEconomy.gov for Standard pick up truck (2WD and 4WD) https://www.fueleconomy.gov/feg/pdfs/guides/FEG2001_Part2.pdf for |
| Medium/Heavy Duty Truck | Ambulance Truck and Commercial Truck | 16.6 | 20.2 | | 13.3 | 19.0 | 0.44 | **Gas, Diesel. & Hybrid**: CT DMV 2021 Registered Vehicles top most common vehicles and average year with fuel efficiencies from FuelEconomy.gov **LPG**: Average from FuelEconomy.gov for Standard Pickup Truck (2WD and 4WD) https://www.fueleconomy.gov/feg/pdfs/guides/FEG2001_Part2.pdf **Electric:** FuelEconomy.gov Standard Pickup Truck https://www.fueleconomy.gov/feg/pdfs/guides/FEG2001_Part2.pdf |
| Other buses | Busses including other buses and public transportation | 3.4 | 3.8 | | 2.4 | 3.35 | | **Gas & Diesel**: Alternative Fuels Data Center Average Fuel Economy By Major Vehicle Category https://afdc.energy.gov/data/10310 **LPG**: DOE Alternative Fuels Data Center Module 5: Propane (LPG) as a Transit Bus Fuel Dec 2003 https://afdc.energy.gov/files/pdfs/mod05_lpg.pdf **Hybrid**: NREL Long Beach Transit: Two-Year Evaluation of Gasoline-Electric Hybrid Transit Buses. Page vi. June 2008. https://www.nrel.gov/docs/fy08osti/42226.pdf |
| School Bus | School Bus | 6.5 | 7.3 | | | 8.5 | | **Gas & Diesel**: DOE Alternative Fuels Data Center Average Fuel Economy By Major Vehicle Category https://afdc.energy.gov/data/10310 **Hybrid**: Institute for Transportation Iowa State University In-Use Fuel Economy and Emission Benefits of Hybrid-Electric School Buses in Iowa. July 2010 https://www.intrans.iastate.edu/wp-content/uploads/2018/03/Hallmark_hybridbus_T2.pdf |
| Van | Ambulance Van, Commercial Van, and Passenger Van | 22.5 | 27.5 | 10.6 | | | | **Gas & Diesel**: DOE FOTW #1342 May 13, 2024: Average On-Road Fuel Economy for Medium/Heavy Trucks https://www.energy.gov/eere/vehicles/articles/fotw-1342-may-13-2024-average-road-fuel-economy-mediumheavy-trucks-ranged-40 *Original Source data for DOE FOTW: U.S. Department of Transportation, Bureau of Transportation Statistics; and, U.S. Department of Commerce, U.S. Census Bureau. (2023-12). 2021 Vehicle Inventory and Use Survey Datasets: 2021 Public Use File (PUF). https://www.census.gov/data/datasets/2021/econ/vius/2021-vius-puf.html* **CNG**: DOE Alternative Fuel Case Study March 2001. https://afdc.energy.gov/files/pdfs/supershuttle.pdf |
| Truck Tractor | Truck Tractor | 5.8 | 6.4 | | | | | **Gas & Diesel:** DOE Alternative Fuels Data Center Average Fuel Economy By Major Vehicle Category https://afdc.energy.gov/data/10310 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Motorcycle | Motorcycles | 44.0 | 49.7 | | | | 0.127 | **Gas & Diesel:** DOE Alternative Fuels Data Center Average Fuel Economy By Major Vehicle Category https://afdc.energy.gov/data/10310 **Electric:** Hernandez, Michael, et al. Emissions and Noise Mitigation Through Use of Electric Motorcycles. Page 11 https://www.caee.utexas.edu/prof/kockelman/public_html/TRB19eMCs.pdf |
| Wrecker | Wreckers | 7.8 | 7.8 | | | | | **Gas & Diesel:** DOE FOTW #1342 May 13, 2024: Average On-Road Fuel Economy for Medium/Heavy Trucks https://www.energy.gov/eere/vehicles/articles/fotw-1342-may-13-2024-average-road-fuel-economy-mediumheavy-trucks-ranged-40 *Original Source data for DOE FOTW: U.S. Department of Transportation, Bureau of Transportation Statistics; and, U.S. Department of Commerce, U.S. Census Bureau. (2023-12). 2021 Vehicle Inventory and Use Survey Datasets: 2021 Public Use File (PUF). https://www.census.gov/data/datasets/2021/econ/vius/2021-vius-puf.html* |

**Table 2: Private On-Road Electric Vehicle - Passenger Vehicle**

| Make | Model | Year | Vehicle year, make, and Model from FuelEconomy.gov (kWh/mi) | Source |
|---|---|---|---|---|
| Tesla | Model Y | 2021 | *0.26* | *US DOE Office of Energy Efficiency and Renewable Energy and EPA Office of Transportation and Air Quality. FuelEconomy.Gov https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=43406* |
| Tesla | Model 3 | 2021 | *0.24* | *US DOE Office of Energy Efficiency and Renewable Energy and EPA Office of Transportation and Air Quality. FuelEconomy.Gov https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=43401* |
| Tesla | Model S | 2021 | *0.28* | *US DOE Office of Energy Efficiency and Renewable Energy and EPA Office of Transportation and Air Quality. FuelEconomy.Gov https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=44051* |
| Chevrolet | Bolt EV | 2021 | *0.29* | *US DOE Office of Energy Efficiency and Renewable Energy and EPA Office of Transportation and Air Quality. FuelEconomy.Gov https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=43663* |
| Nissan | Leaf | 2021 | *0.30* | *US DOE Office of Energy Efficiency and Renewable Energy and EPA Office of Transportation and Air Quality. FuelEconomy.Gov https://www.fueleconomy.gov/feg/PowerSearch.do?action=noform&path=1&year1=2021&year2=2021&make=Nissan&baseModel=Leaf&srchtyp=ymm&pageno=1&rowLimit=50* |
| **Average of all vehicles** | | | **0.274** | |

Utilized the Top 5 Make and Models from the CT DEEP EV Fact Sheet (Statewide Electric Vehicle Inventory) https://portal.ct.gov/-/media/deep/air/mobile/cheapr/ev-reg-fact-sheet.pdf

**Municipal Vehicles:**
No vehicles with a municipal plate classification were included in the CT DMV dataset so therefore the number of municipal vehicles and the associated fuel usage were estimated for each CT municipality based on average data from 62 Massachusetts municipalities which range in population from about 3,000 to 25,00 people. MA data sourced from Mass Energy Insight (MEI) and the MA Vehicle Census.

| Town | County | State | 2022 Population | Estimated number of municipal vehicles | GASOLINE Usage (gallons) | DIESEL Usage (gallons) | GASOLINE CO2 Emissions (MT CO2) | GASOLINE CH4 Emissions (MT CH4) | GASOLINE N2O Emissions (MT N2O) | GASOLINE CO2e Emissions (MT CO2e) | DIESEL CO2 Emissions (MT CO2) | DIESEL CH4 Emissions (MT CH4) | DIESEL N2O Emissions (MT N2O) | DIESEL CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **1,859** | **655,777** | **356,644** | **5,754** | **0.3** | **0.2** | **5,816** | **3,640** | **0.2** | **0.1** | **3,679** |
| Ashford | Windham | CT | 4,222 | 65 | 22,959 | 12,486 | 201.46 | 0.01 | 0.01 | 203.62 | 127.44 | 0.01 | 0.00 | 128.81 |
| Brooklyn | Windham | CT | 8,502 | 131 | 46,233 | 25,144 | 405.69 | 0.02 | 0.01 | 410.05 | 256.63 | 0.01 | 0.01 | 259.38 |
| Canterbury | Windham | CT | 5,102 | 79 | 27,744 | 15,089 | 243.45 | 0.01 | 0.01 | 246.07 | 154.00 | 0.01 | 0.01 | 155.65 |
| Chaplin | Windham | CT | 2,156 | 33 | 11,724 | 6,376 | 102.88 | 0.01 | 0.00 | 103.98 | 65.08 | 0.00 | 0.00 | 65.78 |
| Eastford | Windham | CT | 1,675 | 26 | 9,108 | 4,954 | 79.93 | 0.00 | 0.00 | 80.78 | 50.56 | 0.00 | 0.00 | 51.10 |
| Hampton | Windham | CT | 1,738 | 27 | 9,451 | 5,140 | 82.93 | 0.00 | 0.00 | 83.82 | 52.46 | 0.00 | 0.00 | 53.02 |
| Killingly | Windham | CT | 17,837 | 275 | 96,995 | 52,751 | 851.13 | 0.04 | 0.03 | 860.27 | 538.40 | 0.03 | 0.02 | 544.18 |
| Plainfield | Windham | CT | 15,143 | 233 | 82,345 | 44,783 | 722.58 | 0.04 | 0.03 | 730.34 | 457.08 | 0.02 | 0.02 | 461.99 |
| Pomfret | Windham | CT | 4,307 | 66 | 23,421 | 12,737 | 205.52 | 0.01 | 0.01 | 207.72 | 130.00 | 0.01 | 0.00 | 131.40 |
| Putnam | Windham | CT | 9,302 | 143 | 50,583 | 27,509 | 443.86 | 0.02 | 0.02 | 448.63 | 280.77 | 0.01 | 0.01 | 283.79 |
| Scotland | Windham | CT | 1,577 | 24 | 8,575 | 4,664 | 75.25 | 0.00 | 0.00 | 76.06 | 47.60 | 0.00 | 0.00 | 48.11 |
| Sterling | Windham | CT | 3,623 | 56 | 19,701 | 10,715 | 172.88 | 0.01 | 0.01 | 174.74 | 109.36 | 0.01 | 0.00 | 110.53 |
| Thompson | Windham | CT | 9,315 | 144 | 50,653 | 27,548 | 444.48 | 0.02 | 0.02 | 449.26 | 281.17 | 0.01 | 0.01 | 284.19 |
| Union | Tolland | CT | 793 | 12 | 4,312 | 2,345 | 37.84 | 0.00 | 0.00 | 38.25 | 23.94 | 0.00 | 0.00 | 24.19 |
| Voluntown | New Lond | CT | 2,592 | 40 | 14,095 | 7,666 | 123.68 | 0.01 | 0.00 | 125.01 | 78.24 | 0.00 | 0.00 | 79.08 |
| Windham | Windham | CT | 24,399 | 376 | 132,678 | 72,157 | 1,164.25 | 0.06 | 0.04 | 1,176.75 | 736.47 | 0.04 | 0.03 | 744.38 |
| Woodstoc | Windham | CT | 8,312 | 128 | 45,199 | 24,582 | 396.62 | 0.02 | 0.01 | 400.88 | 250.89 | 0.01 | 0.01 | 253.59 |

# Transportation: Air Travel

The revenue passenger-miles (the number of passengers and the distance flown) for all carriers with an origin airport of Worcester, MA was sourced from the Bureau of Transportation Statistics TranStats for 2022. Carbon dioxide emissions are multiplied by a radiative forcing factor to account for the higher global warming potential from emissions released at higher altitudes.
https://www.transtats.bts.gov/Data_Elements.aspx?Data=3

| Revenue Passenger Miles | Radiative Forcing Factor | CO2 Emissions (MT CO2) | CH4 Emissions (MT CH2) | N2O Emissions (MT N2O) | Total Emissions (MTCO2e) |
|---|---|---|---|---|---|
| 47,962,000 | 2.7 | 16,705 | 0.03 | 0.20 | 16,758.08 |

**Massachusetts Passenger Vehicles:**
MA vehicles data was sourced from the 2022 Massachusetts Vehicle Census Summary Statistics Data from MAPC's Data Common.
https://datacommon.mapc.org/browser/datasets/483

| Town | GASOLINE Miles Traveled | GASOLINE Fuel Used (gal) | GASOLINE CO2 Emissions (MT CO2) | GASOLINE CH4 Emissions (MT CH4) | GASOLINE N2O Emissions (MT N2O) | GASOLINE CO2e Emissions (MT CO2e) | FLEXFUEL Miles Traveled | FLEXFUEL Fuel Used (gal) | FLEXFUEL CO2 Emissions (MT CO2) | FLEXFUEL CH4 Emissions (MT CH4) | FLEXFUEL N2O Emissions (MT N2O) | FLEXFUEL CO2e Emissions (MT CO2e) | HYBRID Miles Traveled | HYBRID Fuel Used (gal) | HYBRID CO2 Emissions (MT CO2) | HYBRID CH4 Emissions (MT CH4) | HYBRID N2O Emissions (MT N2O) | HYBRID CO2e Emissions (MT CO2e) | PLUG IN HYBRID Miles Traveled | PLUG IN HYBRID Fuel Used (gal) | PLUG IN HYBRID CO2 Emissions (MT CO2) | PLUG IN HYBRID CH4 Emissions (MT CH4) | PLUG IN HYBRID N2O Emissions (MT N2O) | PLUG IN HYBRID CO2e Emissions (MT CO2e) | ELECTRIC Miles Traveled | ELECTRIC Fuel Used (kWh) | ELECTRIC CO2 Emissions (MT CO2) | ELECTRIC CH4 Emissions (MT CH4) | ELECTRIC N2O Emissions (MT N2O) | ELECTRIC CO2e Emissions (MT CO2e) | ELECTRIC T&D (kWh) | T&D Losses (MT CO2) | T&D Losses (MT CH4) | T&D Losses (MT N2O) | T&D Losses (MT CO2e) | DIESEL Miles Traveled | DIESEL Fuel Used (gal) | DIESEL CO2 Emissions (MT CO2) | DIESEL CH4 Emissions (MT CH4) | DIESEL N2O Emissions (MT N2O) | DIESEL CO2e Emissions (MT CO2e) | Compressed Nat Gas Miles Traveled | COMPRESSED NATURAL GAS Fuel Used (GGE) | COMPRESSED NATURAL GAS Fuel Used (SCF) | Compressed Nat. Gas CO2 Emissions (MT CO2) | Compressed Nat. Gas CH4 Emissions (MT CH4) | Compressed Nat. Gas N2O Emissions (MT N2O) | Compressed Nat. Gas CO2e Emissions (MT CO2e) | Propane Miles Traveled | Propane Fuel Used (GGE) | Propane Fuel Used (gal) | Propane CO2 Emissions (MT CO2) | Propane CH4 Emissions (MT CH4) | Propane N2O Emissions (MT N2O) | Propane CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Totals*** | **6,313,785,072** | **275,277,035** | **2,415,556** | **119** | **85** | **2,441,493** | **363,904,531** | **18,781,229** | **164,005** | **8** | **6** | **166,575** | **239,785,537** | **7,034,039** | **61,724** | **3** | **2** | **62,386** | **30,762,385** | **537,328** | **4,715** | **0.23** | **0.17** | **4,766** | **41,257,538** | **11,493,171** | **1,955** | **0.2** | **0.0** | **1,965** | **576,749** | **98** | **0.008** | **0.0011** | **99** | **83,848,149** | **4,870,055** | **49,706** | **2** | **2** | **50,240** | **155,681** | **5,604** | **692,543** | **38** | **0.02** | **0.001** | **38** | **117,817** | **4,949** | **6,688** | **38** | **0.00009** | **0.00003** | **38** |
| Ashburnham | 61,749,764 | 2,770,627 | 24,312 | 1.20 | 0.86 | 24,573 | 3,566,834 | 185,015 | 1,624 | 0.08 | 0.06 | 1,640.94 | 1,899,285 | 60,235 | 529 | 0.03 | 0.02 | 534 | 321,721 | 6,165 | 54 | 0.003 | 0.002 | 55 | 153,774 | 42,837 | 8 | 0.001 | 0.00 | 8.24 | 1,812 | 0.35 | 0.00003 | 0.00000 | 0.35 | 1,296,127 | 77,746 | 794 | 0.04 | 0.03 | 802 | 1749.0 | 40.2 | 4970.1 | 0.3 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Ashby | 28,454,403 | 1,290,516 | 11,324 | 0.56 | 0.40 | 11,446 | 2,188,965 | 119,693 | 1,050 | 0.05 | 0.04 | 1,061.58 | 963,511 | 28,126 | 247 | 0.01 | 0.01 | 249 | 113,785 | 1,907 | 17 | 0.001 | 0.001 | 17 | 122,896 | 34,235 | 6 | 0.000 | 0.00 | 5.62 | 1,760 | 0.29 | 0.00002 | 0.00000 | 0.29 | 854,723 | 52,728 | 538 | 0.03 | 0.02 | 544 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Athol | 96,733,837 | 4,274,287 | 37,507 | 1.85 | 1.32 | 37,910 | 6,131,418 | 311,376 | 2,732 | 0.13 | 0.10 | 2,761.66 | 2,478,073 | 71,221 | 625 | 0.03 | 0.02 | 632 | 263,831 | 4,728 | 41 | 0.002 | 0.001 | 42 | 232,870 | 64,871 | 11 | 0.001 | 0.00 | 10.86 | 3,335 | 0.56 | 0.00004 | 0.00001 | 0.56 | 1,582,530 | 99,327 | 1,014 | 0.05 | 0.04 | 1,025 | 8255.3 | 270.3 | 33404.5 | 1.8 | 0.0 | 0.0 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Auburn | 132,220,710 | 5,702,942 | 50,043 | 2.47 | 1.77 | 50,581 | 7,852,657 | 401,976 | 3,527 | 0.17 | 0.12 | 3,565.22 | 4,455,411 | 135,536 | 1,189 | 0.06 | 0.04 | 1,202 | 458,337 | 8,582 | 75 | 0.004 | 0.003 | 76 | 584,860 | 162,925 | 27 | 0.002 | 0.00 | 27.26 | 8,375 | 1.39 | 0.00011 | 0.00002 | 1.40 | 1,631,484 | 96,785 | 988 | 0.05 | 0.03 | 998 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Ayer | 70,659,698 | 3,015,309 | 26,459 | 1.31 | 0.93 | 26,743 | 3,839,100 | 197,116 | 1,730 | 0.09 | 0.06 | 1,748.27 | 3,345,837 | 91,058 | 799 | 0.04 | 0.03 | 808 | 517,615 | 7,542 | 66 | 0.003 | 0.002 | 67 | 674,056 | 187,773 | 31 | 0.002 | 0.00 | 31.42 | 9,652 | 1.61 | 0.00013 | 0.00002 | 1.62 | 591,948 | 34,166 | 349 | 0.02 | 0.01 | 352 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Barre | 50,902,358 | 2,268,703 | 19,908 | 0.98 | 0.70 | 20,122 | 3,358,228 | 177,740 | 1,560 | 0.08 | 0.06 | 1,576.42 | 1,530,870 | 43,582 | 382 | 0.02 | 0.01 | 387 | 187,847 | 2,330 | 20 | 0.001 | 0.001 | 21 | 177,444 | 49,431 | 8 | 0.001 | 0.00 | 8.27 | 2,541 | 0.42 | 0.00003 | 0.00000 | 0.43 | 1,151,819 | 69,522 | 710 | 0.04 | 0.03 | 717 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Berlin | 28,777,760 | 1,274,934 | 11,188 | 0.55 | 0.39 | 11,308 | 1,703,108 | 88,220 | 774 | 0.04 | 0.03 | 782.44 | 1,816,564 | 53,197 | 467 | 0.02 | 0.02 | 472 | 280,596 | 4,502 | 40 | 0.002 | 0.001 | 40 | 506,498 | 141,096 | 23 | 0.002 | 0.00 | 23.61 | 7,253 | 1.21 | 0.00010 | 0.00001 | 1.21 | 623,778 | 35,907 | 366 | 0.02 | 0.01 | 370 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Blackstone | 78,275,361 | 3,505,453 | 30,760 | 1.52 | 1.09 | 31,091 | 5,692,480 | 290,917 | 2,553 | 0.13 | 0.09 | 2,580.21 | 1,953,991 | 59,162 | 519 | 0.03 | 0.02 | 525 | 179,236 | 2,904 | 25 | 0.001 | 0.001 | 26 | 228,655 | 63,697 | 11 | 0.001 | 0.00 | 10.66 | 3,274 | 0.55 | 0.00004 | 0.00001 | 0.55 | 1,376,561 | 84,579 | 863 | 0.04 | 0.03 | 873 | 3878.6 | 90.0 | 11116.4 | 0.6 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Bolton | 47,606,072 | 2,113,229 | 18,544 | 0.92 | 0.65 | 18,743 | 2,856,123 | 150,162 | 1,318 | 0.07 | 0.05 | 1,331.82 | 3,343,782 | 100,545 | 882 | 0.04 | 0.03 | 892 | 599,585 | 11,320 | 99 | 0.005 | 0.004 | 100 | 1,141,945 | 318,113 | 53 | 0.004 | 0.00 | 53.23 | 16,352 | 2.72 | 0.00022 | 0.00003 | 2.74 | 745,529 | 42,220 | 431 | 0.02 | 0.02 | 436 | 8016.1 | 421.9 | 52134.3 | 2.8 | 0.0 | 0.0 | 2.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Boylston | 42,847,269 | 1,870,908 | 16,417 | 0.81 | 0.58 | 16,594 | 2,154,212 | 111,333 | 977 | 0.05 | 0.03 | 987.43 | 2,279,889 | 71,520 | 628 | 0.03 | 0.02 | 634 | 271,341 | 5,376 | 47 | 0.002 | 0.002 | 48 | 529,317 | 147,453 | 26 | 0.002 | 0.00 | 26.50 | 6,768 | 1.21 | 0.00010 | 0.00001 | 1.22 | 731,244 | 39,975 | 408 | 0.02 | 0.01 | 412 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Brookfield | 30,075,701 | 1,326,461 | 11,640 | 0.58 | 0.41 | 11,765 | 2,353,984 | 122,605 | 1,076 | 0.05 | 0.04 | 1,087.41 | 887,447 | 26,420 | 232 | 0.01 | 0.01 | 234 | 112,910 | 2,192 | 19 | 0.001 | 0.001 | 19 | 143,085 | 39,859 | 7 | 0.001 | 0.00 | 6.67 | 2,049 | 0.34 | 0.00003 | 0.00000 | 0.34 | 489,237 | 29,540 | 302 | 0.01 | 0.01 | 305 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Charlton | 120,747,865 | 5,362,382 | 47,055 | 2.32 | 1.66 | 47,560 | 7,598,695 | 397,602 | 3,489 | 0.17 | 0.12 | 3,526.42 | 4,263,188 | 130,476 | 1,145 | 0.06 | 0.04 | 1,157 | 517,258 | 8,508 | 75 | 0.004 | 0.003 | 75 | 632,152 | 176,099 | 29 | 0.002 | 0.00 | 29.47 | 9,052 | 1.51 | 0.00012 | 0.00002 | 1.51 | 2,654,216 | 158,266 | 1,615 | 0.08 | 0.06 | 1,633 | 11139.6 | 403.3 | 49839.4 | 2.7 | 0.0 | 0.0 | 2.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Clinton | 119,432,789 | 5,109,470 | 44,836 | 2.21 | 1.58 | 45,317 | 6,935,204 | 358,343 | 3,144 | 0.16 | 0.11 | 3,178.22 | 4,468,623 | 128,334 | 1,126 | 0.06 | 0.04 | 1,138 | 419,382 | 6,128 | 54 | 0.003 | 0.002 | 54 | 425,989 | 118,668 | 20 | 0.002 | 0.00 | 19.86 | 6,100 | 1.02 | 0.00008 | 0.00001 | 1.02 | 1,101,470 | 61,696 | 630 | 0.03 | 0.02 | 636 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Douglas | 87,977,919 | 3,924,744 | 34,440 | 1.70 | 1.22 | 34,809 | 6,543,831 | 338,803 | 2,973 | 0.15 | 0.10 | 3,004.92 | 2,447,606 | 72,202 | 634 | 0.03 | 0.02 | 640 | 576,250 | 8,662 | 76 | 0.004 | 0.003 | 77 | 275,005 | 76,608 | 13 | 0.001 | 0.00 | 12.82 | 3,938 | 0.66 | 0.00005 | 0.00001 | 0.66 | 1,646,257 | 99,034 | 1,011 | 0.05 | 0.04 | 1,022 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Dudley | 96,738,447 | 4,219,252 | 37,024 | 1.83 | 1.31 | 37,421 | 6,041,399 | 311,163 | 2,730 | 0.13 | 0.10 | 2,759.77 | 2,759,888 | 82,561 | 724 | 0.04 | 0.03 | 732 | 241,907 | 6,317 | 55 | 0.003 | 0.002 | 56 | 393,220 | 109,540 | 18 | 0.001 | 0.00 | 18.33 | 5,631 | 0.94 | 0.00007 | 0.00001 | 0.94 | 1,728,455 | 100,180 | 1,022 | 0.05 | 0.04 | 1,033 | 1761.1 | 41.5 | 5125.3 | 0.3 | 0.0 | 0.0 | 0.3 | 4098.0 | 167.3 | 226.0 | 1.3 | 0.0 | 0.0 | 1.3 |
| East Brook | 19,053,517 | 851,580 | 7,473 | 0.37 | 0.26 | 7,553 | 1,364,399 | 70,539 | 619 | 0.03 | 0.02 | 625.63 | 343,107 | 11,091 | 97 | 0.00 | 0.00 | 98 | 95,419 | 1,079 | 9 | 0.000 | 0.000 | 10 | 44,315 | 12,345 | 2 | 0.000 | 0.00 | 2.07 | 635 | 0.11 | 0.00001 | 0.00000 | 0.11 | 488,182 | 27,849 | 284 | 0.01 | 0.01 | 287 | 1200.0 | 28.4 | 3509.8 | 0.2 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Fitchburg | 284,916,351 | 12,377,025 | 108,608 | 5.37 | 3.83 | 109,775 | 14,299,711 | 744,933 | 6,537 | 0.32 | 0.23 | 6,606.98 | 8,436,495 | 243,579 | 2,137 | 0.11 | 0.08 | 2,160 | 786,561 | 13,834 | 121 | 0.006 | 0.004 | 123 | 527,692 | 147,000 | 24 | 0.002 | 0.00 | 24.14 | 7,556 | 1.23 | 0.00010 | 0.00001 | 1.24 | 2,833,364 | 161,521 | 1,649 | 0.08 | 0.06 | 1,666 | 1892.6 | 43.5 | 5378.3 | 0.3 | 0.0 | 0.0 | 0.3 | 21174.3 | 882.3 | 1192.2 | 6.8 | 0.0 | 0.0 | 6.8 |
| Gardner | 152,540,378 | 6,554,440 | 57,515 | 2.84 | 2.03 | 58,133 | 9,053,904 | 461,495 | 4,050 | 0.20 | 0.14 | 4,093.10 | 4,127,543 | 119,905 | 1,052 | 0.05 | 0.04 | 1,063 | 424,276 | 7,305 | 64 | 0.003 | 0.002 | 65 | 338,319 | 94,246 | 16 | 0.001 | 0.00 | 15.77 | 4,845 | 0.81 | 0.00006 | 0.00001 | 0.81 | 1,573,961 | 88,447 | 903 | 0.04 | 0.03 | 912 | 15217.3 | 531.0 | 65617.3 | 3.6 | 0.0 | 0.0 | 3.6 | 17513.0 | 612.3 | 827.5 | 4.7 | 0.0 | 0.0 | 4.7 |
| Grafton | 148,945,884 | 6,442,997 | 56,537 | 2.79 | 2.00 | 57,144 | 8,120,616 | 419,732 | 3,683 | 0.18 | 0.13 | 3,722.70 | 6,052,905 | 182,463 | 1,601 | 0.08 | 0.06 | 1,618 | 1,065,024 | 18,911 | 166 | 0.008 | 0.006 | 168 | 2,293,175 | 638,813 | 106 | 0.008 | 0.00 | 106.90 | 32,837 | 5.47 | 0.00044 | 0.00006 | 5.50 | 1,868,143 | 102,832 | 1,050 | 0.05 | 0.04 | 1,061 | 1957.2 | 45.4 | 5609.5 | 0.3 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Groton | 91,331,165 | 4,015,273 | 35,234 | 1.74 | 1.24 | 35,612 | 5,471,583 | 288,252 | 2,529 | 0.12 | 0.09 | 2,556.58 | 5,209,747 | 153,566 | 1,348 | 0.07 | 0.05 | 1,362 | 1,097,121 | 19,197 | 168 | 0.008 | 0.006 | 170 | 1,621,507 | 451,705 | 96 | 0.008 | 0.00 | 96.45 | 21,772 | 4.62 | 0.00037 | 0.00005 | 4.65 | 1,527,928 | 85,552 | 873 | 0.04 | 0.03 | 883 | 1364.0 | 31.4 | 3876.2 | 0.2 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Hardwick | 24,086,092 | 1,097,819 | 9,633 | 0.48 | 0.34 | 9,737 | 1,966,894 | 106,695 | 936 | 0.05 | 0.03 | 946.30 | 610,685 | 17,363 | 152 | 0.01 | 0.01 | 154 | 161,535 | 3,095 | 27 | 0.001 | 0.001 | 27 | 96,368 | 26,845 | 4 | 0.000 | 0.00 | 4.49 | 1,380 | 0.23 | 0.00002 | 0.00000 | 0.23 | 470,174 | 28,850 | 294 | 0.01 | 0.01 | 298 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Harvard | 45,271,998 | 1,990,190 | 17,464 | 0.86 | 0.62 | 17,651 | 2,044,569 | 105,623 | 927 | 0.05 | 0.03 | 936.79 | 3,716,337 | 107,430 | 943 | 0.05 | 0.03 | 953 | 1,372,713 | 23,134 | 203 | 0.010 | 0.007 | 205 | 1,716,038 | 478,039 | 80 | 0.006 | 0.00 | 80.00 | 24,573 | 4.09 | 0.00033 | 0.00005 | 4.11 | 1,207,696 | 55,419 | 566 | 0.03 | 0.02 | 572 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Holden | 155,020,382 | 6,712,033 | 58,898 | 2.91 | 2.08 | 59,531 | 9,129,195 | 466,319 | 4,092 | 0.20 | 0.14 | 4,135.89 | 7,071,655 | 215,085 | 1,887 | 0.09 | 0.07 | 1,908 | 868,952 | 15,167 | 133 | 0.007 | 0.005 | 135 | 1,240,621 | 345,601 | 48 | 0.004 | 0.00 | 48.03 | 14,239 | 1.97 | 0.00016 | 0.00002 | 1.98 | 1,852,123 | 109,505 | 1,118 | 0.06 | 0.04 | 1,130 | 2084.9 | 47.9 | 5924.5 | 0.3 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Hopedale | 46,614,097 | 2,026,536 | 17,783 | 0.88 | 0.63 | 17,974 | 3,031,426 | 152,999 | 1,343 | 0.07 | 0.05 | 1,356.98 | 1,411,439 | 43,227 | 379 | 0.02 | 0.01 | 383 | 191,096 | 3,979 | 35 | 0.002 | 0.001 | 35 | 401,136 | 111,745 | 19 | 0.001 | 0.00 | 18.70 | 5,744 | 0.96 | 0.00008 | 0.00001 | 0.96 | 461,515 | 26,669 | 272 | 0.01 | 0.01 | 275 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Hubbardst | 44,921,097 | 1,998,805 | 17,540 | 0.87 | 0.62 | 17,728 | 2,992,402 | 157,632 | 1,383 | 0.07 | 0.05 | 1,398.07 | 1,181,028 | 34,548 | 303 | 0.01 | 0.01 | 306 | 280,209 | 4,481 | 39 | 0.002 | 0.001 | 40 | 216,942 | 60,434 | 10 | 0.001 | 0.00 | 10.11 | 3,107 | 0.52 | 0.00004 | 0.00001 | 0.52 | 1,528,582 | 94,020 | 960 | 0.05 | 0.03 | 970 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Lancaster | 58,440,250 | 2,567,881 | 22,533 | 1.11 | 0.80 | 22,775 | 3,730,556 | 193,612 | 1,699 | 0.08 | 0.06 | 1,717.19 | 2,714,982 | 77,723 | 682 | 0.03 | 0.02 | 689 | 372,543 | 7,621 | 67 | 0.003 | 0.002 | 68 | 546,440 | 152,223 | 25 | 0.002 | 0.00 | 25.47 | 7,825 | 1.30 | 0.00010 | 0.00001 | 1.31 | 1,207,778 | 68,017 | 694 | 0.03 | 0.02 | 702 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Leicester | 90,509,513 | 4,030,770 | 35,370 | 1.75 | 1.25 | 35,750 | 6,064,562 | 317,421 | 2,785 | 0.14 | 0.10 | 2,815.27 | 2,342,333 | 69,724 | 612 | 0.03 | 0.02 | 618 | 193,724 | 3,089 | 27 | 0.001 | 0.001 | 27 | 314,287 | 87,551 | 15 | 0.001 | 0.00 | 14.65 | 4,500 | 0.75 | 0.00006 | 0.00001 | 0.75 | 1,316,827 | 79,922 | 816 | 0.04 | 0.03 | 824 | 26619.4 | 947.0 | 117022.5 | 6.4 | 0.0 | 0.0 | 6.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Leominster | 327,877,262 | 14,102,203 | 123,747 | 6.11 | 4.37 | 125,076 | 16,983,661 | 875,703 | 7,684 | 0.38 | 0.27 | 7,766.81 | 11,514,812 | 332,681 | 2,919 | 0.14 | 0.10 | 2,951 | 1,253,689 | 20,274 | 178 | 0.009 | 0.006 | 180 | 1,174,657 | 327,226 | 54 | 0.004 | 0.00 | 54.76 | 16,821 | 2.80 | 0.00022 | 0.00003 | 2.81 | 3,302,364 | 191,760 | 1,957 | 0.10 | 0.07 | 1,978 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 20003.0 | 943.8 | 1275.4 | 7.2 | 0.0 | 0.0 | 7.2 |
| Lunenburg | 100,232,164 | 4,446,171 | 39,015 | 1.93 | 1.38 | 39,434 | 6,400,886 | 334,863 | 2,938 | 0.15 | 0.10 | 2,969.97 | 4,006,590 | 116,098 | 1,019 | 0.05 | 0.04 | 1,030 | 365,412 | 5,969 | 52 | 0.003 | 0.002 | 53 | 540,831 | 150,660 | 25 | 0.002 | 0.00 | 24.74 | 7,745 | 1.27 | 0.00010 | 0.00001 | 1.27 | 2,057,108 | 121,170 | 1,237 | 0.06 | 0.04 | 1,250 | 5266.0 | 121.1 | 14964.3 | 0.8 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Mendon | 52,315,102 | 2,359,175 | 20,702 | 1.02 | 0.73 | 20,924 | 4,225,646 | 220,012 | 1,931 | 0.10 | 0.07 | 1,951.33 | 1,839,707 | 57,652 | 506 | 0.02 | 0.02 | 511 | 381,275 | 7,277 | 64 | 0.003 | 0.002 | 65 | 513,299 | 142,990 | 24 | 0.002 | 0.00 | 23.93 | 7,350 | 1.22 | 0.00010 | 0.00001 | 1.23 | 1,118,864 | 61,924 | 632 | 0.03 | 0.02 | 639 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Millbury | 108,715,453 | 4,771,428 | 41,869 | 2.07 | 1.48 | 42,319 | 6,873,179 | 358,930 | 3,150 | 0.16 | 0.11 | 3,183.43 | 3,859,171 | 115,817 | 1,016 | 0.05 | 0.04 | 1,027 | 315,675 | 5,554 | 49 | 0.002 | 0.002 | 49 | 498,852 | 138,966 | 23 | 0.002 | 0.00 | 23.26 | 7,143 | 1.19 | 0.00009 | 0.00001 | 1.20 | 1,304,929 | 77,686 | 793 | 0.04 | 0.03 | 801 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Millville | 29,652,230 | 1,327,953 | 11,653 | 0.58 | 0.41 | 11,778 | 1,921,143 | 98,693 | 866 | 0.04 | 0.03 | 875.33 | 576,484 | 14,864 | 130 | 0.01 | 0.00 | 132 | 156,012 | 3,080 | 27 | 0.001 | 0.001 | 27 | 90,190 | 25,124 | 4 | 0.000 | 0.00 | 4.20 | 1,291 | 0.22 | 0.00002 | 0.00000 | 0.22 | 541,516 | 33,321 | 340 | 0.02 | 0.01 | 344 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| New Braintr | 9,496,563 | 435,882 | 3,825 | 0.19 | 0.14 | 3,866 | 824,069 | 42,557 | 373 | 0.02 | 0.01 | 377.44 | 200,283 | 5,924 | 52 | 0.00 | 0.00 | 53 | 28,217 | 370 | 3 | 0.000 | 0.000 | 3 | 48,167 | 13,418 | 2 | 0.000 | 0.00 | 2.25 | 690 | 0.11 | 0.00001 | 0.00000 | 0.12 | 420,350 | 26,273 | 268 | 0.01 | 0.01 | 271 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| North Broo | 41,151,511 | 1,848,038 | 16,217 | 0.80 | 0.57 | 16,391 | 3,000,277 | 156,705 | 1,375 | 0.07 | 0.05 | 1,389.85 | 1,294,888 | 38,346 | 336 | 0.02 | 0.01 | 340 | 33,732 | 537 | 5 | 0.000 | 0.000 | 5 | 129,458 | 36,063 | 6 | 0.000 | 0.00 | 6.03 | 1,854 | 0.31 | 0.00002 | 0.00000 | 0.31 | 970,796 | 53,094 | 542 | 0.03 | 0.02 | 548 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Northboro | 119,141,239 | 5,106,059 | 44,806 | 2.21 | 1.58 | 45,287 | 6,428,817 | 329,231 | 2,889 | 0.14 | 0.10 | 2,920.02 | 6,397,950 | 196,983 | 1,729 | 0.09 | 0.06 | 1,747 | 820,538 | 13,019 | 114 | 0.006 | 0.004 | 115 | 1,940,288 | 540,509 | 90 | 0.007 | 0.00 | 90.45 | 27,784 | 4.63 | 0.00037 | 0.00005 | 4.65 | 832,060 | 48,925 | 499 | 0.02 | 0.02 | 505 | 4254.9 | 284.2 | 35123.3 | 1.9 | 0.0 | 0.0 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Northbridg | 131,607,322 | 5,765,160 | 50,589 | 2.50 | 1.79 | 51,132 | 8,729,677 | 450,532 | 3,953 | 0.20 | 0.14 | 3,995.87 | 4,142,451 | 124,359 | 1,091 | 0.05 | 0.04 | 1,103 | 383,332 | 7,507 | 66 | 0.003 | 0.002 | 67 | 698,750 | 194,652 | 32 | 0.003 | 0.00 | 32.57 | 10,006 | 1.67 | 0.00013 | 0.00002 | 1.67 | 1,285,942 | 74,929 | 765 | 0.04 | 0.03 | 773 | 592.9 | 13.6 | 1684.8 | 0.1 | 0.0 | 0.0 | 0.1 | 12750.3 | 524.0 | 708.1 | 4.0 | 0.0 | 0.0 | 4.0 |
| Oakham | 17,990,947 | 807,934 | 7,090 | 0.35 | 0.25 | 7,166 | 1,539,092 | 80,363 | 705 | 0.03 | 0.02 | 712.76 | 709,725 | 20,718 | 182 | 0.01 | 0.01 | 184 | 47,388 | 896 | 8 | 0.000 | 0.000 | 8 | 31,485 | 8,771 | 1 | 0.000 | 0.00 | 1.47 | 451 | 0.08 | 0.00001 | 0.00000 | 0.08 | 451,701 | 29,716 | 303 | 0.01 | 0.01 | 307 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Oxford | 115,772,149 | 5,073,608 | 44,521 | 2.20 | 1.57 | 44,999 | 7,762,154 | 401,896 | 3,527 | 0.17 | 0.12 | 3,564.51 | 3,688,410 | 110,256 | 967 | 0.05 | 0.03 | 978 | 281,584 | 4,179 | 37 | 0.002 | 0.001 | 37 | 286,611 | 79,842 | 13 | 0.001 | 0.00 | 13.36 | 4,104 | 0.68 | 0.00005 | 0.00001 | 0.69 | 1,811,902 | 111,099 | 1,134 | 0.06 | 0.04 | 1,146 | 12925.5 | 496.0 | 61285.7 | 3.3 | 0.0 | 0.0 | 3.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Paxton | 37,809,388 | 1,685,897 | 14,794 | 0.73 | 0.52 | 14,953 | 2,783,492 | 144,412 | 1,267 | 0.06 | 0.04 | 1,280.82 | 1,331,763 | 42,137 | 370 | 0.02 | 0.01 | 374 | 101,547 | 2,443 | 21 | 0.001 | 0.001 | 22 | 354,922 | 98,871 | 13 | 0.001 | 0.00 | 13.31 | 4,568 | 0.61 | 0.00005 | 0.00001 | 0.62 | 490,313 | 29,726 | 303 | 0.01 | 0.01 | 307 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Petersham | 12,250,480 | 554,724 | 4,868 | 0.24 | 0.17 | 4,920 | 862,649 | 43,873 | 385 | 0.02 | 0.01 | 389.12 | 519,814 | 13,372 | 117 | 0.01 | 0.00 | 119 | 74,063 | 1,179 | 10 | 0.001 | 0.000 | 10 | 115,636 | 32,213 | 5 | 0.000 | 0.00 | 5.39 | 1,656 | 0.28 | 0.00002 | 0.00000 | 0.28 | 505,961 | 27,119 | 277 | 0.01 | 0.01 | 280 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Phillipston | 18,979,951 | 838,775 | 7,360 | 0.36 | 0.26 | 7,439 | 1,633,754 | 86,027 | 755 | 0.04 | 0.03 | 762.99 | 489,218 | 13,208 | 116 | 0.01 | 0.00 | 117 | 71,323 | 1,065 | 9 | 0.000 | 0.000 | 9 | 70,487 | 19,636 | 3 | 0.000 | 0.00 | 3.29 | 1,009 | 0.17 | 0.00001 | 0.00000 | 0.17 | 480,460 | 28,794 | 294 | 0.01 | 0.01 | 297 | 7227.8 | 170.2 | 21037.6 | 1.1 | 0.0 | 0.0 | 1.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Princeton | 35,347,884 | 1,564,467 | 13,728 | 0.68 | 0.48 | 13,876 | 2,092,463 | 110,964 | 974 | 0.05 | 0.03 | 984.16 | 1,858,107 | 53,446 | 469 | 0.02 | 0.02 | 474 | 276,922 | 4,721 | 41 | 0.002 | 0.001 | 42 | 204,197 | 56,884 | 15 | 0.001 | 0.00 | 15.07 | 5,233 | 1.38 | 0.00011 | 0.00002 | 1.39 | 848,537 | 46,053 | 470 | 0.02 | 0.02 | 475 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Royalston | 12,847,501 | 588,193 | 5,161 | 0.25 | 0.18 | 5,217 | 907,822 | 48,082 | 422 | 0.02 | 0.01 | 426.45 | 331,514 | 10,563 | 93 | 0.00 | 0.00 | 94 | 60,793 | 779 

**Massachusetts Commercial Vehicles:**
MA vehicles data was sourced from the 2022 Massachusetts Vehicle Census Summary Statistics Data from MAPC's Data Common.
https://datacommon.mapc.org/browser/datasets/483

| Town | GASOLINE Miles Traveled | GASOLINE Fuel Used (gal) | GASOLINE CO2 Emissions (MT CO2) | GASOLINE CH4 Emissions (MT CH4) | GASOLINE N2O Emissions (MT N2O) | GASOLINE CO2e Emissions (MT CO2e) | FLEXFUEL Miles Traveled | FLEXFUEL Fuel Used (gal) | FLEXFUEL CO2 Emissions (MT CO2) | FLEXFUEL CH4 Emissions (MT CH4) | FLEXFUEL N2O Emissions (MT N2O) | FLEXFUEL CO2e Emissions (MT CO2e) | HYBRID Miles Traveled | HYBRID Fuel Used (gal) | HYBRID CO2 Emissions (MT CO2) | HYBRID CH4 Emissions (MT CH4) | HYBRID N2O Emissions (MT N2O) | HYBRID CO2e Emissions (MT CO2e) | PLUG IN HYBRID Miles Traveled | PLUG IN HYBRID Fuel Used (gal) | PLUG IN HYBRID CO2 Emissions (MT CO2) | PLUG IN HYBRID CH4 Emissions (MT CH4) | PLUG IN HYBRID N2O Emissions (MT N2O) | PLUG IN HYBRID CO2e Emissions (MT CO2e) | ELECTRIC Miles Traveled | ELECTRIC Fuel Used (kWh) | ELECTRIC CO2 Emissions (MT CO2) | ELECTRIC CH4 Emissions (MT CH4) | ELECTRIC N2O Emissions (MT N2O) | ELECTRIC CO2e Emissions (MT CO2e) | ELECTRIC T&D (kWh) | T&D Losses (MT CO2) | T&D Losses (MT CH4) | T&D Losses (MT N2O) | T&D Losses (MT CO2e) | DIESEL Miles Traveled | DIESEL Fuel Used (gal) | DIESEL CO2 Emissions (MT CO2) | DIESEL CH4 Emissions (MT CH4) | DIESEL N2O Emissions (MT N2O) | DIESEL CO2e Emissions (MT CO2e) | Compressed Nat Gas Miles Traveled | COMPRESSED NATURALGAS Fuel Used (GGE) | COMPRESSED NATURALGAS Fuel Used (SCF) | Compressed Nat. Gas CO2 Emissions (MT CO2) | Compressed Nat. Gas CH4 Emissions (MT CH4) | Compressed Nat. Gas N2O Emissions (MT N2O) | Compressed Nat. Gas CO2e Emissions (MT CO2e) | Propane Miles Traveled | Propane Fuel Used (GGE) | Propane Fuel Used (gal) | Propane CO2 Emissions (MT CO2) | Propane CH4 Emissions (MT CH4) | Propane N2O Emissions (MT N2O) | Propane CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Totals*** | **391,802,508** | **21,535,292** | **188,972** | **9** | **7** | **191,001** | **80,386,080** | **4,300,527** | **37,737** | **2** | **1** | **38,142** | **14,524,525** | **373,308** | **3,276** | **0** | **0** | **3,311** | **278,557** | **4,254** | **37** | **0.002** | **0.001** | **38** | **161,229** | **44,914** | **7.485** | **0.001** | **0.000** | **8** | **2,317** | **0** | **0.000** | **0.0000** | **0** | **322,564,137** | **21,028,405** | **214,626** | **11** | **8** | **216,931** | **387,245** | **25,286** | **3,124,594** | **170** | **0.05** | **0.002** | **172** | **14,380** | **801** | **1,083** | **6** | **0.00001** | **0.00000** | **6** |
| Ashburn | 2,550,664 | 146,131 | 1,282 | 0.06 | 0.05 | 1,296 | 595,174 | 32,959 | 289.22 | 0.01 | 0.01 | 292.32 | 24871 | 559 | 5 | 0.00 | 0.00 | 4.96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,912,691 | 129,654 | 1,323 | 0.07 | 0.05 | 1,338 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ashby | 1,536,939 | 92,732 | 814 | 0.04 | 0.03 | 822 | 341,561 | 19,081 | 167.44 | 0.01 | 0.01 | 169.23 | 31795 | 1519 | 13 | 0.00 | 0.00 | 13.47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,076,554 | 77,669 | 793 | 0.04 | 0.03 | 801 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Athol | 2,934,868 | 166,098 | 1,458 | 0.07 | 0.05 | 1,473 | 468,795 | 26,549 | 232.97 | 0.01 | 0.01 | 235.47 | 23448 | 558 | 5 | 0.00 | 0.00 | 4.95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,259,099 | 147,383 | 1,504 | 0.07 | 0.05 | 1,520 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Auburn | 19,574,172 | 1,003,941 | 8,810 | 0.44 | 0.31 | 8,904 | 3,101,006 | 161,099 | 1,413.64 | 0.07 | 0.05 | 1,428.82 | 471649 | 14425 | 127 | 0.01 | 0.00 | 127.93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 22,407,938 | 1,440,496 | 14,702 | 0.73 | 0.52 | 14,860 | 11765 | 490 | 60574 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ayer | 6,787,539 | 358,644 | 3,147 | 0.16 | 0.11 | 3,181 | 987,630 | 52,054 | 456.78 | 0.02 | 0.02 | 461.68 | 708419 | 17374 | 152 | 0.01 | 0.01 | 154.09 | 0 | 0 | 0 | 0 | 0 | 0 | 2833 | 789 | 0 | 0 | 0 | 0 | 41 | 0 | 0 | 0 | 0 | 8,026,756 | 524,952 | 5,358 | 0.26 | 0.19 | 5,415 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Barre | 3,670,070 | 205,721 | 1,805 | 0.09 | 0.06 | 1,825 | 623,935 | 32,983 | 289.42 | 0.01 | 0.01 | 292.53 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,650,604 | 177,421 | 1,811 | 0.09 | 0.06 | 1,830 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Berlin | 1,880,480 | 109,374 | 960 | 0.05 | 0.03 | 970 | 287,721 | 16,702 | 146.56 | 0.01 | 0.01 | 148.14 | 95358 | 2935 | 26 | 0.00 | 0.00 | 26.03 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,491,012 | 100,162 | 1,022 | 0.05 | 0.04 | 1,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blackst | 4,609,741 | 250,193 | 2,195 | 0.11 | 0.08 | 2,219 | 1,612,414 | 87,244 | 765.56 | 0.04 | 0.03 | 773.78 | 13027 | 261 | 2 | 0.00 | 0.00 | 2.31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,377,796 | 219,031 | 2,236 | 0.11 | 0.08 | 2,260 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bolton | 2,220,337 | 120,517 | 1,058 | 0.05 | 0.04 | 1,069 | 430,901 | 21,871 | 191.92 | 0.01 | 0.01 | 193.98 | 4352 | 164 | 1 | 0.00 | 0.00 | 1.46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 834,294 | 56,969 | 581 | 0.03 | 0.02 | 588 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Boylston | 5,492,387 | 306,892 | 2,693 | 0.13 | 0.10 | 2,722 | 1,149,826 | 62,745 | 550.59 | 0.03 | 0.02 | 556.50 | 19056 | 718 | 6 | 0.00 | 0.00 | 6.37 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5,196,025 | 336,756 | 3,437 | 0.17 | 0.12 | 3,474 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brookfie | 1,404,401 | 80,762 | 709 | 0.04 | 0.03 | 716 | 635,274 | 33,679 | 295.53 | 0.01 | 0.01 | 298.71 | 44492 | 1157 | 10 | 0.00 | 0.00 | 10.26 | 0 | 0 | 0 | 0 | 0 | 0 | 11151 | 3106 | 1 | 0 | 0 | 1 | 160 | 0 | 0 | 0 | 0 | 1,790,403 | 100,126 | 1,022 | 0.05 | 0.04 | 1,033 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Charlton | 8,009,984 | 448,451 | 3,935 | 0.19 | 0.14 | 3,977 | 1,489,048 | 78,608 | 689.78 | 0.03 | 0.02 | 697.19 | 239025 | 6107 | 54 | 0.00 | 0.00 | 54.16 | 0 | 0 | 0 | 0 | 0 | 0 | 5481 | 1527 | 0 | 0 | 0 | 0 | 78 | 0 | 0 | 0 | 0 | 8,040,386 | 527,113 | 5,380 | 0.27 | 0.19 | 5,438 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Clinton | 5,716,992 | 328,417 | 2,882 | 0.14 | 0.10 | 2,913 | 1,131,376 | 63,286 | 555.33 | 0.03 | 0.02 | 561.29 | 112711 | 4506 | 40 | 0.00 | 0.00 | 39.97 | 8930 | 114 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,851,415 | 187,547 | 1,914 | 0.09 | 0.07 | 1,935 | 65876 | 3508 | 433538 | 24 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Douglas | 3,790,154 | 210,917 | 1,851 | 0.09 | 0.07 | 1,871 | 1,191,031 | 64,507 | 566.05 | 0.03 | 0.02 | 572.13 | 1580266 | 32154 | 282 | 0.01 | 0.01 | 285.18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,701,443 | 240,414 | 2,454 | 0.12 | 0.09 | 2,480 | 16674 | 695 | 85850 | 5 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dudley | 4,540,745 | 256,899 | 2,254 | 0.11 | 0.08 | 2,278 | 542,127 | 28,988 | 254.37 | 0.01 | 0.01 | 257.10 | 13681 | 276 | 2 | 0.00 | 0.00 | 2.45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,116,433 | 271,154 | 2,768 | 0.14 | 0.10 | 2,797 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| East Bro | 1,213,020 | 70,088 | 615 | 0.03 | 0.02 | 622 | 138,435 | 8,554 | 75.06 | 0.00 | 0.00 | 75.87 | 0 | 0 | 0 | - | - | - | 12612 | 194 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 856,803 | 56,426 | 576 | 0.03 | 0.02 | 582 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fitchbur | 17,150,645 | 930,976 | 8,169 | 0.40 | 0.29 | 8,257 | 2,845,340 | 152,109 | 1,334.76 | 0.07 | 0.05 | 1,349.09 | 1249228 | 28401 | 249 | 0.01 | 0.01 | 251.90 | 51081 | 1178 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 12,820,138 | 841,719 | 8,591 | 0.42 | 0.30 | 8,683 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gardner | 6,083,966 | 338,960 | 2,974 | 0.15 | 0.10 | 3,006 | 1,321,121 | 71,355 | 626.14 | 0.03 | 0.02 | 632.86 | 165855 | 3624 | 32 | 0.00 | 0.00 | 32.15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7,280,147 | 483,551 | 4,935 | 0.24 | 0.17 | 4,988 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grafton | 5,557,965 | 311,088 | 2,730 | 0.13 | 0.10 | 2,759 | 1,011,728 | 57,123 | 501.25 | 0.02 | 0.02 | 506.63 | 22068 | 676 | 6 | 0.00 | 0.00 | 6.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,265,909 | 271,258 | 2,769 | 0.14 | 0.10 | 2,798 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Groton | 3,332,692 | 182,686 | 1,603 | 0.08 | 0.06 | 1,620 | 847,731 | 46,782 | 410.51 | 0.02 | 0.01 | 414.92 | 96423 | 2924 | 26 | 0.00 | 0.00 | 25.93 | 1179 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,001,209 | 126,075 | 1,287 | 0.06 | 0.05 | 1,301 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hardwic | 637,887 | 38,166 | 335 | 0.02 | 0.01 | 338 | 164,847 | 9,529 | 83.62 | 0.00 | 0.00 | 84.52 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 820,365 | 54,099 | 552 | 0.03 | 0.02 | 558 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Harvard | 1,384,962 | 79,381 | 697 | 0.03 | 0.02 | 704 | 241,918 | 12,943 | 113.58 | 0.01 | 0.00 | 114.80 | 8843 | 168 | 1 | 0.00 | 0.00 | 1.49 | 0 | 0 | 0 | 0 | 0 | 0 | 25205 | 7021 | 1 | 0 | 0 | 1 | 361 | 0 | 0 | 0 | 0 | 1,142,327 | 75,934 | 775 | 0.04 | 0.03 | 783 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Holden | 6,142,921 | 339,203 | 2,977 | 0.15 | 0.11 | 3,008 | 1,288,628 | 67,613 | 593.31 | 0.03 | 0.02 | 599.68 | 87965 | 3483 | 31 | 0.00 | 0.00 | 30.89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,106,526 | 278,424 | 2,842 | 0.14 | 0.10 | 2,872 | 649 | 46 | 5718 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hopedal | 6,956,355 | 385,800 | 3,385 | 0.17 | 0.12 | 3,422 | 1,636,142 | 86,522 | 759.23 | 0.04 | 0.03 | 767.38 | 26969 | 1370 | 12 | 0.00 | 0.00 | 12.15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,826,728 | 180,722 | 1,845 | 0.09 | 0.07 | 1,864 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hubbard | 1,627,118 | 96,322 | 845 | 0.04 | 0.03 | 854 | 624,592 | 34,357 | 301.48 | 0.01 | 0.01 | 304.72 | 46871 | 1444 | 13 | 0.00 | 0.00 | 12.81 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,539,343 | 100,079 | 1,021 | 0.05 | 0.04 | 1,032 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lancast | 4,737,918 | 249,773 | 2,192 | 0.11 | 0.08 | 2,215 | 917,872 | 50,038 | 439.08 | 0.02 | 0.02 | 443.80 | 50465 | 1707 | 15 | 0.00 | 0.00 | 15.14 | 2656 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,613,979 | 156,317 | 1,595 | 0.08 | 0.06 | 1,613 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Leiceste | 4,650,981 | 268,146 | 2,353 | 0.12 | 0.08 | 2,378 | 1,553,319 | 84,831 | 744.39 | 0.04 | 0.03 | 752.38 | 834940 | 13051 | 115 | 0.01 | 0.00 | 115.76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,462,071 | 164,229 | 1,676 | 0.08 | 0.06 | 1,694 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Leomins | 21,324,083 | 1,204,700 | 10,571 | 0.52 | 0.37 | 10,685 | 4,878,318 | 257,583 | 2,260.29 | 0.11 | 0.08 | 2,284.56 | 535380 | 15843 | 139 | 0.01 | 0.00 | 140.52 | 85150 | 1588 | 14 | 0 | 0 | 14 | 8295 | 2311 | 0 | 0 | 0 | 0 | 119 | 0 | 0 | 0 | 0 | 14,570,952 | 970,152 | 9,902 | 0.49 | 0.35 | 10,008 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lunenbu | 6,733,831 | 395,577 | 3,471 | 0.17 | 0.12 | 3,508 | 1,536,466 | 87,642 | 769.06 | 0.04 | 0.03 | 777.32 | 113665 | 3882 | 34 | 0.00 | 0.00 | 34.43 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6,223,842 | 399,527 | 4,078 | 0.20 | 0.14 | 4,122 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mendon | 4,218,066 | 239,543 | 2,102 | 0.10 | 0.07 | 2,125 | 738,075 | 39,012 | 342.33 | 0.02 | 0.01 | 346.01 | 31782 | 782 | 7 | 0.00 | 0.00 | 6.93 | 9066 | 206 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,385,423 | 162,372 | 1,657 | 0.08 | 0.06 | 1,675 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 14380 | 801 | 1083 | 6 | 0 | 0 | 6 |
| Millbury | 8,824,773 | 481,504 | 4,225 | 0.21 | 0.15 | 4,271 | 1,069,674 | 56,999 | 500.17 | 0.02 | 0.02 | 505.54 | 165877 | 6234 | 55 | 0.00 | 0.00 | 55.29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8,207,810 | 501,441 | 5,118 | 0.25 | 0.18 | 5,173 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Millville | 947,242 | 52,113 | 457 | 0.02 | 0.02 | 462 | 274,515 | 15,099 | 132.49 | 0.01 | 0.00 | 133.92 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 537,998 | 37,678 | 385 | 0.02 | 0.01 | 389 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| New Bra | 385,975 | 21,572 | 189 | 0.01 | 0.01 | 191 | 138,063 | 7,716 | 67.71 | 0.00 | 0.00 | 68.44 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1,397,423 | 93,910 | 958 | 0.05 | 0.03 | 969 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| North Br | 1,784,072 | 105,984 | 930 | 0.05 | 0.03 | 940 | 345,219 | 18,819 | 165.14 | 0.01 | 0.01 | 166.91 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 875,159 | 60,176 | 614 | 0.03 | 0.02 | 621 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Northbo | 8,866,498 | 491,980 | 4,317 | 0.21 | 0.15 | 4,363 | 1,655,766 | 88,133 | 773.36 | 0.04 | 0.03 | 781.67 | 302539 | 9171 | 80 | 0.00 | 0.00 | 81.34 | 0 | 0 | 0 | 0 | 0 | 0 | 225 | 63 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 7,525,206 | 507,203 | 5,177 | 0.26 | 0.18 | 5,232 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Northbri | 7,258,289 | 395,892 | 3,474 | 0.17 | 0.12 | 3,511 | 2,284,031 | 119,984 | 1,052.86 | 0.05 | 0.04 | 1,064.16 | 277642 | 11438 | 100 | 0.00 | 0.00 | 101.45 | 7984 | 157 | 1 | 0 | 0 | 1 | 22279 | 6206 | 1 | 0 | 0 | 1 | 319 | 0 | 0 | 0 | 0 | 7,668,249 | 484,639 | 4,946 | 0.24 | 0.17 | 5,000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oakham | 1,014,396 | 58,744 | 515 | 0.03 | 0.02 | 521 | 196,207 | 12,206 | 107.10 | 0.01 | 0.00 | 108.25 | 19456 | 741 | 7 | 0.00 | 0.00 | 6.57 | 3571 | 128 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 941,952 | 65,380 | 667 | 0.03 | 0.02 | 674 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oxford | 8,906,040 | 496,096 | 4,353 | 0.22 | 0.15 | 4,400 | 1,539,361 | 83,843 | 735.73 | 0.04 | 0.03 | 743.63 | 85784 | 2248 | 20 | 0.00 | 0.00 | 19.94 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6,934,565 | 464,401 | 4,740 | 0.23 | 0.17 | 4,791 | 233082 | 16620 | 2053675 | 112 | 0 | 0 | 113 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Paxton | 1,709,945 | 97,388 | 855 | 0.04 | 0.03 | 864 | 133,166 | 7,562 | 66.36 | 0.00 | 0.00 | 67.07 | 58367 | 2020 | 18 | 0.00 | 0.00 | 17.92 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 932,839 | 64,050 | 654 | 0.03 | 0.02 | 661 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Petersh | 536,473 | 29,084 | 255 | 0.01 | 0.01 | 258 | 118,211 | 5,917 | 51.92 | 0.00 | 0.00 | 52.48 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 522,029 | 37,390 | 382 | 0.02 | 0.01 | 386 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phillipst | 649,460 | 38,021 | 334 | 0.02 | 0.01 | 337 | 107,949 | 6,533 | 57.33 | 0.00 | 0.00 | 57.94 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 643,016 | 41,920 | 428 | 0.02 | 0.02 | 432 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Princeto | 1,226,751 | 69,946 | 614 | 0.03 | 0.02 | 620 | 198,361 | 10,489 | 92.04 | 0.00 | 0.00 | 93.03 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 949,375 | 65,751 | 671 | 0.03 | 0.02 | 678 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Royalsto | 326,312 | 19,976 | 175 | 0.01 | 0.01 | 177 | 52,649 | 2,718 | 23.85 | 0.00 | 0.00 | 24.11 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 265,760 | 17,775 | 181 | 0.01 | 0.01 | 183 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rutland | 4,598,922 | 260,898 | 2,289 | 0.11 | 0.08 | 2,314 | 954,964 | 50,181 | 440.34 | 0.02 | 0.02 | 445.07 | 8807 | 175 | 2 | 0.00 | 0.00 | 1.55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,570,870 | 213,214 | 2,176 | 0.11 | 0.08 | 2,200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shirley | 4,351,667 | 231,032 | 2,027 | 0.10 | 0.07 | 2,049 | 1,143,730 | 61,119 | 536.32 | 0.03 | 0.02 | 542.07 | 7666 | 217 | 2 | 0.00 | 0.00 | 1.93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,546,731 | 234,040 | 2,389 | 0.12 | 0.08 | 2,414 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shrewsb | 23,640,220 | 1,274,673 | 11,185 | 0.55 | 0.39 | 11,305 | 5,463,045 | 278,251 | 2,441.65 | 0.12 | 0.09 | 2,467.87 | 463545 | 15545 | 136 | 0.01 | 0.00 | 137.87 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 19,205,643 | 1,248,244 | 12,740 | 0.63 | 0.45 | 12,877 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Southbri | 4,460,588 | 245,140 | 2,151 | 0.11 | 0.08 | 2,174 | 1,106,262 | 57,698 | 506.30 | 0.03 | 0.02 | 511.74 | 185288 | 4399 | 39 | 0.00 | 0.00 | 39.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3,186,577 | 208,037 | 2,123 | 0.10 | 0.07 | 2,146 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spencer | 5,401,972 | 309,100 | 2,712 | 0.13 | 0.10 | 2,741 | 726,754 | 42,087 | 369.31 | 0.02 | 0.01 | 373.28 | 30034 | 1301 | 11 | 0.00 | 0.00 | 11.54 | 0 | 0 | 0 | 0 | 0 | 0 | 3237 | 902 | 0 | 0 | 0 | 0 | 46 | 0 | 0 | 0 | 0 | 3,323,262 | 231,498 | 2,363 | 0.12 | 0.08 | 2,388 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sterling | 7,288,379 | 411,672 | 3,612 | 0.18 | 0.13 | 3,651 | 1,904,326 | 103,555 | 908.70 | 0.04 | 0.03 | 918.45 | 12787 | 644 | 6 | 0.00 | 0.00 | 5.71 | 23476 | 0 | 0 | 0 | 0 | 0 | 7180 | 2000 | 0 | 0 | 0 | 0 | 111 | 0 | 0 | 0 | 0 | 8,437,784 | 566,017 | 5,777 | 0.29 | 0.20 | 5,839 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sturbrid | 4,119,880 | 219,080 | 1,922 | 0.09 | 0.07 | 1,943 | 870,339 | 46,384 | 407.02 | 0.02 | 0.01 | 411.39 | 111029 | 3044 | 27 | 0.00 | 0.00 | 26.99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,564,116 | 172,002 | 1,756 | 0.09 | 0.06 | 1,774 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sutton | 6,210,583 | 339,222 | 2,977 | 0.15 | 0.11 | 3,009 | 1,506,296 | 84,417 | 740.76 | 0.04 | 0.03 | 748.71 | 151604 | 3817 | 33 | 0.00 | 0.00 | 33.86 | 0 | 0 | 0 | 0 | 0 | 0 | 4158 | 1158 | 0 | 0 | 0 | 0 | 60 | 0 | 0 | 0 | 0 | 8,407,526 | 541,115 | 5,523 | 0.27 | 0.19 | 5,582 | 25576 | 1824 | 225346 | 12 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Templet | 2,362,706 | 139,231 | 1,222 | 0.06 | 0.04 | 1,235 | 644,363 | 34,855 | 305.85 | 0.02 | 0.01 | 309.13 | 0 | 0 | 0 | - | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4,313,740 | 271,579 | 2,772 | 0.14 | 0.10 | 2,802 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Townse | 3,341,585 | 188,337 | 1,653

**Massachusetts State and Municipal Vehicles:**
MA vehicles data was sourced from the 2022 Massachusetts Vehicle Census Summary Statistics Data from MAPC's Data Common.
https://datacommon.mapc.org/browser/datasets/483

| Town | GASOLINE Miles Traveled | GASOLINE Fuel Used (gal) | GASOLINE CO2 Emissions (MT CO2) | GASOLINE CH4 Emissions (MT CH4) | GASOLINE N2O Emissions (MT N2O) | GASOLINE CO2e Emissions (MT CO2e) | FLEXFUEL Miles Traveled | FLEXFUEL Fuel Used (gal) | FLEXFUEL CO2 Emissions (MT CO2) | FLEXFUEL CH4 Emissions (MT CH4) | FLEXFUEL N2O Emissions (MT N2O) | FLEXFUEL CO2e Emissions (MT CO2e) | HYBRID Miles Traveled | HYBRID Fuel Used (gal) | HYBRID CO2 Emissions (MT CO2) | HYBRID CH4 Emissions (MT CH4) | HYBRID N2O Emissions (MT N2O) | HYBRID CO2e Emissions (MT CO2e) | PLUG IN HYBRID Miles Traveled | PLUG IN HYBRID Fuel Used (gal) | PLUG IN HYBRID CO2 Emissions (MT CO2) | PLUG IN HYBRID CH4 Emissions (MT CH4) | PLUG IN HYBRID N2O Emissions (MT N2O) | PLUG IN HYBRID CO2e Emissions (MT CO2e) | ELECTRIC Miles Traveled | ELECTRIC Fuel Used (kWh) | ELECTRIC CO2 Emissions (MT CO2) | ELECTRIC CH4 Emissions (MT CH4) | ELECTRIC N2O Emissions (MT N2O) | ELECTRIC CO2e Emissions (MT CO2e) | ELECTRIC T&D (kWh) | T&D Losses (MT CO2) | T&D Losses (MT CH4) | T&D Losses (MT N2O) | T&D Losses (MT CO2e) | DIESEL Miles Traveled | DIESEL Fuel Used (gal) | DIESEL CO2 Emissions (MT CO2) | DIESEL CH4 Emissions (MT CH4) | DIESEL N2O Emissions (MT N2O) | DIESEL CO2e Emissions (MT CO2e) | Compressed Nat Gas Miles Traveled | COMPRESSED NATURAL GAS Fuel Used (GGE) | COMPRESSED NATURAL GAS Fuel Used (SCF) | Compressed Nat. Gas CO2 Emissions (MT CO2) | Compressed Nat. Gas CH4 Emissions (MT CH4) | Compressed Nat. Gas N2O Emissions (MT N2O) | Compressed Nat. Gas CO2e Emissions (MT CO2e) | Propane Miles Traveled | Propane Fuel Used (GGE) | Propane Fuel Used (gal) | Propane CO2 Emissions (MT CO2) | Propane CH4 Emissions (MT CH4) | Propane N2O Emissions (MT N2O) | Propane CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Totals*** | **31,017,028** | **1,693,132** | **14,857** | **1** | **1** | **15,017** | **2,917,007** | **162,270** | **1,424** | **0** | **0** | **1,439** | **1,187,778** | **51,106** | **448** | **0** | **0** | **453** | **8,969** | **174** | **2** | **0** | **0** | **2** | **71,065** | **19,797** | **3** | **0.000** | **0** | **3** | **1,003** | **0** | **0.000** | **0.0000** | **0** | **13,184,216** | **858,895** | **8,766** | **0** | **0** | **8,860** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **20,880** | **1,202** | **1,624** | **9** | **0.00002** | **0.00001** | **9** |
| Ashburnham | 193,569 | 10,771 | 94.51 | 0.00 | 0.00 | 95.53 | 11373 | 688 | 6 | 0 | 0 | 6 | 11081 | 494 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 8009 | 2231 | 0 | 0 | 0 | 0 | 94 | 0 | 0 | 0 | 0 | 156758 | 10408 | 106 | 0 | 0 | 107 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ashby | 112,654 | 6,647 | 58.33 | 0.00 | 0.00 | 58.95 | 22968 | 1211 | 11 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 73979 | 5108 | 52 | 0 | 0 | 53 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Athol | 343,303 | 18,491 | 162.26 | 0.01 | 0.01 | 164.01 | 28108 | 1662 | 15 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 191182 | 12663 | 129 | 0 | 0 | 131 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Auburn | 536,928 | 27,861 | 244.48 | 0.01 | 0.01 | 247.11 | 19688 | 1062 | 9 | 0 | 0 | 9 | 21285 | 956 | 8 | 0 | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 224585 | 14412 | 147 | 0 | 0 | 149 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ayer | 362,591 | 20,587 | 180.65 | 0.01 | 0.01 | 182.59 | 43501 | 2436 | 21 | 0 | 0 | 22 | 23882 | 1053 | 9 | 0 | 0 | 9 | 669 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 289913 | 19514 | 199 | 0 | 0 | 201 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Barre | 291,564 | 15,686 | 137.65 | 0.01 | 0.00 | 139.13 | 142473 | 7390 | 65 | 0 | 0 | 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 256312 | 16048 | 164 | 0 | 0 | 166 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Berlin | 66,420 | 3,712 | 32.57 | 0.00 | 0.00 | 32.92 | 4855 | 291 | 3 | 0 | 0 | 3 | 62758 | 2709 | 24 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 74165 | 4577 | 47 | 0 | 0 | 47 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Blackstone | 506,429 | 29,458 | 258.49 | 0.01 | 0.01 | 261.27 | 41968 | 2206 | 19 | 0 | 0 | 20 | 8230 | 370 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 143166 | 9701 | 99 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bolton | 279,670 | 15,467 | 135.72 | 0.01 | 0.00 | 137.18 | 19832 | 1187 | 10 | 0 | 0 | 11 | 38164 | 1650 | 14 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60021 | 3890 | 40 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Boylston | 558,709 | 28,528 | 250.33 | 0.01 | 0.01 | 253.02 | 5372 | 321 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 128548 | 8325 | 85 | 0 | 0 | 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brookfield | 83,140 | 4,204 | 36.89 | 0.00 | 0.00 | 37.28 | 7335 | 386 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 84768 | 5738 | 59 | 0 | 0 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Charlton | 547,463 | 29,678 | 260.43 | 0.01 | 0.01 | 263.22 | 34814 | 1889 | 17 | 0 | 0 | 17 | 26742 | 1201 | 11 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 125586 | 9040 | 92 | 0 | 0 | 93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Clinton | 848,306 | 49,254 | 432.21 | 0.02 | 0.02 | 436.85 | 44283 | 2458 | 22 | 0 | 0 | 22 | 16737 | 737 | 6 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 283793 | 18119 | 185 | 0 | 0 | 187 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Douglas | 259,115 | 14,193 | 124.54 | 0.01 | 0.00 | 125.88 | 15036 | 837 | 7 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 104369 | 6359 | 65 | 0 | 0 | 66 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Dudley | 286,634 | 15,466 | 135.72 | 0.01 | 0.00 | 137.17 | 4464 | 187 | 2 | 0 | 0 | 2 | 2196 | 98 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 113010 | 7384 | 75 | 0 | 0 | 76 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| East Brookfiel | 127,799 | 7,042 | 61.79 | 0.00 | 0.00 | 62.45 | 3994 | 262 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 87025 | 5781 | 59 | 0 | 0 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fitchburg | 3,569,492 | 183,752 | 1,612.43 | 0.08 | 0.06 | 1,629.74 | 242174 | 13228 | 116 | 0 | 0 | 117 | 9391 | 430 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 287 | 80 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 705278 | 39643 | 405 | 0 | 0 | 409 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gardner | 745,317 | 41,314 | 362.53 | 0.02 | 0.01 | 366.42 | 96155 | 5771 | 51 | 0 | 0 | 51 | 15905 | 348 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 2392 | 666 | 0 | 0 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 418864 | 27973 | 286 | 0 | 0 | 289 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grafton | 676,316 | 37,299 | 327.30 | 0.02 | 0.01 | 330.81 | 16624 | 927 | 8 | 0 | 0 | 8 | 43273 | 1906 | 17 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 194493 | 12928 | 132 | 0 | 0 | 133 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Groton | 615,601 | 36,706 | 322.10 | 0.02 | 0.01 | 325.56 | 114453 | 6552 | 57 | 0 | 0 | 58 | 89209 | 3886 | 34 | 0 | 0 | 34 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 327272 | 21545 | 220 | 0 | 0 | 222 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hardwick | 206,532 | 11,652 | 102.25 | 0.01 | 0.00 | 103.35 | 1423 | 75 | 1 | 0 | 0 | 1 | 225 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 312 | 87 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 97609 | 6464 | 66 | 0 | 0 | 67 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Harvard | 114,690 | 5,940 | 52.12 | 0.00 | 0.00 | 52.68 | 0 | 0 | 0 | 0 | 0 | 0 | 17285 | 753 | 7 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 111164 | 7212 | 74 | 0 | 0 | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Holden | 554,099 | 29,465 | 258.55 | 0.01 | 0.01 | 261.33 | 6714 | 406 | 4 | 0 | 0 | 4 | 9750 | 377 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 296516 | 21180 | 216 | 0 | 0 | 218 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hopedale | 75,337 | 3,913 | 34.34 | 0.00 | 0.00 | 34.71 | 18574 | 1096 | 10 | 0 | 0 | 10 | 8165 | 367 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 80064 | 5199 | 53 | 0 | 0 | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hubbardston | 88,400 | 4,615 | 40.50 | 0.00 | 0.00 | 40.93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 57103 | 3909 | 40 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lancaster | 338,204 | 20,386 | 178.89 | 0.01 | 0.01 | 180.81 | 44342 | 2507 | 22 | 0 | 0 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2196 | 612 | 0 | 0 | 0 | 0 | 31 | 0 | 0 | 0 | 0 | 74203 | 5541 | 57 | 0 | 0 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Leicester | 341,153 | 18,576 | 163.01 | 0.01 | 0.01 | 164.76 | 33356 | 2123 | 19 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 174083 | 11616 | 119 | 0 | 0 | 120 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Leominster | 947,345 | 52,197 | 458.03 | 0.02 | 0.02 | 462.95 | 216265 | 11668 | 102 | 0 | 0 | 103 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 552698 | 35424 | 362 | 0 | 0 | 365 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lunenburg | 341,281 | 19,662 | 172.53 | 0.01 | 0.01 | 174.38 | 14504 | 816 | 7 | 0 | 0 | 7 | 151481 | 6658 | 58 | 0 | 0 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 127516 | 8637 | 88 | 0 | 0 | 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mendon | 226,079 | 12,152 | 106.63 | 0.01 | 0.00 | 107.78 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 438 | 122 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 56753 | 4051 | 41 | 0 | 0 | 42 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Millbury | 331,308 | 19,142 | 167.97 | 0.01 | 0.01 | 169.78 | 9390 | 513 | 5 | 0 | 0 | 5 | 44516 | 1961 | 17 | 0 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 5619 | 1565 | 0 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 0 | 108804 | 7176 | 73 | 0 | 0 | 74 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Millville | 83,460 | 4,317 | 37.88 | 0.00 | 0.00 | 38.29 | 21646 | 1089 | 10 | 0 | 0 | 10 | 15965 | 525 | 5 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 34206 | 2215 | 23 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| New Braintree | 47,483 | 2,715 | 23.82 | 0.00 | 0.00 | 24.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 82214 | 6091 | 62 | 0 | 0 | 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| North Brookfie | 188,194 | 10,876 | 95.43 | 0.00 | 0.00 | 96.46 | 1855 | 98 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 123534 | 8975 | 92 | 0 | 0 | 93 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Northborough | 472,835 | 26,523 | 232.74 | 0.01 | 0.01 | 235.24 | 10894 | 696 | 6 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 244962 | 16440 | 168 | 0 | 0 | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Northbridge | 242,854 | 12,796 | 112.29 | 0.01 | 0.00 | 113.49 | 13794 | 811 | 7 | 0 | 0 | 7 | 71724 | 3096 | 27 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 123625 | 8358 | 85 | 0 | 0 | 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oakham | 71,837 | 3,735 | 32.78 | 0.00 | 0.00 | 33.13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 71893 | 4498 | 46 | 0 | 0 | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Oxford | 364,456 | 19,970 | 175.24 | 0.01 | 0.01 | 177.12 | 4583 | 255 | 2 | 0 | 0 | 2 | 87116 | 3760 | 33 | 0 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 210144 | 14360 | 147 | 0 | 0 | 148 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Paxton | 161,348 | 8,520 | 74.77 | 0.00 | 0.00 | 75.57 | 31462 | 1742 | 15 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 112123 | 6953 | 71 | 0 | 0 | 72 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Petersham | 109,204 | 6,492 | 56.97 | 0.00 | 0.00 | 57.58 | 7888 | 417 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 47110 | 3234 | 33 | 0 | 0 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Phillipston | 97,258 | 5,972 | 52.40 | 0.00 | 0.00 | 52.96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 161665 | 10817 | 110 | 0 | 0 | 112 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Princeton | 197,179 | 10,902 | 95.67 | 0.00 | 0.00 | 96.69 | 1475 | 95 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 196597 | 13478 | 138 | 0 | 0 | 139 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Royalston | 89,489 | 5,276 | 46.30 | 0.00 | 0.00 | 46.80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 37435 | 2581 | 26 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rutland | 245,033 | 14,104 | 123.76 | 0.01 | 0.00 | 125.09 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 142149 | 9651 | 99 | 0 | 0 | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shirley | 217,679 | 12,268 | 107.65 | 0.01 | 0.00 | 108.81 | 22540 | 1243 | 11 | 0 | 0 | 11 | 2794 | 123 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 80349 | 5430 | 55 | 0 | 0 | 56 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shrewsbury | 929,329 | 52,184 | 457.91 | 0.02 | 0.02 | 462.83 | 233651 | 13510 | 119 | 0 | 0 | 120 | 29201 | 1279 | 11 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 4444 | 1238 | 0 | 0 | 0 | 0 | 57 | 0 | 0 | 0 | 0 | 244324 | 15427 | 157 | 0 | 0 | 159 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Southbridge | 469,109 | 24,696 | 216.71 | 0.01 | 0.01 | 219.03 | 4198 | 266 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 820 | 228 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 | 117251 | 7930 | 81 | 0 | 0 | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spencer | 309,181 | 16,850 | 147.86 | 0.01 | 0.01 | 149.45 | 43471 | 2551 | 22 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1909 | 532 | 0 | 0 | 0 | 0 | 27 | 0 | 0 | 0 | 0 | 132417 | 8867 | 91 | 0 | 0 | 91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sterling | 295,231 | 16,279 | 142.85 | 0.01 | 0.01 | 144.39 | 26781 | 1571 | 14 | 0 | 0 | 14 | 46365 | 2025 | 18 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 10471 | 2917 | 0 | 0 | 0 | 0 | 162 | 0 | 0 | 0 | 0 | 128349 | 8720 | 89 | 0 | 0 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sturbridge | 437,866 | 23,608 | 207.16 | 0.01 | 0.01 | 209.39 | 96906 | 5410 | 47 | 0 | 0 | 48 | 13999 | 617 | 5 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 8000 | 2229 | 0 | 0 | 0 | 0 | 115 | 0 | 0 | 0 | 0 | 119910 | 8077 | 82 | 0 | 0 | 83 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sutton | 560,078 | 28,686 | 251.72 | 0.01 | 0.01 | 254.42 | 17501 | 962 | 8 | 0 | 0 | 9 | 13360 | 499 | 4 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 3304 | 921 | 0 | 0 | 0 | 0 | 47 | 0 | 0 | 0 | 0 | 145275 | 12077 | 123 | 0 | 0 | 125 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Templeton | 496,523 | 27,551 | 241.76 | 0.01 | 0.01 | 244.35 | 52080 | 2926 | 26 | 0 | 0 | 26 | 761 | 34 | 0 | 0 | 0 | 0 | 6985 | 146 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 172904 | 10314 | 105 | 0 | 0 | 106 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Townsend | 274,160 | 15,634 | 137.19 | 0.01 | 0.00 | 138.67 | 18151 | 924 | 8 | 0 | 0 | 8 | 6157 | 224 | 2 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 136285 | 9277 | 95 | 0 | 0 | 96 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Upton | 251,370 | 14,491 | 127.16 | 0.01 | 0.00 | 128.52 | 62286 | 3635 | 32 | 0 | 0 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 121052 | 8312 | 85 | 0 | 0 | 86 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Uxbridge | 357,905 | 18,107 | 158.89 | 0.01 | 0.01 | 160.59 | 16670 | 1034 | 9 | 0 | 0 | 9 | 21556 | 968 | 8 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 7965 | 2219 | 0 | 0 | 0 | 0 | 114 | 0 | 0 | 0 | 0 | 134129 | 8824 | 90 | 0 | 0 | 91 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Warren | 231,192 | 13,182 | 115.67 | 0.01 | 0.00 | 116.91 | 13721 | 738 | 6 | 0 | 0 | 7 | 44826 | 1975 | 17 | 0 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90373 | 6009 | 61 | 0 | 0 | 62 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Webster | 279,664 | 14,778 | 129.68 | 0.01 | 0.00 | 131.07 | 4733 | 275 | 2 | 0 | 0 | 2 | 39556 | 1743 | 15 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 180831 | 11988 | 122 | 0 | 0 | 124 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| West Boylst

**Rail:**
Commuter Rail data for Worcester County is sourced by the MAPC DataCommon. The MBTA Frequency Weighted Trip Miles, including both municipal and system wide, were used to calculate the percent of Commuter Rail that travels in the MSA to calculate the fuel usage that can be attributed to the region.
https://datacommon.mapc.org/browser/datasets/408
https://datacommon.mapc.org/browser/datasets/409

Freight Rail data was sourced from the State Inventory Tool for both MA and CT and scaled based on the miles of active rail in each respective portion of the MSA. The miles of rail was determined through a GIS analysis using the "MassGIS Data: Trains" data from the Bureau of Geographic Information and the "Connecticut Railroads" layer available from CT DEEP

https://www.mass.gov/lists/massdep-emissions-inventories
https://portal.ct.gov/deep/climate-change/ct-greenhouse-gas-inventory-reports
https://www.mass.gov/info-details/massgis-data-trains
https://ct-deep-gis-open-data-website-ctdeep.hub.arcgis.com/datasets/CTDEEP::connecticut-railroads/about

| Rail Type | Line Annual Diesel Consumption (gallons/year)* | Portion of Total MBTA Energy Use Attributable to MSA | MSA Annual Diesel Consumption (gallons/year) | MSA Annual Diesel Emissions (MT CO2) | MSA Annual Diesel Emissions (MT CH4) | MSA Annual Diesel Emissions (MT N2O) | MSA Annual Diesel Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|
| | | | 606,860 | 6,194 | 0.3 | 0.2 | 6,260.4 |
| *Commuter Rail* | 13,761,972 | 4.4% | 606,860 | 6,194 | 0.31 | 0.22 | 6,260 |

| Rail Type | MA Statewide Active Train Rail (Miles) | MSA (MA) Statewide Active Train Rail (Miles) | Percent of State | MSA Annual Diesel Consumption (gallons/year) | MSA Annual CO2 Emissions (MT CO2) | MSA Annual CH4 Emissions (MT CH4) | MSA Annual N2O Emissions (MT N2O) | Total Emissions (MTCO2e) |
|---|---|---|---|---|---|---|---|---|
| | | | | 9,051,705 | 92,386 | 4.6 | 3.3 | 93,378.1 |
| *Freight Rail - MA* | 2,254 | 388.00 | 17% | 8,688,735 | 88,681 | 4.38 | 3.13 | 89,634 |
| *Freight Rail - CT* | 831.51 | 57.70 | 7% | 362,970 | 3,705 | 0.18 | 0.13 | 3,744 |

**Waste Summary Emissions:**
This following summary sheet highlights the four sectors of waste in the MSA. This includes: Solid Waste Disposal, Biological Treatment of Waste, Incineration and Open Burning, Wastewater Treatment and Discharge. Calculations and methods can be found in the following pages under "Waste".

# Summary: Community-wide Waste Emissions

**Table 1: Summary of Waste Activity Data & Emissions by Subsector**

| Subsector | Est. Total Waste to Landfill (short tons) | Est. Mass of Waste Incinerated (short tons) | Est. Mass of Organics Sent to Compositing Facility (short tons) | Est. Mass of Organics Sent to Anaerobic Digester (short tons) | CO2 Emissions (MT CO2) | CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) | CO2e Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|
| Solid Waste Disposal | 103,547 | | | | | 1,129 | | 31,610 |
| Biological Treatment of Waste | | | 3,202 | 32,100 | | 41 | 3 | 1,939 |
| Incineration and Open Burning | | 619,166 | | | 10,562 | 0.1 | 19 | 15,729 |
| Wastewater Treatment and Discharge | | | | | | 4,465 | 82 | 146,719 |
| | | | | **All Waste:** | **10,562** | **5,634** | **104.4** | **195,998** |

**Table 2: Summary of Waste Activity Data & Emissions by Subsector & by SCOPE**

| Subsector | Carbon Dioxide Equivalent Emissions (MT CO2e) | SCOPE 1 CO2 Emissions (MT CO2) | SCOPE 1 CH4 Emissions (MT CH4) | SCOPE 1 N2O Emissions (MT N2O) | SCOPE 1 Carbon Dioxide Equivalent Emissions (MT CO2e) | SCOPE 3 CO2 Emissions (MT CO2) | SCOPE 3 CH4 Emissions (MT CH4) | SCOPE 3 N2O Emissions (MT N2O) | SCOPE 3 Carbon Dioxide Equivalent Emissions (MT CO2e) |
|---|---|---|---|---|---|---|---|---|---|
| Solid Waste Disposal | 31,610 | | 485 | | 13,570 | | 644 | | 18,040 |
| Biological Treatment of Waste | 1,939 | | 41 | 3 | 1,939 | | | | |
| Incineration and Open Burning | 15,729 | 5,444 | 0.01 | 2 | 5,866 | 5,117 | 0.03 | 8 | 7,348 |
| Wastewater Treatment and Discharge | 146,719 | | 4,465 | 82 | 146,719 | | | | |
| **All Waste:** | **195,998** | **5,444** | **4,990** | **87** | **168,095** | **5,117** | **644** | **8** | **25,388** |

# Waste: Community-wide Solid Waste Disposal

Methane emissions associated with landfilled waste were calculated using GPC equations 8.1, 8.3 and 8.4. Equation 8.3 estimates methane emissions resulting from solid waste sent to landfills. The following tables were sourced from the Greenhouse Gas Protocol Standards. https://ghgprotocol.org/sites/default/files/ghgp/standards/GHGP_GPC_0.pdf

**Table 1. Methane Commitment Estimate for Solid Waste Sent to Landfill (GPC Equation 8.3)**

| Description of Variable | Mass Solid Waste Sent to Landfill (MT) | Methane Generation Potential | Fraction of Methane Recovered at Landfill | Oxidation Factor | CH4 Emissions (MT CH4) |
|---|---|---|---|---|---|
| GPC Equation 8.4 Variable Corresponding Letter | MSWt | Lo | frec | OX | |
| Data | 124,723 | 0.07 | 0.956693 | 0.100 | 1,128.2 |

in accordance with Equation 8.3:
1) The Fraction of Methane Recovered in Landfill was assumed to be 0 because it cannot be determined at this time which landfills each city/town sends waste to.
2) An Oxidation Factor (OX) of 0.1 was selected because the landfills that most cities/towns send waste to in Massachusetts are managed.

**Equation 8.3 Methane commitment estimate for solid waste sent to landfill**

$$CH_4 \text{ emissions} = MSW_t \times L_o \times (1-f_{rec}) \times (1-OX)$$

| Description | | | Value |
|---|---|---|---|
| $CH_4$ emissions | = | Total $CH_4$ emissions in metric tonnes | Computed |
| $MSW_t$ | = | Mass of solid waste sent to landfill in inventory year, measured in metric tonnes | User input |
| $L_o$ | = | Methane generation potential | Equation 8.4 Methane generation potential |
| $f_{rec}$ | = | Fraction of methane recovered at the landfill (flared or energy recovery) | User input |
| OX | = | Oxidation factor | 0.1 for well-managed landfills; 0 for unmanaged landfills |

*Source:* Adapted from *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*

**Table 2. Methane Generation Potential (GPC Equation 8.4) and Degradable Organic Carbon (Equation 8.1)**

| Description of Variable | Methane Correction Factor | Degradable Organic Carbon (tonnes Ctonnes waste) | Fraction of Degradable Organic Carbon Degraded | Fraction of Methane in Landfill Gas | Stoichiometric Ratio Between Methane and Carbon | Methane Generation Potential |
|---|---|---|---|---|---|---|
| GPC Equation 8.4 Variable Corresponding Letter | MCF | DOC | DOCf | F | 16/12 | Lo |
| Data | 1.00 | 0.18 | 0.6 | 0.500 | 1.3 | 0.1 |

in accordance with Equation 8.4:
1) A value of 1.00 was input for Methane Correction Factor (MCF) since landfills waste is sent to are actively managed.
2) A default value of 0.6 was input for Fraction of Degradable Organic Carbon Degraded (DOCf).
3) A default value 0.5 was input for Fraction of Methane in Landfill Gas (F).
4) The default fraction of 16/12 was input for Stoichiometric Ratio Between Methane and Carbon.

**Equation 8.4 Methane generation potential, $L_o$**

$$L_o = MCF \times DOC \times DOC_f \times F \times 16/12$$

| Description | | | Value |
|---|---|---|---|
| $L_o$ | = | Methane generation potential | Computed |
| MCF | = | Methane correction factor based on type of landfill site for the year of disposition (managed, unmanaged, etc. fraction) | Managed = 1.0<br>Unmanaged (≥5 m deep) = 0.8<br>Unmanaged (<5 m deep) = 0.4<br>Uncategorized = 0.8 |
| DOC | = | Degradable organic carbon in year of disposition, fraction of carbon mass basis | Equation 8.1 |
| $DOC_f$ | = | Fraction of DOC that is ultimately degraded (reflects the fact that some organic carbon does not degrade) | Assumed equal to 0.6 |
| F | = | Fraction of methane in landfill gas | Default range 0.4-0.6 (usually taken to be 0.5) |
| 16/12 | = | Stoichiometric ratio between methane and carbon | |

*Source:* IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)

**Equation 8.1 Degradable organic carbon (DOC)[2]**

$$DOC = (0.15 \times A) + (0.2 \times B) + (0.4 \times C) + (0.43 \times D) + (0.24 \times E) + (0.15 \times F)$$

| | | |
|---|---|---|
| A | = | Fraction of solid waste that is food |
| B | = | Fraction of solid waste that is garden waste and other plant debris |
| C | = | Fraction of solid waste that is paper |
| D | = | Fraction of solid waste that is wood |
| E | = | Fraction of solid waste that is textiles |
| F | = | Fraction of solid waste that is industrial waste |

**Table 3. Waste Characterization Allocation by GPC Equation 8.1 Categories**

| Equation 8.1 Waste Category | Equation 8.1 Corresponding Variable | State Data: Percent of Total Disposed Waste in Category | Equation 8.1 Default Carbon Content Value (tonnes Ctonnes waste) |
|---|---|---|---|
| Food | A | 21.6% | 0.15 |
| Garden Waste and Plant Debris | B | 8.0% | 0.20 |
| Paper | D | 21.8% | 0.40 |
| Wood | D | 6.4% | 0.43 |
| Textiles | E | 5.2% | 0.24 |
| Industrial Waste | F | 0.0% | 0.15 |

This table assumes default State-level composition of waste unless local data is entered on the "Input" tab of this workbook. See Table 7 below for a detailed explanation of how each waste type was allocated to the appropriate GPC waste category.

**Table 4. Overall Waste Composition By Detailed Material Category Mapped to GPC Waste Categories**

| Waste Category/Sub-category | Weighted Average | GPC Waste Category |
|---|---|---|
| **Paper** | | |
| Uncoated Corrugated Cardboard/Kraft Paper | 5.8% | Paper |
| Washed Newsprint | 0.5% | Paper |
| High Grade Office Paper | 0.5% | Paper |
| Magazines/Catalogs | 0.4% | Paper |
| Newsprint | 0.3% | Paper |
| Other Recyclable Paper | 3.9% | Paper |
| Compostable Paper | 7.2% | Paper |
| Remainder/Composite Paper | 3.2% | Paper |
| **Plastic** | | |
| PET Beverage Containers (non-MA deposit containers) | 0.8% | Other |
| PET Containers other than Beverage Containers | 0.5% | Other |
| Plastic MA Deposit Beverage Containers | 0.1% | Other |
| HDPE Bottles, colored and natural | 0.6% | Other |
| Plastic Tubs and lids (HDPE, PP, etc.) | 0.4% | Other |
| #5 PP Bottles & Containers | 0.9% | Other |
| Plastic Containers #3-#7 (which originally contained non-hazardous material) | 0.9% | Other |
| Other Plastic Bottles & Containers | 0.3% | Other |
| Expanded Polystyrene Food Grade | 0.4% | Other |
| Expanded Polystyrene Non-food Grade | 0.2% | Other |
| Bulk Rigid Plastic Items | 1.8% | Other |
| Film (non-bag clean commercial and industrial packaging film) | 1.0% | Other |
| Grocery and other Merchandise Bags | 0.3% | Other |
| Other Film means plastic film | 5.7% | Other |
| Remainder/Composite Plastic | 2.5% | Other |
| **Metal** | | |
| Aluminum Beverage Containers (non-MA deposit containers) | 0.1% | Other |
| Aluminum MA Deposit Beverage Containers | 0.3% | Other |
| Tin/Steel Containers | 0.8% | Other |
| Other Aluminum | 0.4% | Other |
| Other Ferrous and non-ferrous | 1.6% | Other |
| White Goods | 0.1% | Other |
| Remainder/Composite Metal | 1.5% | Other |
| **Glass** | | |
| Glass Beverage Containers (non-MA deposit containers) | 0.8% | Other |
| Other Glass Packaging Containers (non-MA deposit containers) | 0.5% | Other |
| Glass MA Deposit Beverage Containers | 0.4% | Other |
| Remainder/Composite Glass | 0.8% | Other |
| **Organic Materials** | | |
| Food Waste | 21.6% | Food |
| Branches and Stumps | 0.4% | Garden Waste and Plant Debris |
| Prunings, Trimmings, Leaves and Grass | 1.3% | Garden Waste and Plant Debris |
| Manures | 0.2% | Garden Waste and Plant Debris |
| Remainder/Composite Organic | 6.0% | Garden Waste and Plant Debris |
| **Construction and Demolition (on the MSW stream)** | | |
| Asphalt Pavement, Brick, and Concrete | 0.1% | Other |
| Aggregates, Stone, Rock | 0.6% | Other |
| Wood – Treated | 3.4% | Wood |
| Wood – Untreated | 3.0% | Wood |
| Asphalt Roofing | 0.3% | Other |
| Drywall/Gypsum Board | 0.9% | Other |
| Carpet and Carpet Padding | 1.8% | Other |
| Remainder/Composite Construction and Demolition | 2.1% | Other |
| **Household Hazardous Waste** | | |
| Ballasts, CFLs, and Other Fluorescents | 0.0% | Other |
| Batteries – Lead Acid | 0.0% | Other |
| Batteries – Other | 0.1% | Other |
| Paint | 0.1% | Other |
| Bio-Hazardous | 3.6% | Other |
| Vehicle and Equipment Fluids | 0.0% | Other |
| Empty Motor, Cleaning, and Plastic Containers | 0.1% | Other |
| Other Hazardous Waste | 0.1% | Other |
| **Electronics** | | |
| Computer-related Electronics | 0.1% | Other |
| Other "brown goods" | 0.2% | Other |
| Televisions and Computer Monitors | 0.0% | Other |
| **Other Materials** | | |
| Tires and other rubber | 0.4% | Other |
| Textiles | 5.2% | Textiles |
| Bulky Materials | 2.2% | Other |
| Mattresses | 0.1% | Other |
| Restaurant Fats, Oils and Grease | 0.0% | Food |
| Other Miscellaneous | 2.3% | Other |
| **Total** | 100% | |

The above data is from the Massachusetts's Department of Environmental Protection (DEP) "Summary of Waste Combustor Class II Recycling Program Waste Characterization Studies (includes 2010, 2013, 2015, 2018, and 2022 Data)". Data from the "2022 Detailed Fall & Winter" tab of the workbook was used. For data that was entered as "N/A" in 2022, the 2019 Spring/Summer value was used. This data provides a weighted average composition by material category based on the amount of waste that each incineration facility burned in calendar year 2022.

https://www.mass.gov/guides/solid-waste-master-plan#waste-characterization-&-capacity-studies-

**Table 5. Fraction of Methane Recovered at Landfills Which Receive Waste From the MSA**

| Landfill | Estimated Gas Collection System Efficiency, fREC | EPA FLIGHT Link |
|---|---|---|
| CROSPEE SANITARY LANDFILL | 0.9500 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1007958&em=undefined |
| CARVER-MARION-WAREHAM LANDFILL | 0.9500 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1007714&em=undefined |
| FITCHBURG WESTMINSTER LANDFILL RECYCLING CENTER | 0.8727 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1007753&em=undefined |
| GRANBY SANITARY LANDFILL | 0.9500 | https://ghgdata.epa.gov/ghgp/service/facility/Detail/2022?id=1007658&ds=E&em |
| HALIFAX LANDFILL | 0.9500 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1007950&em=undefined |
| HAVERHILL LANDFILL | 0.9000 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1008213&em=undefined |
| MARTONE LANDFILL & GAS GENERATING FACILITY | 0.9500 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1008987&em=undefined |
| MIDDLEBOROUGH LANDFILL | 0.8570 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1010391&em=undefined |
| NORTHAMPTON LANDFILL | 0.9500 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1009958&em=undefined |
| PLAINVILLE LANDFILL | 0.9500 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1009268&em=undefined |
| SOUTHBRIDGE RECYCLING & DISPOSAL PARK | 0.9500 | https://ghgdata.epa.gov/ghgp/service/facility/Detail/2022?id=1009254&ds=E&em |
| TAUNTON SANITARY LANDFILL | 0.9500 | https://ghgdata.epa.gov/ghgp/service/html/2022?id=1009353&em=undefined |
| **Average** | **0.86** | |

# Waste: Community-wide Incineration and Open Burning

Methodology: Carbon dioxide, methane, and nitrous oxide emissions associated with incineration of solid waste were calculated using GPC equations 8.6, 8.7, and 8.8. Equation 8.6 estimates non-biogenic carbon dioxide emissions from the incineration of waste, Equation 8.7 estimates methane emissions from the incineration of waste, and Equation 8.8 estimates nitrous oxide emissions from the incineration of waste. State default values are available for the amount of waste that is incinerated versus sent to landfill. These default values can be replaced with community-specific values on the "Inputs" worksheet if community-specific data is available. In general, the mass of incinerated waste in total and for each fraction of matter type i (paper, textiles, food, etc.) are used to determine the emissions. The quantities for CO2, CH4 and NO2 are summed, and then multiplied by the mass to calculate the total emissions from incinerated waste.

In Massachusetts, the incinerated waste is used to generate electricity. Emissions generated as a result of incineration occurring outside of a city's boundary are considered Scope 3 emissions. According to the GPC, waste used to generate energy is considered a stationary energy source. Stationary energy sources outside of the city's boundary are not included in the inventory. If a waste incineration power plant is located inside the city's boundary, it is accounted for the "Stationary Energy - E. Indus." worksheet.

**Table 1. Summary of Emissions From Waste Incineration**

| CO2 Emissions (MT CO2) | CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) | Total Emissions (MTCO2e) |
|---|---|---|---|
| 10,562 | 0.1 | 19.5 | 15,729 |

**Table 2. Non-biogenic CO2 Emissions From Waste Incineration (GPC Equation 8.6)**

| Description of Variable | Category of Type of Waste Incinerated | Mass of Waste Incinerated (short tons) | Fraction of Waste Consisting of Type i Matter | Dry Matter Content in Type i Matter | Fraction of Carbon in the Dry Matter of Type i Matter | Fraction of Fossil Carbon in the Total Carbon Component of Type i Matter | Oxidation Factor | Wfi x dmi x Cfi x FCFi x Ofi |
|---|---|---|---|---|---|---|---|---|
| GPC Equation 8.6 Variable Corresponding Letter | i | m | WFi | dm(i) | CF(i) | FCF(i) | OF(i) | |
| Data | **All Incinerated Waste** | **684,935** | | | | | | |
| | Food Waste | | 0.216273 | 0.40 | 0.38 | 0.0 | 100% | 0.00% |
| | Garden Waste and Plant Debris | | 0.079804 | 0.40 | 0.49 | 0.0 | 100% | 0.00% |
| | Paper | | 0.218376 | 0.90 | 0.46 | 0.0 | 100% | 0.09% |
| | Wood | | 0.063530 | 0.85 | 0.50 | 0.0 | 100% | 0.00% |
| | Textiles | | 0.051584 | 0.80 | 0.50 | 0.2 | 100% | 0.33% |
| | Industrial Waste | | 0.000000 | 0.90 | 0.03 | 0.0 | 100% | 0.00% |
| | | | | | | | **All CO2 Incinerated Waste Emissions:** | **10,561.7** |

| | |
|---|---|
| In accordance with GPC Equation 8.6:<br>1) Default values for Dry Matter Content (dm) and Fraction of Carbon in the Dry Matter (CF) were pulled from 2006 IPCC Guidelines, Vol. 5, Ch. 2, Table 2.4.<br>2) Default values for Fraction of Fossil Carbon in the Total Carbon Component (FCF) were pulled from 2006 IPCC Guidelines, Vol. 5, Ch. 2, Table 2.5. | 2006 IPCC Guidelines, Vol. 5, Ch. 2 |
| 3) Default Values for Oxidation Factor (OF) were pulled from GPC Table 8.4. | See GPC Table 8.4 |

**Equation 8.6** **Non-biogenic $CO_2$ emissions from the incineration of waste**

$$CO_2 \text{ Emissions} = m \times \sum_i (WF_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times (44/12)$$

| Description | | | Value |
|---|---|---|---|
| $CO_2$ emissions | = | Total $CO_2$ emissions from incineration of solid waste in tonnes | Computed |
| m | = | Mass of waste incinerated, in tonnes | User input |
| $WF_i$ | = | Fraction of waste consisting of type i matter | User input[54] |
| $dm_i$ | = | Dry matter content in the type i matter | User input (default values provided in Table 8.4 below) |
| $CF_i$ | = | Fraction of carbon in the dry matter of type i matter | |
| $FCF_i$ | = | Fraction of fossil carbon in the total carbon component of type i matter | |
| $OF_i$ | = | Oxidation fraction or factor | |
| i | = | Matter type of the Solid Waste incinerated such as paper/cardboard, textile, food waste, etc. | |

*Note:* $\sum_i WF_i = 1$

*Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories*

**Table 8.4** **Default data for $CO_2$ emission factors for incineration and open burning**

| Parameters | Management practice | MSW | Industrial Waste (%) | Clinical Waste (%) | Sewage Sludge (%)[Note 4] | Fossil liquid waste (%)[Note 5] |
|---|---|---|---|---|---|---|
| Dry matter content in % of wet weight | | (see Note 1) | NA | NA | NA | NA |
| Total carbon content in % of dry weight | | (see Note 1) | 50 | 60 | 40 – 50 | 80 |
| Fossil carbon fraction in % of total carbon content | | (see Note 2) | 90 | 40 | 0 | 100 |
| Oxidation factor in % of carbon input | Incineration | 100 | 100 | 100 | 100 | 100 |
| | Open-burning (see Note 3) | 58 | NO | NO | NO | NO |

*Note 1:* Use default data from Default data available in *2006 IPCC Guidelines*, Vol. 5, Ch. 2, Table 2.4 in Section 2.3 Waste composition and equation 5.8 (for dry matter), Equation 5.9 (for carbon content) and Equation 5.10 (for fossil carbon fraction) in *2006 IPCC Guidelines*, Vol. 5, Ch. 5
*Note 2:* Default data by industry type is given in *2006 IPCC Guidelines*, Vol. 5, Ch. 2 Table 2.5 in Section 2.3 Waste composition. For estimation of emissions, use equations mentioned in Note 1.
*Note 3:* When waste is open-burned, refuse weight is reduced by approximately 49 to 67 percent (US-EPA, 1997, p.79). A default value of 58 percent is suggested.
*Note 4:* See Section 2.3.2 Sludge in Chapter 2.
*Note 5:* Fossil liquid waste is here defined as industrial and municipal residues, based on mineral oil, natural gas or other fossil fuels. It includes waste formerly used as solvents and lubricants. It does not include wastewater, unless it is incinerated (e.g., because of a high solvent content) The total carbon content of fossil liquid waste is provided in percent of wet weight and not in percent of dry weight (GIO, 2005).
References: *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 5, chapter 5: Incineration and Open Burning of Waste

**Table 3. CH4 Emissions From Waste Incineration (GPC Equation 8.7)**

| Description of Variable | Category of Type of Waste Incinerated | Mass of Waste Incinerated (short tons) | Fraction of Waste Consisting of Type i Matter | Amount of Solid Waste of Type i Incinerated (short tons) | Aggregate CH4 Emission Factor (g CH4/ton of waste type i) | CH4 Emissions (MT) |
|---|---|---|---|---|---|---|
| GPC Equation 8.7 Variable Corresponding Letter | i | m | WFi | IW(i) | EF(i) | |
| Data | **All Incinerated Waste** | **619,166** | | | | |
| | Food Waste | | 21.6% | 133,909 | 0.2 | 0.027 |
| | Garden Waste and Plant Debris | | 8.0% | 49,412 | 0.2 | 0.010 |
| | Paper | | 21.8% | 135,211 | 0.2 | 0.027 |
| | Wood | | 6.4% | 39,335 | 0.2 | 0.008 |
| | Textiles | | 5.2% | 31,939 | 0.2 | 0.006 |
| | Industrial Waste | | 0.0% | 0 | 0.2 | 0.000 |
| | | | | | **All CH4 Incinerated Waste Emissions:** | **0.078** |
| In accordance with GPC equation 8.7 Aggregate CH4 Emission Factor for "Continuous Incineration: Stoker" from GPC Table 8.5 was used. | | | | | See GPC Table 8.5 | Massachusetts Waste Combustion Overview |

**Equation 8.7** $CH_4$ **emissions from the incineration of waste**

$$CH_4 \text{ Emissions} = \sum(IW_i \times EF_i) \times 10^{-6}$$

| Description | | | Value |
|---|---|---|---|
| $CH_4$ Emissions | = | $CH_4$ emissions in inventory year, tonnes | Computed |
| $IW_i$ | = | Amount of solid waste of type i incinerated or open-burned, tonnes | User Input |
| $EF_i$ | = | Aggregate $CH_4$ emission factor, g $CH_4$/ton of waste type i | User Input (default values provided in Table 8.5 below) |
| $10^{-6}$ | = | Converting factor from g$CH_4$ to t $CH_4$ | |
| i | = | Category or type of waste incinerated/open-burned, specified as follows: MSW municipal solid waste, ISW: industrial solid waste, HW: hazardous waste, CW: clinical waste, SS: sewage sludge, others (that must be specified) | User input |

**Table 8.5** $CH_4$ **emission factors for incineration of MSW**

| Type of premises | Temporary | Permanent |
|---|---|---|
| **Continuous incineration** | stoker | 0.2 |
| | fluidised bed Note1 | ~0 |
| **Semi-continuous incineration** | stoker | 6 |
| | fluidised bed | 188 |
| **Batch type incineration** | stoker | 60 |
| | fluidised bed | 237 |

*Note:* In the study cited for this emission factor, the measured $CH_4$ concentration in the exhaust air was lower than the concentration in ambient air.
*Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 5, chapter 5: Incineration and Open Burning of Waste

**Table 4. N2O Emissions From Waste Incineration (GPC Equation 8.8)**

| Description of Variable | Category of Type of Waste Incinerated | Mass of Waste Incinerated (short tons) | Fraction of Waste Consisting of Type i Matter | Amount of Solid Waste of Type i Incinerated (short tons) | Aggregate N2O Emission Factor (g N2O/ton of waste type i) | N2O Emissions (MT) |
|---|---|---|---|---|---|---|
| **GPC Equation 8.8 Variable Corresponding Letter** | **i** | **m** | **WFi** | **IW(i)** | **EF(i)** | |
| **Data** | **All Incinerated Waste** | **619,166** | | | | |
| | Food Waste | | 21.6% | 133,909 | 50 | 6.70 |
| | Garden Waste and Plant Debris | | 8.0% | 49,412 | 50 | 2.47 |
| | Paper | | 21.8% | 135,211 | 50 | 6.76 |
| | Wood | | 6.4% | 39,335 | 50 | 1.97 |
| | Textiles | | 5.2% | 31,939 | 50 | 1.60 |
| | Industrial Waste | | 0.0% | 0 | 50 | 0.00 |
| | | | | | **All N2O Incinerated Waste Emissions:** | **19.5** |
| In accordance with GPC Equation 8.8 Aggregate N2O Emission Factor (EF) for "continuous and semi-continuous incinerators" from GPC Table 8.6 was used. | | | | | See GPC Table 8.6 | |

**Equation 8.8** $N_2O$ **emissions from the incineration of waste**

$$N_2O \text{ Emissions} = \sum(IW_i \times EF_i) \times 10^{-6}$$

| Description | | | Value |
|---|---|---|---|
| $N_2O$ Emissions | = | $N_2O$ emissions in inventory year, in tonnes | Computed |
| $IW_i$ | = | Amount of solid waste of type i incinerated or open-burned, in tonnes | User Input |
| $EF_i$ | = | Aggregate $N_2O$ emission factor, g $CH_4$/ton of waste type i | User Input (default values provided in Table 8.6 below) |
| i | = | Category or type of waste incinerated/open-burned, specified as follows: MSW: municipal solid waste, ISW: industrial solid waste, HW: hazardous | User input |

**Table 8.6** **Default** $N_2O$ **emission factors for different types of waste and management practices**

| Type of waste | Technology / Management practice | Emission factor (g $N_2O$ / t waste) | weight basis |
|---|---|---|---|
| **MSW** | continuous and semi-continuous incinerators | 50 | wet weight |
| **MSW** | batch-type incinerators | 60 | wet weight |
| **MSW** | open burning | 150 | dry weight |
| **Industrial waste** | all types of incineration | 100 | wet weight |
| **Sludge (except sewage sludge)** | all types of incineration | 450 | wet weight |

waste, CW: clinical waste, SS: sewage sludge, others (that must be specified)

*Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 5, chapter 5: Incineration and Open Burning of Waste

| | | | |
|---|---|---|---|
| **Sewage sludge** | incineration | 990 | dry weight |
| | | 900 | wet weight |

*Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 5, chapter 5: Incineration and Open Burning of Waste

# Waste: Biological Treatment of Solid Waste

Compost and anaerobic digestion data for food waste was provided by MassDEP. The methodology to calculate emissions associated with the disposal of organics via composting and anaerobic digestion follows the Global Protocol for Community Scale GHG Inventories. https://ghgprotocol.org/sites/default/files/standards/GPC_Full_MASTER_RW_v7.pdf

**Table 1. MA Total Mass of Compost by Facility and Town**

| Facility | Town | Type | Mass (short tons) |
|---|---|---|---|
| JoBarb Farm | Bolton | Compost | 5 |
| Smith Farm | Charlton | Compost | 312 |
| Black Earth Compost, Groton | Groton | Compost | 2,188 |
| Davidian Brothers Farm | Northborough | Compost | 200 |
| Catlin Farmstead | Winchendon | Compost | 497 |
| | | **Total Compost MA MSA Portion (short tons)** | **3,202** |
| Vanguard Renewables (Jordan Farr | Rutland | Anaerobic Digestion | 14,661 |
| Vanguard Renewables (Spencer) | Spencer | Anaerobic Digestion | 17,439 |
| | | **Total Anaerobic Digestion MA MSA Portion (short tons)** | **32,100** |

*No AD occurring in CT portion according to CT DEEP*

**Table 2. CT Total Mass of Compost by Town**

| Town | Type | Mass (short tons) |
|---|---|---|
| Ashford | Compost | 6 |
| Brooklyn | Compost | 19 |
| Canterbury | Compost | - |
| Chaplin | Compost | 1 |
| Eastford | Compost | - |
| Hampton | Compost | - |
| Killingly | Compost | 426 |
| Plainfield | Compost | 2,530 |
| Pomfret | Compost | - |
| Putnam | Compost | - |
| Scotland | Compost | 903 |
| Sterling | Compost | - |
| Thompson | Compost | - |
| Union | Compost | 15 |
| Voluntown | Compost | 65 |
| Windham | Compost | 3,995 |
| Woodstock | Compost | - |
| **Total Compost CT MSA Portion (short tons)** | | **7,961** |

**Table 3. Direct Emissions From Biologically Treated Solid Waste (GPC Equation 8.5)**

| Biological Treatment Type | Mass of Organic Waste Treated (kg/year) | CH4 Emissions Factor (g CH4 / kg waste) | N2O Emissions Factor (g N2O / kg waste) | CH4 Emissions Excluding Methane Capture (MT CH4) | Percent of CH4 Recovered (%) | CH4 Emissions Including Methane Capture (MT CH4) | N2O Emissions (MT N2O) | Total Emissions (MTCO2e) |
|---|---|---|---|---|---|---|---|---|
| **Compositing Facility** | 10,126,716 | 4 | 0.3 | 40.5 | 0% | 41 | 3.04 | 1,939 |
| **Anaerobic Digestion Facility** | 29,120,639 | 1 | 0.0 | 29.1 | 100% | 0.00 | 0.00 | 0 |
| | | | | | **Total Biologically Treated Solid Waste:** | 41 | 3 | 1,939 |

Methane and nitrous oxide emissions associated with biological treatment of solid waste were calculated using GPC equation 8.5.
1) The default biological treatment emission factors from GPC Table 8.3 were used. "Wet waste" emission factors were used for both compositing and anaerobic digestion at biogas facilities.
2) The estimated percent of CH4 recovered at compositing facilities and anerobic digestion facilities. This analysis assumes 0% methane recovery for compositing facilities and 100% methane recovery for anaerobic digestion facilities.
https://ghgprotocol.org/sites/default/files/standards/GPC_Full_MASTER_RW_v7.pdf

**Equation 8.5 Direct emissions from biologically treated solid waste**

$$CH_4 \text{ Emissions} = (\Sigma (m_x \times F_{CH4,x}) \times 10^{-3} - R)$$

**Table 8.3 Biological treatment emission factors**

| Treatment type | $CH_4$ Emissions Factors (g $CH_4$/ kg waste) | $N_2O$ Emissions Factors (g $N_2O$ /kg waste) |
|---|---|---|

$$N_2O \text{ Emissions} = (\Sigma_i(m_i \times EF_N2O_i) \times 10^{-3})$$

| Description | | | Value |
|---|---|---|---|
| $CH_4$ emissions | = | Total $CH_4$ emissions in tonnes | Computed |
| $N_2O$ emissions | = | Total $N_2O$ emissions in tonnes | Computed |
| m | = | Mass of organic waste treated by biological treatment type i, kg | User input |
| EF_ CH4 | = | $CH_4$ emissions factor based upon treatment type, i | User input or default value from table 8.3 Biological treatment emission factor |
| EF_ N2O | = | $N_2O$ emissions factor based upon treatment type, i | User input or default value User input or default value from table 8.3 Biological treatment emission factor |
| i | = | Treatment type: composting or anaerobic digestion | User input |

**EQUATION 4.1**
**$CH_4$ EMISSIONS FROM BIOLOGICAL TREATMENT**

$$CH_4\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

Where:

$CH_4$ Emissions = total $CH_4$ emissions in inventory year, Gg $CH_4$

$M_i$ = mass of organic waste treated by biological treatment type *i*, Gg

EF = emission factor for treatment *i*, g $CH_4$/kg waste treated

i = composting or anaerobic digestion

R = total amount of $CH_4$ recovered in inventory year, Gg $CH_4$

| Treatment type | Dry waste | Wet waste | Dry waste | Wet waste |
|---|---|---|---|---|
| Composting | 10 | 4 | 0.6 | 0.3 |
| Anaerobic digestion at biogas facilities | 2 | 1 | N/A | N/A |

*Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories,* Volume 5, Chapter 4: Biological Treatment of Solid Waste

**Waste Summary Emissions:**
Waste generated in the MSA and disposed of in the MSA is considered Scope 1, while waste generated in the MSA and disposed of outside of the MSA is considered Scope 3. The tables below summarize waste data by municipality and type, using scaled statewide data as needed.

## Solid Waste Calculations

**Table 1: Population by Town**

| Town | County | State | Population |
|---|---|---|---|
| Ashburnham | Worcester | MA | 6,372 |
| Ashby | Middlesex | MA | 3,163 |
| Athol | Worcester | MA | 11,897 |
| Auburn | Worcester | MA | 16,762 |
| Ayer | Middlesex | MA | 8,424 |
| Barre | Worcester | MA | 5,533 |
| Berlin | Worcester | MA | 4,189 |
| Blackstone | Worcester | MA | 9,211 |
| Bolton | Worcester | MA | 5,728 |
| Boylston | Worcester | MA | 4,924 |
| Brookfield | Worcester | MA | 3,432 |
| Charlton | Worcester | MA | 13,360 |
| Clinton | Worcester | MA | 15,484 |
| Douglas | Worcester | MA | 9,153 |
| Dudley | Worcester | MA | 11,850 |
| East Brookfield | Worcester | MA | 2,204 |
| Fitchburg | Worcester | MA | 41,502 |
| Gardner | Worcester | MA | 20,902 |
| Grafton | Worcester | MA | 8 |
| Groton | Middlesex | MA | 11,162 |
| Hardwick | 0 | MA | 2,658 |
| Harvard | Worcester | MA | 6,870 |
| Holden | Worcester | MA | 19,880 |
| Hopedale | Worcester | MA | 6,008 |
| Hubbardston | Worcester | MA | 4,335 |
| Lancaster | Worcester | MA | 8,394 |
| Leicester | Worcester | MA | 11,033 |
| Leominster | Worcester | MA | 43,646 |
| Lunenburg | Worcester | MA | 11,835 |
| Mendon | Worcester | MA | 6,286 |
| Millbury | Worcester | MA | 13,936 |
| Millville | Worcester | MA | 3,147 |
| New Braintree | Worcester | MA | 990 |
| North Brookfield | Worcester | MA | 4,728 |
| Northborough | Worcester | MA | 15,663 |
| Northbridge | Worcester | MA | 16,337 |
| Oakham | Worcester | MA | 1,866 |
| Oxford | Worcester | MA | 13,287 |
| Paxton | Worcester | MA | 5,024 |

**Table 2: MSA 2022 Total Population**

| MSA MA | MSA CT |
|---|---|
| 840,994 | 120,595 |
| **Total MSA Populatior** | **961,589** |

**Table 3: 2022 Total Statewide Population**

| MA | CT |
|---|---|
| **6,981,974** | **1,395,231** |

Data Source: All population data sourced from MAPC Data Common for 2022 https://datacommon.mapc.org/browser/datasets/316 and CT data was obtained from the US Census source which informs that Data Common. These populations are consistently used throughout the GHG inventory

**Table 4: MA Solid Waste**

| Disposal (MASSDEP) | 2022 (tons) | Data Source |
|---|---|---|
| Landfill (MSW only) | 410,000 | Table 2 on page 3 https://www.mass.gov/doc/2022-solid-waste-data-update/download |
| Landfill (C&D only) | | |
| Landfill (Other only) | 80,000 | |
| Combustion (MSW only) | 2,900,000 | |
| Combustion (Non-MSW) | 20,000 | |
| Total Net Exports | 2,590,000 | |
| Total Statewide | 6,000,000 | |
| Total/pp Statewide | 0.9 | **US average is 0.8-0.9* |
| **Total in MA MSA portion** | **722713.1** | |

**Table 5: CT Solid Waste**

| Town | Incineration in MSA (tons) *scope 1* | Incineration Outside MSA (tons) *scope 3* | Landfill Outside MSA (tons) *scope 3* |
|---|---|---|---|
| Ashford | | 1,156 | 548 |
| Brooklyn | | 2,293 | 1,059 |
| Canterbury | | 341 | 154 |
| Chaplin | | 502 | 238 |
| Eastford | | 251 | 119 |
| Hampton | | 294 | 146 |
| Killingly | | 2,346 | 669 |
| Plainfield | | 2,329 | 751 |
| Pomfret | | 900 | 426 |
| Putnam | | 1,254 | 585 |
| Scotland | | 292 | 138 |
| Sterling | | 201 | 65 |
| Thompson | 1,356 | 454 | 215 |
| Union | | 91 | 49 |
| Voluntown | | 75 | 35 |
| Windham | | 50,334 | 28,123 |
| Woodstock | | 1,299 | 616 |
| **Totals** | **1,356** | **64,413** | **33,937** |

**Table 6: MA Split Between Landfill and Incineration**

| MA In-State Disposal Total | 3,420,000 | Percent | Source |
|---|---|---|---|
| Landfill | 490,000 | 14% | Table 2 on page 3 |
| Combustion | 2,930,000 | 86% | https://www.mass.gov/doc/20 |

**Table 7:Total Tons Percent in MA vs. MSA**

| MA TOTAL | 2022 (tons) | Percent |
|---|---|---|
| Total in MA (short tons) | 722,713 | 100% |

| | | | |
|---|---|---|---|
| Petersham | Worcester | MA | 1,183 |
| Phillipston | Worcester | MA | 1,720 |
| Princeton | Worcester | MA | 3,504 |
| Royalston | Worcester | MA | 1,261 |
| Rutland | Worcester | MA | 9,298 |
| Shirley | Middlesex | MA | 6,782 |
| Shrewsbury | Worcester | MA | 39,805 |
| Southbridge | Worcester | MA | 17,619 |
| Spencer | Worcester | MA | 11,911 |
| Sterling | Worcester | MA | 8,139 |
| Sturbridge | Worcester | MA | 9,882 |
| Sutton | Worcester | MA | 9,379 |
| Templeton | Worcester | MA | 8,183 |
| Townsend | Middlesex | MA | 8,948 |
| Upton | Worcester | MA | 8,128 |
| Uxbridge | Worcester | MA | 14,386 |
| Warren | Worcester | MA | 4,968 |
| Webster | Worcester | MA | 17,601 |
| West Boylston | Worcester | MA | 7,757 |
| West Brookfield | Worcester | MA | 3,817 |
| Westborough | Worcester | MA | 21,506 |
| Westminster | Worcester | MA | 8,330 |
| Winchendon | Worcester | MA | 10,385 |
| Worcester | Worcester | MA | 205,319 |
| Ashford | Windham | CT | 4,222 |
| Brooklyn | Windham | CT | 8,502 |
| Canterbury | Windham | CT | 5,102 |
| Chaplin | Windham | CT | 2,156 |
| Eastford | Windham | CT | 1,675 |
| Hampton | Windham | CT | 1,738 |
| Killingly | Windham | CT | 17,837 |
| Plainfield | Windham | CT | 15,143 |
| Pomfret | Windham | CT | 4,307 |
| Putnam | Windham | CT | 9,302 |
| Scotland | Windham | CT | 1,577 |
| Sterling | Windham | CT | 3,623 |
| Thompson | Windham | CT | 9,315 |
| Union | Tolland | CT | 793 |
| Voluntown | New London | CT | 2,592 |
| Windham | Windham | CT | 24,399 |
| Woodstock | Windham | CT | 8,312 |

| | | |
|---|---|---|
| Total MA Landfilled Waste (short tons) | 103,547 | **14%** |
| Total MA Incinerated Waste (short ton | 619,166 | **86%** |
| **Total MSA** | **822,419** | **100%** |
| **Total MSA Landfilled Waste (short t** | **137,483** | **17%** |
| **Total MSA Incinerated Waste (short** | **684,935** | **83%** |

**Table 8: Waste By Scope**

| Disposal | 2022 (tons) | Percent of Total Disposal | Scope |
|---|---|---|---|
| MA Statewide In-State Landfilled | 490,000 | 8.2% | *Scope 1* |
| MA Statewide In-State Incinerated | 2,920,000 | 49% | *Scope 1* |
| MA Statewide Net Exports | 2,590,000 | 43.2% | *Scope 3* |
| MA Portion MSA In-State Landfilled | 59,022 | | *Scope 1* |
| MA Portion MSA In-State Incinerated | 351,720 | | *Scope 1* |
| MA Portion MSA Net Exports | 311,971 | | *Scope 3* |
| CT Portion MSA In-MSA Incinerated | 1,356 | | *Scope 1* |
| CT Portion MSA Out-MSA Incinerated | 64,413 | | *Scope 3* |
| CT Portion MSA Out-MSA Landfilled | 33,937 | | *Scope 3* |
| Total MSA In-State/MSA Landfilled | 59,022 | 7% | Scope 1 |
| Total MSA In-State/MSA Incinerated | 353,076 | 43% | Scope 1 |
| Total MSA Out-State/MSA | 410,321 | 50% | Scope 3 |
| Out-State/MSA assumed Landfilled | 58,789 | | Scope 3 |
| Out-State/MSA assumed Incinerated | 351,532 | | Scope 3 |
| **Landfilled In MSA** | | **42.9%** | **Scope 1** |
| **Landfilled Outside MSA** | | **57.1%** | **Scope 3** |
| **Incinerated In MSA** | | **51.5%** | **Scope 1** |
| **Incinerated Outside MSA** | | **48.5%** | **Scope 3** |

# Waste: Community-wide Wastewater Treated & Emissions

**Summary of Methodology Used**

The analysis of wastewater emissions follows the approach used by the Massachusetts Department of Environmental Protection (DEP) to estimate wastewater treatment emissions for communities in Massachusetts in Appendix C of the Greenhouse Gas Baseline & Inventory report. The data and methodology from the "Wastewater" tab of the Appendix C workbook was used to calculate the total methane and nitrous oxide emissions from wastewater treatment plants (WWTP) and septic systems. This methodology in compliance with methodologies recommended by the GPC.

For communities served by the Clinton Wastewater Treatment Plant, only indirect nitrous oxide emissions from wastewater effluent is calculated. This wastewater treatment plant does not release methane because the methane is captured during an anaerobic digestion (AD) process and diverted to co-generation systems where it is used to heat buildings and generate electricity via steam turbine generators. This wastewater treatment plant is referred to as wastewater treatment plants with anaerobic digestion (WWTPs w/ AD). For communities served by a wastewater treatment plant without anaerobic digestion (WWTPs w/o AD), indirect nitrous oxide emissions from wastewater effluent and methane generation emissions from wastewater treatment are calculated using the methodology outlined in the Massachusetts DEP Greenhouse Gas Baseline & Inventory report. Communities that are served by WWTPs w/o AD do have some methane emissions associated with wastewater treatment because methane capture and co-generation systems are not in place.

Some communities are only partially served by WWTPs, and the remainder of the population is on septic systems. For the portion of the community's population on septic systems, the methane emissions and indirect nitrous oxide emissions from wastewater effluent are calculated using the methodology outlined in the Massachusetts DEP Greenhouse Gas Baseline & Inventory report.

**Table 1: Total Wastewater Emissions**

| CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) | Total Emissions (MTCO2e) |
|---|---|---|
| 4,464.9 | 81.9 | 146,719 |

**Massachusetts**

**Table 2: Summary of Emissions From Wastewater Treatment and Discharge**

| CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) |
|---|---|
| **2,232.5** | **40.9** |

**Table 3: Population Served by WWTPs with and without Anaerobic Digestion and**

| Description | Data |
|---|---|
| Community Population Served by WWTP w/ AD: | 18,842 |
| Community Population on Septic Systems: | 332,498 |
| Community Population Served by WWTP w/o AD: | 504,425 |

**Table 4: CH4 Emissions from Septic**

| Description | Data |
|---|---|
| Septic Biochemical Oxygen Demand (BOD) (kg/cap/ | 0.085 |
| Septic Maximum CH4 Producing Potential (Bo) (kg C | 0.6 |
| Septic Methane Correction Factor (MCF) | 0 |
| Septic Emission Factor for wastewater treatment (EF | 0 |
| Fraction of population managing their septic tank in compliance with the sludge removal instruction of their septic system (F) | 1 |
| **CH4 Emissions (MT CH4):** | **1,934** |

**Table 5: CH4 Generation from Wastewater Treatment Plans w/o Anaerobic Digestion**

| Description | Data |
|---|---|
| WWTP Biochemical Oxygen Demand (BOD) (kg/cap/day) | 0 |

**Connecticut**

**Table 8: Summary of Emissions From Wastewater Treatment and Discharge**

| CH4 Emissions (MT CH4) | N2O Emissions (MT N2O) |
|---|---|
| **2232.469059** | **40.945** |

**Table 9: Population Served by WWTPs with and without Anaerobic Digestion**

| Description | Data |
|---|---|
| Community Population Served by WWTP w/ AD: | 0.000 |
| Community Population on Septic Systems: | 87556.750 |
| Community Population Served by WWTP w/o AD: | 33038.250 |

**Table 10: CH4 Emissions from Septic**

| Description | Data |
|---|---|
| Septic Biochemical Oxygen Demand (BOD) (kg/cap/ | 0.085 |
| Septic Maximum CH4 Producing Potential (Bo) (kg C | 0.600 |
| Septic Methane Correction Factor (MCF) | 0.5 |
| Septic Emission Factor for wastewater treatment (EF | 0.3 |
| Fraction of population managing their septic tank in compliance with the sludge removal instruction of their septic system (F) | 0.75 |
| **CH4 Emissions (MT CH4):** | **509** |

**Table 11: CH4 Generation from Wastewater Treatment Plans w/o Anaerobic**

| Description | Data |
|---|---|
| WWTP Biochemical Oxygen Demand (BOD) (kg/cap/day) | 0.09 |

| | |
|---|---|
| WWTP Maximum CH4 Producing Potential (Bo) (kg CH4/kg BOD) | 1 |
| WWTP Methane Correction Factor (MCF) | 0 |
| WWTP Emission Factor for wastewater treatment (EF) (kg CH4/kg BOD) | 0 |
| **CH4 Emissions (MT CH4):** | **298** |

| **Table 6: Direct N2O Emissions from all WWTPs** | |
|---|---|
| **Description** | **Data** |
| WWTP N2O Process Emissions (g N2O / cap / year) | 4 |
| **N2O Emissions (MT N2O):** | **2** |

| **Table 7: Indirect N2O Emissions from Wastewater Effluent** | |
|---|---|
| **Description** | **Data** |
| Effluent Fraction of nitrogen in protein (F_NPR) (kg N/kg protein) | 0 |
| Effluent Factor for nitrogen in non-consumed protein disposed in sewer system (F_NonCon) (kg N/kg N) | 2 |
| Effluent Emission factor for biosolids EF_biosolids (kg N2O-N/kg sewage-N produced) | 0 |
| Annual Per Capita Protein Consumption (kg/person/year) | 34 |
| Effluent Fraction for nitrogen in fertilizer (F_Fertilizer) | 0 |
| **N2O Emissions (MT N2O):** | **39** |

| | |
|---|---|
| WWTP Maximum CH4 Producing Potential (Bo) (kg CH4/kg BOD) | 0.6 |
| WWTP Methane Correction Factor (MCF) | 0.03 |
| WWTP Emission Factor for wastewater treatment (EF) (kg CH4/kg BOD) | 0.018 |
| **CH4 Emissions (MT CH4):** | **20** |

| **Table 12: Direct N2O Emissions from all WWTPs** | |
|---|---|
| **Description** | **Data** |
| WWTP N2O Process Emissions (g N2O / cap / year) | 4 |
| **N2O Emissions (MT N2O):** | **0.13** |

| **Table 13: Indirect N2O Emissions from Wastewater Effluent** | |
|---|---|
| **Description** | **Data** |
| Effluent Fraction of nitrogen in protein (F_NPR) (kg N/kg protein) | 0.16 |
| Effluent Factor for nitrogen in non-consumed protein disposed in sewer system (F_NonCon) (kg N/kg N) | 1.75 |
| Effluent Emission factor for biosolids EF_biosolids (kg N2O-N/kg sewage-N produced) | 0.005 |
| Annual Per Capita Protein Consumption (kg/person/year) | 34.4 |
| Effluent Fraction for nitrogen in fertilizer (F_Fertilizer) | 0.4 |
| **N2O Emissions (MT N2O):** | **5.48** |

## Sewer & Septic Systems by Town Population

**Table 1: Summary of Methodology Used**

Several sources were used to estimate populations served by different treatment types including wastewater treatment facilities (WWTFs) with anaerobic digestion (AD), WWTFs without AD, and septic systems. Data sources included MassDEP 2017 Septic and Sewer Population Map, direct correspondence with MWRA, and CT DEEP's Connected Sewer Service Area map.
https://geodata.ct.gov/datasets/CTDEEP::connected-sewer-service-areas/explore https://www.mass.gov/doc/title-5groundwater-stakeholder-

| Table 2: Total Population Served by Wastewater Treatment Type and State | Population | Percent of total by state |
|---|---|---|
| MA Population Served by WWTF with Anaerobic Digestion | 18841.600000 | 0.022 |
| MA Population Served by WWTF without Anaerobic Digestion | 504425.125000 | 0.589 |
| MA Population Served by Septic | 332497.875000 | 0.389 |
| CT Population Served by Septic | 87556.750000 | 0.726 |
| CT Population Served by Sewer | 33038.250000 | 0.274 |

| Table 3: MWRA WWTP - Clinton WWTP | |
|---|---|
| Clinton, MA population | 15,484 |
| Estimated percent of Clinton served by Clinton WWTP | 100% |
| Lancaster, MA population | 8,394 |
| Estimated percent of Lancaster population served by Clinton WWTP | 40% |
| **Population Served by WWTP w/ AD** | **18,842** |

**Table 4: MassDEP Septic and Sewer System Map**

The percent of population served by septic systems was estimated based on 2017 data from MA DEP. For communities which are "Partially Sewered - Percent Unknown" it was assumed to be 50%.
https://www.mass.gov/doc/title-5groundwater-stakeholder-group-regulatory-review-presentation/download

| Town | County | State | Percent of Population on Septic | Population total | Population Septic | Population Sewer |
|---|---|---|---|---|---|---|
| Ashburnham | Worcester | MA | 0.500000 | 6372.000 | 3186.0000000 | 3186.0 |
| Ashby | Worcester | MA | 100% | 3,163 | 3,163 | - |
| Athol | Worcester | MA | 35% | 11,897 | 4,164 | 7,733 |
| Auburn | Worcester | MA | 15% | 16,762 | 2,514 | 14,248 |
| Ayer | Middlesex | MA | 15% | 8,424 | 1,264 | 7,160 |
| Barre | Worcester | MA | 85% | 5,533 | 4,703 | 830 |
| Berlin | Worcester | MA | 100% | 4,189 | 4,189 | - |
| Blackstone | Worcester | MA | 85% | 9,211 | 7,829 | 1,382 |
| Bolton | Worcester | MA | 100% | 5,728 | 5,728 | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| Boylston | Worcester | MA | 100% | 4,924 | 4,924 | - |
| Brookfield | Worcester | MA | 100% | 3,432 | 3,432 | - |
| Charlton | Worcester | MA | 85% | 13,360 | 11,356 | 2,004 |
| Clinton | Worcester | MA | 5% | 15,484 | | |
| Douglas | Worcester | MA | 85% | 9,153 | 7,780 | 1,373 |
| Dudley | Worcester | MA | 35% | 11,850 | 4,148 | 7,703 |
| East Brookfield | Worcester | MA | 100% | 2,204 | 2,204 | - |
| Fitchburg | Worcester | MA | 24% | 41,502 | 9,960 | 31,542 |
| Gardner | Worcester | MA | 24% | 20,902 | 5,016 | 15,886 |
| Grafton | Worcester | MA | 55% | 19,815 | 10,898 | 8,917 |
| Groton | Middlesex | MA | 85% | 11,162 | 9,488 | 1,674 |
| Hardwick | Worcester | MA | 50% | 2,658 | 1,329 | 1,329 |
| Harvard | Worcester | MA | 50% | 6,870 | 3,435 | 3,435 |
| Holden | Worcester | MA | 65% | 19,880 | 12,922 | 6,958 |
| Hopedale | Worcester | MA | 15% | 6,008 | 901 | 5,107 |
| Hubbardston | Worcester | MA | 100% | 4,335 | 4,335 | - |
| Lancaster | Worcester | MA | 40% | 8,394 | | |
| Leicester | Worcester | MA | 65% | 11,033 | 7,171 | 3,862 |
| Leominster | Worcester | MA | 15% | 43,646 | 6,547 | 37,099 |
| Lunenburg | Worcester | MA | 50% | 11,835 | 5,918 | 5,918 |
| Mendon | Worcester | MA | 100% | 6,286 | 6,286 | - |
| Millbury | Worcester | MA | 24% | 13,936 | 3,345 | 10,591 |
| Millville | Worcester | MA | 100% | 3,147 | 3,147 | - |
| New Braintree | Worcester | MA | 100% | 990 | 990 | - |
| North Brookfield | Worcester | MA | 85% | 4,728 | 4,019 | 709 |
| Northborough | Worcester | MA | 63% | 15,663 | 9,868 | 5,795 |
| Northbridge | Worcester | MA | 24% | 16,337 | 3,921 | 12,416 |
| Oakham | Worcester | MA | 100% | 1,866 | 1,866 | - |
| Oxford | Worcester | MA | 85% | 13,287 | 11,294 | 1,993 |
| Paxton | Worcester | MA | 100% | 5,024 | 5,024 | - |
| Petersham | Worcester | MA | 100% | 1,183 | 1,183 | - |
| Phillipston | Worcester | MA | 100% | 1,720 | 1,720 | - |
| Princeton | Worcester | MA | 100% | 3,504 | 3,504 | - |
| Royalston | Worcester | MA | 0% | 1,261 | - | 1,261 |
| Rutland | Worcester | MA | 85% | 9,298 | 7,903 | 1,395 |
| Shirley | Middlesex | MA | 24% | 6,782 | 1,628 | 5,154 |
| Shrewsbury | Worcester | MA | 15% | 39,805 | 5,971 | 33,834 |
| Southbridge | Worcester | MA | 24% | 17,619 | 4,229 | 13,390 |
| Spencer | Worcester | MA | 85% | 11,911 | 10,124 | 1,787 |
| Sterling | Worcester | MA | 100% | 8,139 | 8,139 | - |
| Sturbridge | Worcester | MA | 63% | 9,882 | 6,226 | 3,656 |
| Sutton | Worcester | MA | 85% | 9,379 | 7,972 | 1,407 |
| Templeton | Worcester | MA | 65% | 8,183 | 5,319 | 2,864 |
| Townsend | Middlesex | MA | 100% | 8,948 | 8,948 | - |
| Upton | Worcester | MA | 95% | 8,128 | 7,722 | 406 |
| Uxbridge | Worcester | MA | 55% | 14,386 | 7,912 | 6,474 |
| Warren | Worcester | MA | 50% | 4,968 | 2,484 | 2,484 |
| Webster | Worcester | MA | 63% | 17,601 | 11,089 | 6,512 |
| West Boylston | Worcester | MA | 50% | 7,757 | 3,879 | 3,879 |

| | | | | | | |
|---|---|---|---|---|---|---|
| West Brookfield | Worcester | MA | 100% | 3,817 | 3,817 | - |
| Westborough | Worcester | MA | 15% | 21,506 | 3,226 | 18,280 |
| Westminster | Worcester | MA | 85% | 8,330 | 7,081 | 1,250 |
| Winchendon | Worcester | MA | 38% | 10,385 | 3,894 | 6,491 |
| Worcester | Worcester | MA | 5% | 205,319 | 10,266 | 195,053 |
| | | | | ***Totals*** | **332,498** | **504,425** |

**Table 5: CT DEEP SEWER SERVICE AREAS**

Percent of population served by the sewer system was estimated based on the Connected Sewer Service Area data from CT DEEP. The project team emailed DPWs and WPCAs in some communities but they were unable to provide a percentage of population served.
https://geodata.ct.gov/datasets/CTDEEP::connected-sewer-service-areas/about

| Town | County | State | Percent of Population on Sewer | Population total | Population Sewer | Population Septic |
|---|---|---|---|---|---|---|
| Ashford | Windham | Connecticut | 0% | 4222 | 0 | 4222 |
| Brooklyn | Windham | Connecticut | 25% | 8502 | 2126 | 6377 |
| Canterbury | Windham | Connecticut | 0% | 5102 | 0 | 5102 |
| Chaplin | Windham | Connecticut | 0% | 2156 | 0 | 2156 |
| Eastford | Windham | Connecticut | 0% | 1675 | 0 | 1675 |
| Hampton | Windham | Connecticut | 0% | 1738 | 0 | 1738 |
| Killingly | Windham | Connecticut | 75% | 17837 | 13378 | 4459 |
| Plainfield | Windham | Connecticut | 50% | 15143 | 7572 | 7572 |
| Pomfret | Windham | Connecticut | 0% | 4307 | 0 | 4307 |
| Putnam | Windham | Connecticut | 50% | 9302 | 4651 | 4651 |
| Scotland | Windham | Connecticut | 0% | 1577 | 0 | 1577 |
| Sterling | Windham | Connecticut | 25% | 3623 | 906 | 2717 |
| Thompson | Windham | Connecticut | 25% | 9315 | 2329 | 6986 |
| Union | Tolland | Connecticut | 0% | 793 | 0 | 793 |
| Voluntown | New London | Connecticut | 0% | 2592 | 0 | 2592 |
| Windham | Windham | Connecticut | 0% | 24399 | 0 | 24399 |
| Woodstock | Windham | Connecticut | 25% | 8312 | 2078 | 6234 |
| | | | | ***Totals*** | **33,038** | **87,557** |

**Natural Working Lands:**
Carbon sequestration from forested lands are included in the emissions inventory. Land area by forest type was sourced from the National Land Cover Database for 2021 and a GIS analysis was conducted to determine the values for each town in the MSA. The carbon sequestration factor of 2.23 metric tons C/hectare/year was sourced from the EPA Community Greenhouse Gas Inventory Tool and the EPA State Inventory Tools, Land-Use Land Use Change and Forestry module.
National Land Cover Database | U.S. Geological Survey

| Town | County | State | Deciduous Forest (sq m) | Evergreen Forest (sq m) | Mixed Forest (sq m) | Total forest sequestering land (sq m) | TOTAL Carbon Sequestering Land (hectare) | Annual Carbon Sequestration (MTCO2) Forested Lands |
|---|---|---|---|---|---|---|---|---|
| | | ***Totals*** | **1,743,840,900** | **460,632,600** | **1,258,772,400** | **3,463,245,900** | **346,325** | **2,831,781** |
| Ashburnham | Worcester | MA | 14,285,700 | 15,228,900 | 41,175,000 | 70,689,600 | 7,069 | 57,801 |
| Ashby | Middlesex | MA | 10,414,800 | 9,169,200 | 26,812,800 | 46,396,800 | 4,640 | 37,937 |
| Athol | Worcester | MA | 12,816,000 | 20,301,300 | 26,620,200 | 59,737,500 | 5,974 | 48,845 |
| Auburn | Worcester | MA | 10,957,500 | 588,600 | 3,724,200 | 15,270,300 | 1,527 | 12,486 |
| Ayer | Middlesex | MA | 3,458,700 | 794,700 | 2,322,900 | 6,576,300 | 658 | 5,377 |
| Barre | Worcester | MA | 32,061,600 | 13827600.000000 | 32422500.000 | 78311700.0000000 | 7831.2 | 64,033 |
| Berlin | Worcester | MA | 10,509,300 | 2187000.000000 | 7128900.000 | 19825200.0000000 | 1982.5 | 16,210 |
| Blackstone | Worcester | MA | 10,918,800 | 461700.000000 | 3011400.000 | 14391900.0000000 | 1439.2 | 11,768 |
| Bolton | Worcester | MA | 15,858,900 | 4083300.000000 | 11047500.000 | 30989700.0000000 | 3099.0 | 25,339 |
| Boylston | Worcester | MA | 13,712,400 | 3845700.000000 | 9106200.000 | 26664300.0000000 | 2666.4 | 21,803 |
| Brookfield | Worcester | MA | 13,183,200 | 2567700.000000 | 8139600.000 | 23890500.0000000 | 2389.1 | 19,534 |
| Charlton | Worcester | MA | 32,269,500 | 6547500.000000 | 29079000.000 | 67896000.0000000 | 6789.6 | 55,516 |
| Clinton | Worcester | MA | 2,631,600 | 603000.000000 | 882900.000 | 4117500.0000000 | 411.8 | 3,367 |
| Douglas | Worcester | MA | 45,127,800 | 4194000.000000 | 21351600.000 | 70673400.0000000 | 7067.3 | 57,787 |
| Dudley | Worcester | MA | 19,901,700 | 1484100.000000 | 8922600.000 | 30308400.0000000 | 3030.8 | 24,782 |
| East Brookfield | Worcester | MA | 4,660,200 | 2277000.000000 | 7018200.000 | 13955400.0000000 | 1395.5 | 11,411 |
| Fitchburg | Worcester | MA | 15,037,200 | 5046300.000000 | 16639200.000 | 36722700.0000000 | 3672.3 | 30,027 |
| Gardner | Worcester | MA | 5,001,300 | 9809100.000000 | 11355300.000 | 26165700.0000000 | 2616.6 | 21,395 |
| Grafton | Worcester | MA | 19,209,600 | 1323000.000000 | 6176700.000 | 26709300.0000000 | 2670.9 | 21,839 |
| Groton | Middlesex | MA | 17,655,300 | 14192100.000000 | 16072200.000 | 47919600.0000000 | 4792.0 | 39,182 |
| Hardwick | Worcester | MA | 40,696,200 | 6392700.000000 | 22572000.000 | 69660900.0000000 | 6966.1 | 56,959 |
| Harvard | Worcester | MA | 16,848,000 | 6846300.000000 | 13863600.000 | 37557900.0000000 | 3755.8 | 30,710 |
| Holden | Worcester | MA | 21,688,200 | 7,043,400 | 27,106,200 | 55,837,800 | 5,584 | 45,657 |
| Hopedale | Worcester | MA | 3255300 | 306900 | 1695600 | 5,257,800 | 526 | 4,299 |
| Hubbardston | Worcester | MA | 20,046,600 | 16,823,700 | 33,853,500 | 70,723,800 | 7,072 | 57,828 |
| Lancaster | Worcester | MA | 16,759,800 | 5,582,700 | 12,309,300 | 34,651,800 | 3,465 | 28,334 |
| Leicester | Worcester | MA | 21,168,900 | 1,767,600 | 13,905,000 | 36,841,500 | 3,684 | 30,124 |
| Leominster | Worcester | MA | 14,649,300 | 3,217,500 | 15,020,100 | 32,886,900 | 3,289 | 26,891 |
| Lunenburg | Worcester | MA | 16,606,800 | 5,391,000 | 16,370,100 | 38,367,900 | 3,837 | 31,372 |
| Mendon | Worcester | MA | 17,590,500 | 1,772,100 | 8,900,100 | 28,262,700 | 2,826 | 23,109 |
| Millbury | Worcester | MA | 14,974,200 | 523,800 | 3,582,900 | 19,080,900 | 1,908 | 15,602 |
| Millville | Worcester | MA | 6,452,100 | 79,200 | 1,343,700 | 7,875,000 | 788 | 6,439 |
| New Braintree | Worcester | MA | 19,334,700 | 4,560,300 | 9,172,800 | 33,067,800 | 3,307 | 27,038 |
| North Brookfield | Worcester | MA | 23,717,700 | 1,993,500 | 6,850,800 | 32,562,000 | 3,256 | 26,625 |
| Northborough | Worcester | MA | 10,179,900 | 1,413,000 | 5,253,300 | 16,846,200 | 1,685 | 13,775 |
| Northbridge | Worcester | MA | 12042000 | 2079900 | 9145800 | 23,267,700 | 2,327 | 19,025 |
| Oakham | Worcester | MA | 19,808,100 | 5,812,200 | 13,825,800 | 39,446,100 | 3,945 | 32,254 |
| Oxford | Worcester | MA | 23,057,100 | 2,475,900 | 12,993,300 | 38,526,300 | 3,853 | 31,502 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Paxton | Worcester | MA | 10,242,900 | 2,018,700 | 10,292,400 | 22,554,000 | 2,255 | 18,442 |
| Petersham | Worcester | MA | 37,081,800 | 25,896,600 | 53,397,900 | 116,376,300 | 11,638 | 95,157 |
| Phillipston | Worcester | MA | 16,908,300 | 6,597,900 | 19,475,100 | 42,981,300 | 4,298 | 35,144 |
| Princeton | Worcester | MA | 32,275,800 | 7,849,800 | 29,761,200 | 69,886,800 | 6,989 | 57,144 |
| Royalston | Worcester | MA | 13,977,900 | 29,797,200 | 40,676,400 | 84,451,500 | 8,445 | 69,053 |
| Rutland | Worcester | MA | 23,200,200 | 9,749,700 | 23,581,800 | 56,531,700 | 5,653 | 46,224 |
| Shirley | Middlesex | MA | 9,214,200 | 4,992,300 | 9,162,000 | 23,368,500 | 2,337 | 19,108 |
| Shrewsbury | Worcester | MA | 11,262,600 | 394,200 | 1,481,400 | 13,138,200 | 1,314 | 10,743 |
| Southbridge | Worcester | MA | 8,612,100 | 4,919,400 | 18,483,300 | 32,014,800 | 3,201 | 26,177 |
| Spencer | Worcester | MA | 24,920,100 | 5,557,500 | 20,472,300 | 50,949,900 | 5,095 | 41,660 |
| Sterling | Worcester | MA | 21,079,800 | 6,057,900 | 18,571,500 | 45,709,200 | 4,571 | 37,375 |
| Sturbridge | Worcester | MA | 22,951,800 | 9,324,900 | 33,265,800 | 65,542,500 | 6,554 | 53,592 |
| Sutton | Worcester | MA | 37,981,800 | 1,604,700 | 14,607,000 | 54,193,500 | 5,419 | 44,312 |
| Templeton | Worcester | MA | 10,538,100 | 14,575,500 | 21,963,600 | 47,077,200 | 4,708 | 38,493 |
| Townsend | Middlesex | MA | 14,511,600 | 20,239,200 | 24,890,400 | 59,641,200 | 5,964 | 48,767 |
| Upton | Worcester | MA | 18,318,600 | 5,525,100 | 14,688,900 | 38,532,600 | 3,853 | 31,507 |
| Uxbridge | Worcester | MA | 29,124,900 | 1,833,300 | 10,486,800 | 41,445,000 | 4,145 | 33,888 |
| Warren | Worcester | MA | 40,090,500 | 2,588,400 | 8,521,200 | 51,200,100 | 5,120 | 41,865 |
| Webster | Worcester | MA | 11,434,500 | 655,200 | 3,187,800 | 15,277,500 | 1,528 | 12,492 |
| West Boylston | Worcester | MA | 8,953,200 | 2,125,800 | 6,707,700 | 17,786,700 | 1,779 | 14,544 |
| West Brookfield | Worcester | MA | 22,950,000 | 2,880,000 | 8,620,200 | 34,450,200 | 3,445 | 28,169 |
| Westborough | Worcester | MA | 12,206,700 | 666,000 | 2,757,600 | 15,630,300 | 1,563 | 12,780 |
| Westminster | Worcester | MA | 22,284,000 | 9,546,300 | 28,511,100 | 60,341,400 | 6,034 | 49,339 |
| Winchendon | Worcester | MA | 7,139,700 | 32,821,200 | 34,365,600 | 74,326,500 | 7,433 | 60,774 |
| Worcester | Worcester | MA | 13,557,600 | 167400 | 881,100 | 14,606,100 | 1,461 | 11,943 |
| Ashford | Windham | CT | 60,026,400 | 1,497,600 | 14,230,800 | 75,754,800 | 7,575 | 61,942 |
| Brooklyn | Windham | CT | 31,032,000 | 1,497,600 | 9,193,500 | 41,723,100 | 4,172 | 34,116 |
| Canterbury | Windham | CT | 54,264,600 | 878,400 | 8,189,100 | 63,332,100 | 6,333 | 51,785 |
| Chaplin | Windham | CT | 33,402,600 | 514,800 | 4,034,700 | 37,952,100 | 3,795 | 31,032 |
| Eastford | Windham | CT | 32,999,400 | 3,360,600 | 18,450,000 | 54,810,000 | 5,481 | 44,816 |
| Hampton | Windham | CT | 41,184,000 | 969,300 | 3,996,900 | 46,150,200 | 4,615 | 37,735 |
| Killingly | Windham | CT | 43,443,000 | 5,445,900 | 30,249,900 | 79,138,800 | 7,914 | 64,709 |
| Plainfield | Windham | CT | 44,688,600 | 2,256,300 | 9,110,700 | 56,055,600 | 5,606 | 45,835 |
| Pomfret | Windham | CT | 54,359,100 | 628,200 | 12,237,300 | 67,224,600 | 6,722 | 54,967 |
| Putnam | Windham | CT | 12,483,000 | 2,547,900 | 11,587,500 | 26,618,400 | 2,662 | 21,765 |
| Scotland | Windham | CT | 28,884,600 | 432,900 | 4,506,300 | 33,823,800 | 3,382 | 27,657 |
| Sterling | Windham | CT | 31,334,400 | 3,366,900 | 14,097,600 | 48,798,900 | 4,880 | 39,901 |
| Thompson | Windham | CT | 39,388,500 | 7,258,500 | 31,999,500 | 78,646,500 | 7,865 | 64,307 |
| Union | Tolland | CT | 21,736,800 | 8,019,900 | 32,415,300 | 62,172,000 | 6,217 | 50,836 |
| Voluntown | New London | CT | 35,250,300 | 11,660,400 | 24,471,000 | 71,381,700 | 7,138 | 58,366 |
| Windham | Windham | CT | 26,205,300 | 1,074,600 | 9,886,500 | 37,166,400 | 3,717 | 30,390 |
| Woodstock | Windham | CT | 43,793,100 | 8,225,100 | 44,532,900 | 96,551,100 | 9,655 | 78,947 |

**Fertilizer Emissions:**
The total square miles of cultivated crop land by town was sourced from the most recent National Land Cover GIS Data set. The Lime, Urea, and Agriculture Soils emissions were sourced from the Massachusetts and Connecticut Statewide Emissions Inventory. The following totals were applied to each town and scaled down, assuming these fertilizers were applied to Cultivated Crops. See Supplemental Table 20 and 21 for details on Statewide emissions source for liming, urea, and agriculture soils.

| Town | County | Cultivated Crops (sq m) | % of Statewide cropland | 2021 Liming Emissions (MMTCO2e) | 2021 Liming Emissions (MTCO2e) | 2021 Urea Fertilizer Emissions (MMTCO2e) | 2021 Urea Emissions (MTCO2e) | 2021 Ag Soils (MMT N2O) | 2021 Ag Soils (MTCO2e) | Total Emissions (MTCO2e) |
|---|---|---|---|---|---|---|---|---|---|---|
| | ***Totals*** | **42,742,800** | | **0.00035** | **352** | **0.000014** | **14** | **0.0001** | **14,761** | **15,127** |
| Ashby | Middlesex | 900 | 0.0% | 0.000000 | 0.050 | 0.0000000 | 0.0 | 0.00000 | 0.3 | 0.3 |
| Ayer | Middlesex | - | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Groton | Middlesex | 354,600 | 0.2% | 0.000020 | 19.566 | 0.0000008 | 0.8 | 0.00000 | 104.3 | 124.6 |
| Shirley | Middlesex | 83,700 | 0.0% | 0.000005 | 4.618 | 0.0000002 | 0.2 | 0.00000 | 24.6 | 29.4 |
| Townsend | Middlesex | 313,200 | 0.1% | 0.000017 | 17.282 | 0.0000007 | 0.7 | 0.00000 | 92.1 | 110.1 |
| Voluntown | New Londc | 1,413,900 | 0.7% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 501.0 | 501.0 |
| Union | Tolland | 94,500 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 33.5 | 33.5 |
| Ashford | Windham | 871,200 | 0.5% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 308.7 | 308.7 |
| Brooklyn | Windham | 2,115,900 | 1.1% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 749.7 | 749.7 |
| Canterbury | Windham | 2,838,600 | 1.5% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 1005.8 | 1005.8 |
| Chaplin | Windham | 133,200 | 0.1% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 47.2 | 47.2 |
| Eastford | Windham | 522,900 | 0.3% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 185.3 | 185.3 |
| Hampton | Windham | 1,015,200 | 0.5% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 359.7 | 359.7 |
| Killingly | Windham | 399,600 | 0.2% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 141.6 | 141.6 |
| Plainfield | Windham | 4,723,200 | 2.5% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00001 | 1673.6 | 1673.6 |
| Pomfret | Windham | 4,633,200 | 2.4% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00001 | 1641.7 | 1641.7 |
| Putnam | Windham | 797,400 | 0.4% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 282.5 | 282.5 |
| Scotland | Windham | 3,004,200 | 1.6% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 1064.5 | 1064.5 |
| Sterling | Windham | 2,925,900 | 1.5% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 1036.8 | 1036.8 |
| Thompson | Windham | 2,511,000 | 1.3% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 889.7 | 889.7 |
| Windham | Windham | 2,063,700 | 1.1% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 731.2 | 731.2 |
| Woodstock | Windham | 6,292,800 | 3.3% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00001 | 2229.8 | 2229.8 |
| Ashburnham | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Athol | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Auburn | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Barre | Worcester | 119,700 | 0.1% | 0.000007 | 6.605 | 0.0000003 | 0.3 | 0.00000 | 35.2 | 42.1 |
| Berlin | Worcester | 12,600 | 0.0% | 0.000001 | 0.695 | 0.0000000 | 0.0 | 0.00000 | 3.7 | 4.4 |
| Blackstone | Worcester | 68,400 | 0.0% | 0.000004 | 3.774 | 0.0000002 | 0.2 | 0.00000 | 20.1 | 24.0 |
| Bolton | Worcester | 47,700 | 0.0% | 0.000003 | 2.632 | 0.0000001 | 0.1 | 0.00000 | 14.0 | 16.8 |
| Boylston | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Brookfield | Worcester | 54900 | 0.0% | 0.000003 | 3.029 | 0.0000001 | 0.1 | 0.00000 | 16.1 | 19.3 |
| Charlton | Worcester | 27900 | 0.0% | 0.000002 | 1.539 | 0.0000001 | 0.1 | 0.00000 | 8.2 | 9.8 |
| Clinton | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Douglas | Worcester | 900 | 0.0% | 0.000000 | 0.050 | 0.0000000 | 0.0 | 0.00000 | 0.3 | 0.3 |
| Dudley | Worcester | 464400 | 0.2% | 0.000026 | 25.625 | 0.0000010 | 1.0 | 0.00000 | 136.6 | 163.2 |
| East Brookfield | Worcester | 34200 | 0.0% | 0.000002 | 1.887 | 0.0000001 | 0.1 | 0.00000 | 10.1 | 12.0 |
| Fitchburg | Worcester | 108900 | 0.0% | 0.000006 | 6.009 | 0.0000002 | 0.2 | 0.00000 | 32.0 | 38.3 |
| Gardner | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Grafton | Worcester | 55800 | 0.0% | 0.000003 | 3.079 | 0.0000001 | 0.1 | 0.00000 | 16.4 | 19.6 |
| Hardwick | Worcester | 171000 | 0.1% | 0.000009 | 9.435 | 0.0000004 | 0.4 | 0.00000 | 50.3 | 60.1 |
| Harvard | Worcester | 216900 | 0.1% | 0.000012 | 11.968 | 0.0000005 | 0.5 | 0.00000 | 63.8 | 76.2 |
| Holden | Worcester | 58500 | 0.0% | 0.000003 | 3.228 | 0.0000001 | 0.1 | 0.00000 | 17.2 | 20.6 |
| Hopedale | Worcester | 900 | 0.0% | 0.000000 | 0.050 | 0.0000000 | 0.0 | 0.00000 | 0.3 | 0.3 |
| Hubbardston | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Lancaster | Worcester | 905400 | 0.4% | 0.000050 | 49.958 | 0.0000020 | 2.0 | 0.00000 | 266.3 | 318.3 |
| Leicester | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Leominster | Worcester | 75600 | 0.0% | 0.000004 | 4.171 | 0.0000002 | 0.2 | 0.00000 | 22.2 | 26.6 |
| Lunenburg | Worcester | 215100 | 0.1% | 0.000012 | 11.869 | 0.0000005 | 0.5 | 0.00000 | 63.3 | 75.6 |
| Mendon | Worcester | 48600 | 0.0% | 0.000003 | 2.682 | 0.0000001 | 0.1 | 0.00000 | 14.3 | 17.1 |
| Millbury | Worcester | 40500 | 0.0% | 0.000002 | 2.235 | 0.0000001 | 0.1 | 0.00000 | 11.9 | 14.2 |
| Millville | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| New Braintree | Worcester | 457200 | 0.2% | 0.000025 | 25.227 | 0.0000010 | 1.0 | 0.00000 | 134.5 | 160.7 |
| North Brookfield | Worcester | 95400 | 0.0% | 0.000005 | 5.264 | 0.0000002 | 0.2 | 0.00000 | 28.1 | 33.5 |
| Northborough | Worcester | 117900 | 0.1% | 0.000007 | 6.505 | 0.0000003 | 0.3 | 0.00000 | 34.7 | 41.4 |
| Northbridge | Worcester | 225000 | 0.1% | 0.000012 | 12.415 | 0.0000005 | 0.5 | 0.00000 | 66.2 | 79.1 |
| Oakham | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Oxford | Worcester | 67500 | 0.0% | 0.000004 | 3.725 | 0.0000002 | 0.2 | 0.00000 | 19.9 | 23.7 |
| Paxton | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Petersham | Worcester | 120600 | 0.1% | 0.000007 | 6.654 | 0.0000003 | 0.3 | 0.00000 | 35.5 | 42.4 |
| Phillipston | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Princeton | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Royalston | Worcester | 40500 | 0.0% | 0.000002 | 2.235 | 0.0000001 | 0.1 | 0.00000 | 11.9 | 14.2 |
| Rutland | Worcester | 568800 | 0.2% | 0.000031 | 31.385 | 0.0000013 | 1.3 | 0.00000 | 167.3 | 199.9 |
| Shrewsbury | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Southbridge | Worcester | 27900 | 0.0% | 0.000002 | 1.539 | 0.0000001 | 0.1 | 0.00000 | 8.2 | 9.8 |
| Spencer | Worcester | 253800 | 0.1% | 0.000014 | 14.004 | 0.0000006 | 0.6 | 0.00000 | 74.6 | 89.2 |
| Sterling | Worcester | 100800 | 0.0% | 0.000006 | 5.562 | 0.0000002 | 0.2 | 0.00000 | 29.6 | 35.4 |
| Sturbridge | Worcester | 8100 | 0.0% | 0.000000 | 0.447 | 0.0000000 | 0.0 | 0.00000 | 2.4 | 2.8 |
| Sutton | Worcester | 160200 | 0.1% | 0.000009 | 8.840 | 0.0000004 | 0.4 | 0.00000 | 47.1 | 56.3 |
| Templeton | Worcester | 145800 | 0.1% | 0.000008 | 8.045 | 0.0000003 | 0.3 | 0.00000 | 42.9 | 51.3 |
| Upton | Worcester | 16200 | 0.0% | 0.000001 | 0.894 | 0.0000000 | 0.0 | 0.00000 | 4.8 | 5.7 |
| Uxbridge | Worcester | 334800 | 0.1% | 0.000018 | 18.474 | 0.0000008 | 0.8 | 0.00000 | 98.5 | 117.7 |
| Warren | Worcester | 21600 | 0.0% | 0.000001 | 1.192 | 0.0000000 | 0.0 | 0.00000 | 6.4 | 7.6 |
| Webster | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| West Boylston | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| West Brookfield | Worcester | 28800 | 0.0% | 0.000002 | 1.589 | 0.0000001 | 0.1 | 0.00000 | 8.5 | 10.1 |
| Westborough | Worcester | 85500 | 0.0% | 0.000005 | 4.718 | 0.0000002 | 0.2 | 0.00000 | 25.1 | 30.1 |
| Westminster | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |
| Winchendon | Worcester | 29700 | 0.0% | 0.000002 | 1.639 | 0.0000001 | 0.1 | 0.00000 | 8.7 | 10.4 |
| Worcester | Worcester | 0 | 0.0% | 0.000000 | 0.000 | 0.0000000 | 0.0 | 0.00000 | 0.0 | 0.0 |

**Livestock:**
Emissions associated with livestock result from enteric fermentation and manure management. The number of heads by animal type for each county were sourced from the National Agricultural Statistics Service 2022 Census of Agriculture. To estimate the share of county data for each town, a GIS analysis was conducted to determine the land area used for pasture/hay by each community using the 2021 National Land Cover Database.

USDA - National Agricultural Statistics Service - 2022 Census of Agriculture - Volume 1, Chapter 2: County Level Data Table 1, with the exception of poultry which was sourced from Table 19. https://www.nass.usda.gov/Publications/AgCensus/2022/Full_Report/Volume_1,_Chapter_2_County_Level/Connecticut/

| County | State | Animal | Number of Heads | Totals emissions MANURE MANAGEMENT (kg CH4) | Totals emissions ENTERIC FERMENTATION (kg CH4) | Totals emissions MANURE MANAGEMENT (Metric Tons CH4) | Totals emissions ENTERIC FERMENTATION (Metric Tons CH4) | Adjusted MSA ONLY total emissions by animal type (Metric Tons CH4) MANURE | Adjusted MSA ONLY total emissions by animal type (Metric Tons CH4) Enteric | TOTAL MTCO2e Manure Management | TOTAL MTCO2e Enteric Fermentation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***Totals*** | **250,060** | **1,110,452** | **2,364,370** | **1,110** | **2,364** | **426** | **982** | **11,926** | **27,484** |
| Worcester | MA | Beef cows | 2,162 | 4107.8 | 101614.0 | 4.1 | 101.6 | 4.1 | 100.8 | 114.1 | 2823.5 |
| Worcester | MA | Milk cows | 1,719 | 110187.9 | 202842.0 | 110.2 | 202.8 | 109.3 | 201.3 | 3061.8 | 5636.3 |
| Worcester | MA | Hogs and Pigs | 1,655 | 19198.0 | 2482.5 | 19.2 | 2.5 | 19.1 | 2.5 | 533.4 | 69.0 |
| Worcester | MA | Sheep and Lambs | 2,771 | 1108.4 | 22168.0 | 1.1 | 22.2 | 1.1 | 22.0 | 30.8 | 616.0 |
| Worcester | MA | Horses and Ponies | 3,078 | 3693.6 | 55404.0 | 3.7 | 55.4 | 3.7 | 55.0 | 102.6 | 1539.5 |
| Worcester | MA | Goats | 2,442 | 244.2 | 12210.0 | 0.2 | 12.2 | 0.2 | 12.1 | 6.8 | 339.3 |
| Worcester | MA | Broilers and other meat-type c | 123,576 | 6178.8 | 0.0 | 6.2 | 0.0 | 6.1 | 0.0 | 171.7 | 0.0 |
| Middlesex | MA | Beef cows | 304 | 577.6 | 14288.0 | 0.6 | 14.3 | 0.1 | 3.7 | 4.1 | 102.4 |
| Middlesex | MA | Milk cows | 282 | 18076.2 | 33276.0 | 18.1 | 33.3 | 4.6 | 8.5 | 129.5 | 238.5 |
| Middlesex | MA | Hogs and Pigs | 171 | 1983.6 | 256.5 | 2.0 | 0.3 | 0.5 | 0.1 | 14.2 | 1.8 |
| Middlesex | MA | Horses and Ponies | 1,514 | 1816.8 | 27252.0 | 1.8 | 27.3 | 0.5 | 7.0 | 13.0 | 195.3 |
| Middlesex | MA | Sheep and Lambs | 1,015 | 406.0 | 8120.0 | 0.4 | 8.1 | 0.1 | 2.1 | 2.9 | 58.2 |
| Middlesex | MA | Goats | 433 | 43.3 | 2165.0 | 0.0 | 2.2 | 0.0 | 0.6 | 0.3 | 15.5 |
| Middlesex | MA | Broilers and other meat-type c | 23,495 | 1174.8 | 0.0 | 1.2 | 0.0 | 0.3 | 0.0 | 8.4 | 0.0 |
| New London | MA | Beef cows | 1,096 | 2082.4 | 51512.0 | 2.1 | 51.5 | 0.1 | 1.9 | 2.1 | 52.1 |
| New London | MA | Milk cows | 5,664 | 363062.4 | 668352.0 | 363.1 | 668.4 | 13.1 | 24.1 | 367.3 | 676.2 |
| New London | MA | Hogs and Pigs | 1,356 | 15729.6 | 2034.0 | 15.7 | 2.0 | 0.6 | 0.1 | 15.9 | 2.1 |
| New London | MA | Sheep and Lambs | 668 | 267.2 | 5344.0 | 0.3 | 5.3 | 0.0 | 0.2 | 0.3 | 5.4 |
| New London | MA | Broilers and other meat-type c | 10,706 | 535.3 | 0.0 | 0.5 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 |
| New London | MA | Horses and Ponies | 1,402 | 1682.4 | 25236.0 | 1.7 | 25.2 | 0.1 | 0.9 | 1.7 | 25.5 |
| New London | MA | Goats | 1,029 | 102.9 | 5145.0 | 0.1 | 5.1 | 0.0 | 0.2 | 0.1 | 5.2 |
| Tolland | CT | Beef cows | 575 | 1092.5 | 27025.0 | 1.1 | 27.0 | 0.0 | 0.8 | 0.9 | 21.2 |
| Tolland | CT | 0 | 1,050 | 1260.0 | 18900.0 | 1.3 | 18.9 | 0.0 | 0.5 | 1.0 | 14.8 |
| Tolland | CT | Milk cows | 4,644 | 297680.4 | 547992.0 | 297.7 | 548.0 | 8.4 | 15.4 | 233.8 | 430.5 |
| Tolland | CT | Hogs and Pigs | 287 | 3329.2 | 430.5 | 3.3 | 0.4 | 0.1 | 0.0 | 2.6 | 0.3 |
| Tolland | CT | Sheep and Lambs | 843 | 337.2 | 6744.0 | 0.3 | 6.7 | 0.0 | 0.2 | 0.3 | 5.3 |
| Tolland | CT | Broilers and other meat-type c | 14,243 | 712.2 | 0.0 | 0.7 | 0.0 | 0.0 | 0.0 | 0.6 | 0.0 |
| Tolland | CT | Goats | 368 | 36.8 | 1840.0 | 0.0 | 1.8 | 0.0 | 0.1 | 0.0 | 1.4 |
| Windham | CT | Beef cows | 1,167 | 2217.3 | 54849.0 | 2.2 | 54.8 | 2.2 | 54.8 | 62.1 | 1535.8 |
| Windham | CT | Milk cows | 3,809 | 244156.9 | 449462.0 | 244.2 | 449.5 | 244.2 | 449.5 | 6836.4 | 12584.9 |
| Windham | CT | Hogs and Pigs | 399 | 4628.4 | 598.5 | 4.6 | 0.6 | 4.6 | 0.6 | 129.6 | 16.8 |
| Windham | CT | Sheep and Lambs | 291 | 116.4 | 2328.0 | 0.1 | 2.3 | 0.1 | 2.3 | 3.3 | 65.2 |
| Windham | CT | Broilers and other meat-type c | 34,792 | 1739.6 | 0.0 | 1.7 | 0.0 | 1.7 | 0.0 | 48.7 | 0.0 |
| Windham | CT | Horses and Ponies | 710 | 852.0 | 12780.0 | 0.9 | 12.8 | 0.9 | 12.8 | 23.9 | 357.8 |
| Windham | CT | Goats | 344 | 34.4 | 1720.0 | 0.0 | 1.7 | 0.0 | 1.7 | 1.0 | 48.2 |

**Additional Industrial Emissions Information:**
Data Extracted from EPA's FLIGHT Tool , reported to EPA by facilities as of 08/16/2024 for all direct emitters. All emissions data is presented in unit of metric tons of carbon dioxide equivalent using AR4 Global Warming Potentials. These values are not included in the emissions inventory totals but are provided for informational purposes only, as much of these may be accounted for elsewhere in the inventory. The inventory uses AR5 GWPs.
http://ghgdata.epa.gov/ghgp

| REPORTING YEAR | FACILITY NAME | CITY NAME | COUNTY NAME | STATE | PARENT COMPANIES | TOTAL GHG QUANTITY (METRIC TONS CO2e) | Stationary CO2e Emissions (MTCO2) | Fuels Used | Other Emissions (MTCO2e) | Process | Link |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2022 | Blackstone Power Generation LLC | BLACKSTONE | Worcester | MA | Vistra Corp (100%) | 1,046,845 | 10 | Natural Gas, | 1,046,835 | Electricity Ger | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1006657&ds=E&et=&popup=true |
| 2022 | FITCHBURG WESTMINSTER LANDFILL RECYCLING CENTER | WESTMINSTER | Worcester | MA | WASTE MANAGEMENT INC (100%) | 34,008 | 661 | Distillate Fue | 33,347 | Municipal Lan | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1007753&ds=E&et=&popup=true |
| 2022 | MARTONE LANDFILL & GAS GENERATING FACILITY | BARRE | Worcester | MA | WASTE MANAGEMENT INC (100%) | 1,503 | - | N/A | 1503 | Municipal Lan | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1003587&ds=E&et=&popup=true |
| 2022 | Millennium Power | CHARLTON | Worcester | MA | MILLENNIUM POWER CO LLC (100%) | 444,270 | 348 | Natural Gas | 443,922 | Electricity Ger | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1001307&ds=E&et=&popup=true |
| 2022 | NEWARK AMERICA | FITCHBURG | Worcester | MA | GREIF INC (100%) | 28,659 | 28,659 | Natural Gas | 0 | | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1005970&ds=E&et=&popup=true |
| 2022 | SAINT-GOBAIN ABRASIVES and SAINT-GOBAIN CERAMICS & PLASTICS, INC. | WORCESTER | Worcester | MA | SAINT-GOBAIN CORP (100%) | 51,947 | 51,947 | Distillate Fue | 0 | | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1003037&ds=E&et=&popup=true |
| 2022 | SOUTHBRIDGE RECYCLING & DISPOSAL PARK | SOUTHBRIDGE | Worcester | MA | CASELLA WASTE SYSTEMS INC (100%) | 5,528 | 43 | Distillate Fue | 5,486 | Municipal Lan | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1005254&ds=E&et=&popup=true |
| 2022 | TGP Station 264 Charlton | Charlton | Worcester | MA | KINDER MORGAN INC (100%) | 32,158 | 31,252 | Natural Gas | 906 | Petroleum and | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1009333&ds=E&et=&popup=true |
| 2022 | UMASS MEDICAL SCHOOL | WORCESTER | Worcester | MA | COMMONWEALTH OF MASSACHUSETTS (10 | 85,142 | 85,142 | Distillate Fue | 0 | | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1006902&ds=E&et=&popup=true |
| 2022 | WHEELABRATOR MILLBURY INC | MILLBURY | Worcester | MA | WHEELABRATOR TECHNOLOGIES HOLDING | 215,640 | 215,640 | Municipal So | 0 | | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1006267&ds=E&et=&popup=true |
| 2022 | Wyman-Gordon Company | North Grafton | Worcester | MA | BERKSHIRE HATHAWAY INC (100%) | 24,177 | 24,177 | Natural Gas | 0 | | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1004817&ds=E&et=&popup=true |
| 2022 | Chaplin Station | Chaplin | Windham | CT | Enbridge (US) Inc (100%) | 49,345 | 46,473 | Natural Gas | 2,872 | Petroleum and | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1008146&ds=E&et=&popup=true |
| 2022 | FRITO-LAY | KILLINGLY (DAY | Windham | CT | PEPSICO INC (100%) | 42,756 | 42,756 | Natural Gas, | 0 | | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1004983&ds=E&et=&popup=true |
| 2022 | Lake Road Generating Company | DAYVILLE | Windham | CT | Vistra Corp (100%) | 2,189,121 | - | N/A | 2,189,121 | Electricity Ger | https://ghgdata.epa.gov/ghgp/service/facilityDetail/2022?id=1001338&ds=E&et=&popup=true |

**Additional Industrial Process Emissions Information:**
The MA statewide GHG inventory (accessible here: https://www.mass.gov/lists/massdep-emissions-inventories) an the CT statewide GHG inventory (accessible here: https://portal.ct.gov/deep/climate-change/ct-greenhouse-gas-inventory-reports) include the following industrial processes and associated emissions.

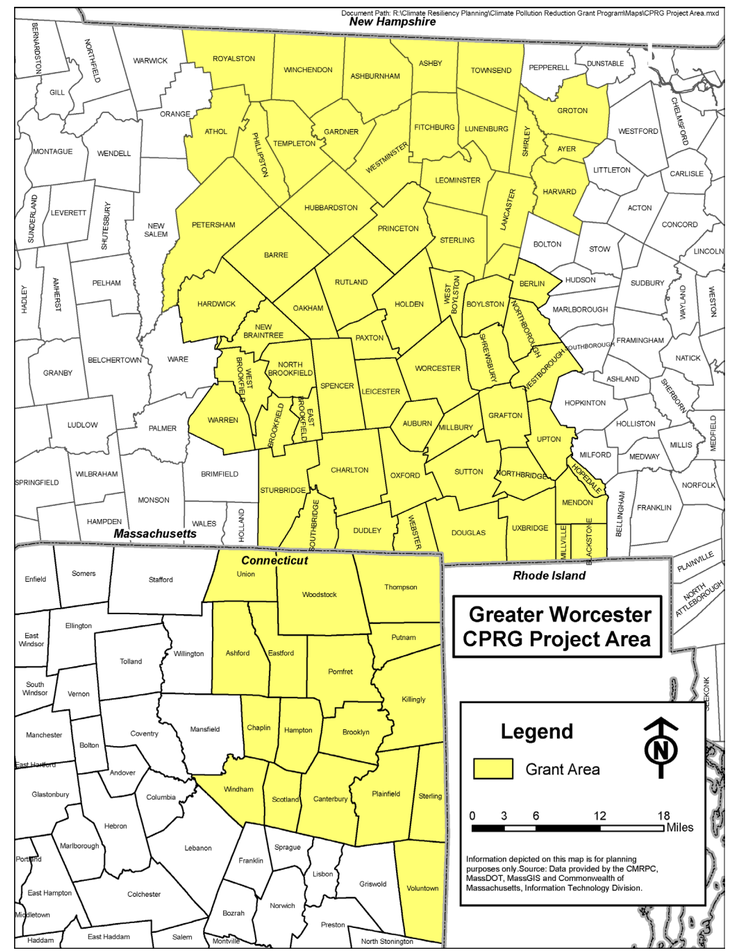
| PROCESS | Rationale for exclusion |
|---|---|
| Lime Manufacturing* | Lime Manufacturing occurs in the towns of Lee and Adams which are not located within the MSA, as state din the Mineral Industry Surveys from USGS: https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/media/files/dir-2022-lime.pdf. There is also none present in CT. |
| Limestone and Dolomite Use | Given the wide range of uses for limestone and dolomite, it could not be determined what was an appropriate metric to scale down statewide data to represent the MSA. |
| Soda Ash* | Given the wide range of uses for soda ash, it could not be determined what was an appropriate metric to scale down statewide data to represent the MSA. |
| Urea Consumption | Given the wide range of uses for urea, it could not be determined what was an appropriate metric to scale down statewide data to represent the MSA. |
| ODS Substitutes | Unable to identify source information to determine if present in the MSA. |
| Semiconductor Manufacturing* | Based on information in the EPA FLIGHT, the only electronics manufacturing (which includes semiconductors) in MA is occurring in Middlesex County, outside of the MSA. http://ghgdata.epa.gov/ghgp |
| Electric Power Transmission and Distribution Systems | Transmission and distribution losses are calculated as a percent of the electricity used by town and are included in the GHG inventory elsewhere. |

** Not included in the CT statewide inventory*

# Greater Worcester Business-As-Usual Emissions Scenario

The Business-As-Usual (BAU) scenario and estimated historic emissions through 1990 are calculated within this spreadsheet as part of the Climate Pollution Reduction Grant (CPRG) program funded by the Environmental Protection Agency (EPA). These estimates use the regional GHG emissions inventory for 2022 which includes 80 communities across Massachusetts and Connecticut that were included in the Metropolitan Statistical Area (MSA), as mapped below.

The methodology for the BAU is aligned with the approach used by the MA Office of Climate Innovation and Resilience for the statewide CCAP. Statewide estimated emissions by sector for 2030, 2040, and 2050 were sourced from the draft memo titled, *Massachusetts Decarbonization Greenhouse Gas Methodology Memo Task 4 and Task 16 Deliverable* (05/05/2025) developed by AECOM (Table 3). These values were scaled to the Greater Boston region using the Energy Policy Simulator (EPS) Adjusted 2021 GHG Inventory, included in Table 1 of the memo.



**MA emissions data from MA DEP Appendix C from "Summary by Gas" sheet, modified cells AM43, AN43, and AO43 from AR4 to AR5 values**

https://www.mass.gov/doc/appendix-c-massachusetts-annual-greenhouse-gas-emissions-inventory-1990-2021-with-partial-2022-2023-data/download

*filled with 2021*
*Partial*

| Emissions (MMTCO2E) | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Residential** | 15.1 | 14.3 | 16.4 | 16.5 | 16.3 | 14.8 | 14.5 | 14.4 | 13.2 | 14.0 | 15.7 | 16.0 | 15.9 | 16.4 | 15.0 | 14.9 | 12.8 | 13.5 | 14.4 | 13.9 | 13.6 | 13.6 | 11.8 | 12.3 | 13.6 | 13.5 | 11.3 | 12.2 | 13.3 | 13.6 | 12.1 | 12.5 | *12.9* |
| **Commercial**** | 8.4 | 9.2 | 8.9 | 8.0 | 8.9 | 9.0 | 9.1 | 9.5 | 8.1 | 6.2 | 6.8 | 5.8 | 5.9 | 7.1 | 6.5 | 6.7 | 5.0 | 5.3 | 5.6 | 5.8 | 6.7 | 6.3 | 5.2 | 6.8 | 7.1 | 7.5 | 7.0 | 7.3 | 7.9 | 8.0 | 7.2 | 7.4 | *8.1* |
| **Industrial*** | 5.5 | 4.6 | 6.3 | 6.5 | 5.6 | 4.9 | 4.9 | 5.0 | 4.8 | 5.5 | 5.3 | 6.5 | 6.4 | 4.3 | 4.2 | 4.5 | 4.3 | 4.2 | 3.9 | 3.2 | 3.7 | 3.8 | 3.3 | 3.5 | 3.4 | 3.4 | 3.2 | 3.3 | 3.3 | 3.4 | 3.2 | 3.3 | *3.4* |
| **Transportation** | 28.5 | 26.9 | 26.4 | 26.7 | 26.9 | 27.5 | 28.3 | 28.7 | 29.0 | 29.7 | 30.8 | 30.4 | 30.6 | 31.0 | 32.3 | 32.3 | 31.5 | 31.8 | 30.9 | 29.0 | 29.2 | 29.1 | 28.6 | 29.9 | 28.1 | 28.5 | 28.9 | 28.3 | 29.0 | 28.7 | 22.6 | 25.3 | *25.9* |
| **Electric Power** | 25.3 | 25.9 | 24.4 | 22.0 | 22.3 | 21.4 | 20.9 | 26.2 | 26.7 | 24.0 | 22.2 | 22.0 | 22.9 | 25.0 | 23.7 | 24.5 | 21.6 | 23.7 | 20.2 | 17.6 | 18.3 | 14.4 | 12.1 | 12.7 | 10.8 | 11.3 | 10.7 | 10.3 | 7.6 | 6.2 | 5.7 | 6.1 | *6.8* |
| **Natural Gas Systems (Leaks)** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Industrial Processes** | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | *0.1* |
| **Agriculture & Land Use** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Solid Waste (Electric & Industrial Municipal Waste Combustion)** | 1.0 | 1.1 | 1.2 | 1.3 | 1.4 | 1.4 | 1.5 | 1.5 | 1.5 | 1.5 | 1.7 | 1.8 | 1.8 | 1.8 | 1.8 | 1.9 | 2.0 | 1.9 | 2.2 | 2.1 | 2.4 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 | 1.1 | 1.2 | *1.2* |
| **CO2** | 83.9 | 82.2 | 83.9 | 81.1 | 81.6 | 79.1 | 79.4 | 85.4 | 83.4 | 81.1 | 82.7 | 82.6 | 83.7 | 85.9 | 83.9 | 85.1 | 77.5 | 80.8 | 77.3 | 71.7 | 74.1 | 68.5 | 62.3 | 66.4 | 64.3 | 65.7 | 62.4 | 62.8 | 62.4 | 61.2 | 52.2 | 56.0 | *58.5* |
| **Residential** | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | *0.1* |
| **Commercial** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Industrial** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Electric Power** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Solid Waste (Electric & Industrial Municipal Waste Combustion)** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Transportation** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Natural Gas Systems (Leaks)** | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 | 1.5 | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.2 | 1.2 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 0.9 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | *0.7* |
| **Agriculture & Land Use** | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | *0.1* |
| **Solid Waste (Landfill)** | 2.3 | 2.3 | 2.2 | 2.1 | 2.1 | 2.1 | 1.7 | 1.3 | 1.2 | 1.2 | 0.8 | 0.5 | 0.8 | 1.3 | 1.1 | 1.1 | 1.0 | 0.9 | 0.9 | 0.9 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | *0.2* |
| **Wastewater** | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | *0.3* |
| **CH4** | 5.2 | 5.2 | 5.1 | 4.9 | 4.8 | 4.8 | 4.4 | 3.8 | 3.6 | 3.6 | 2.9 | 2.5 | 2.8 | 3.2 | 3.0 | 2.8 | 2.6 | 2.5 | 2.5 | 2.5 | 2.1 | 1.9 | 1.9 | 1.8 | 1.8 | 1.8 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | *1.3* |
| **Residential** | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Commercial** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Industrial** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Electric Power** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Solid Waste (Electric & Industrial Municipal Waste Combustion)** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Solid Waste (Landfill)** | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | *0.0* |
| **Transportation** | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 0.9 | 0.9 | 0.8 | 0.8 | 0.8 | 0.7 | 0.6 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | *0.3* |
| **Agriculture & Land Use** | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | *0.1* |
| **Wastewater** | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | *0.1* |
| **N2O** | 1.6 | 1.5 | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | 1.6 | 1.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.4 | 1.3 | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 1.0 | 0.9 | 0.9 | 0.9 | 0.8 | 0.8 | 0.7 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | *0.5* |
| Electric Power Transmission and Distribution Systems | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | *0.1* |
| ODS Substitutes | 0.0 | 0.0 | 0.0 | 0.1 | 0.3 | 0.6 | 0.8 | 1.0 | 1.2 | 1.3 | 1.5 | 1.6 | 1.7 | 1.8 | 1.8 | 1.9 | 2.0 | 2.2 | 2.3 | 2.4 | 2.2 | 2.4 | 2.6 | 3.1 | 3.5 | 3.4 | 3.4 | 2.9 | 3.3 | 3.2 | 3.5 | 3.6 | *3.6* |
| Semiconductor Manufacturing | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 | *0.3* |
| **SF6 & Other GHG Gases** | 0.5 | 0.5 | 0.5 | 0.6 | 0.7 | 1.0 | 1.2 | 1.4 | 1.6 | 1.9 | 2.0 | 2.1 | 2.2 | 2.3 | 2.3 | 2.3 | 2.4 | 2.5 | 2.7 | 2.7 | 2.6 | 2.8 | 3.0 | 3.5 | 3.9 | 3.7 | 3.8 | 3.3 | 3.6 | 3.5 | 3.8 | 3.9 | *3.9* |
| **Imported Electric Power (CO2, CH4 & N2O combinec** | 1.9 | 1.2 | 1.5 | 2.2 | 1.9 | 1.9 | 2.1 | 0.9 | 0.9 | 2.2 | 3.1 | 2.7 | 3.4 | 2.7 | 2.9 | 3.4 | 2.6 | 2.2 | 2.7 | 2.7 | 2.4 | 2.8 | 2.6 | 2.6 | 2.9 | 3.1 | 2.8 | 2.1 | 3.3 | 3.4 | 5.9 | 5.1 | *5.1* |
| **Total GHG Emissions** | **93.0** | **90.6** | **92.5** | **90.3** | **90.5** | **88.5** | **88.7** | **93.2** | **91.2** | **90.2** | **92.3** | **91.3** | **93.6** | **95.5** | **93.3** | **94.9** | **86.4** | **89.2** | **86.3** | **80.7** | **82.1** | **77.0** | **70.7** | **75.1** | **73.6** | **75.0** | **71.3** | **70.5** | **71.6** | **70.4** | **64.0** | **67.0** | **69.4** |

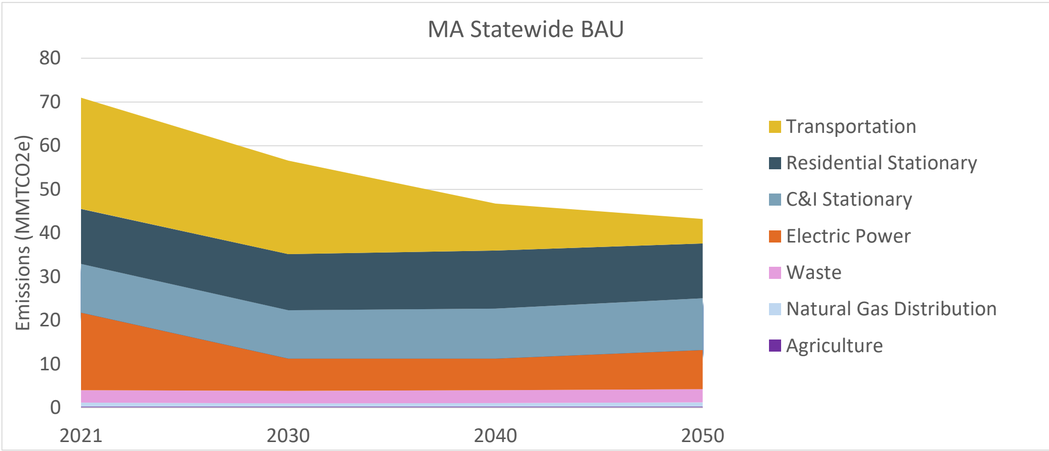
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO2 (Metric Tons CO2)** | 83,895,847 | 82,232,474 | 83,863,533 | 81,132,199 | 81,558,014 | 79,138,614 | 79,415,169 | 85,374,735 | 83,431,043 | 81,053,843 | 82,669,759 | 82,559,101 | 83,728,504 | 85,897,545 | 83,897,375 | 85,123,776 | 77,531,823 | 80,777,660 | 77,317,256 | 71,746,397 | 74,058,219 | 68,529,751 | 62,286,281 | 66,353,334 | 64,306,225 | 65,663,343 | 62,396,613 | 62,766,065 | 62,415,085 | 61,206,245 | 52,168,713 | 55,952,979 | *58,455,607* |
| **CH4 (Metric Tons CH4)** | 184,909 | 186,928 | 183,143 | 175,988 | 172,877 | 171,649 | 155,507 | 135,424 | 129,328 | 126,881 | 104,282 | 87,816 | 100,053 | 115,537 | 105,792 | 99,857 | 93,475 | 88,602 | 88,323 | 89,144 | 73,271 | 67,904 | 68,585 | 65,436 | 62,544 | 63,346 | 60,485 | 58,779 | 58,030 | 58,468 | 56,599 | 52,893 | *48,981* |
| **N2O (Metric Tons N2O)** | 5,904 | 5,644 | 5,798 | 5,754 | 5,845 | 5,944 | 6,144 | 6,153 | 6,073 | 5,796 | 5,775 | 5,619 | 5,351 | 5,217 | 5,006 | 4,888 | 4,775 | 4,450 | 4,211 | 3,862 | 3,628 | 3,569 | 3,273 | 3,302 | 3,160 | 2,859 | 2,587 | 2,430 | 2,333 | 2,442 | 2,136 | 2,055 | *807* |

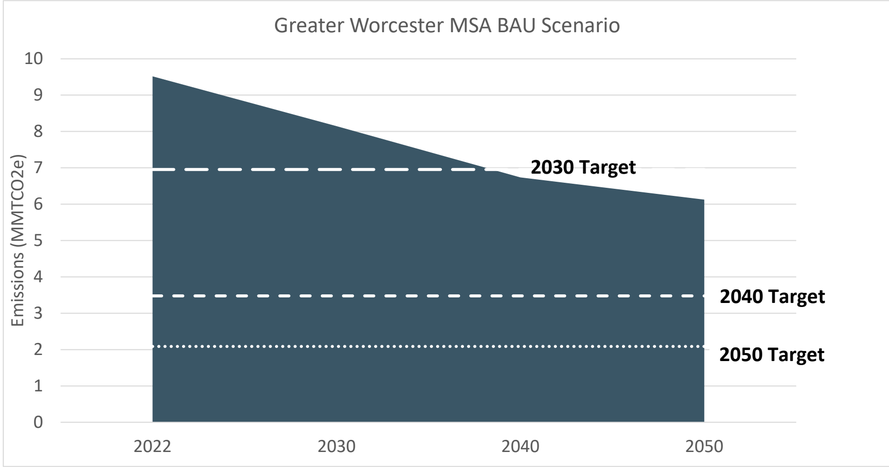
7% Percent that semicond makes up of indutrial proc emissions

| Statewide EPS Adjusted Inventory & BAU from Draft Memo (5/5/25) Table 1 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Gross Total | Residential Stationary | C&I Stationary | Electric Power | Natural Gas Distribution | Transportation | Waste | Agriculture | Natural & Working Lands | Net Total |
| **2021** | 71.0 | 12.560 | 11.170 | 17.760 | 0.950 | 25.470 | 2.800 | 0.260 | -7.120 | 63.850 |
| **2022** | | | | | | | | | | |
| 2030 | 56.58 | 12.84 | 11.07 | 7.38 | 0.74 | 21.42 | 2.87 | 0.26 | -7.120 | 49.460 |
| 2040 | 46.72 | 13.34 | 11.40 | 7.25 | 0.81 | 10.71 | 2.94 | 0.27 | -7.120 | 39.600 |
| 2050 | 43.19 | 12.52 | 11.88 | 8.93 | 0.97 | 5.60 | 3.02 | 0.27 | -7.120 | 36.070 |

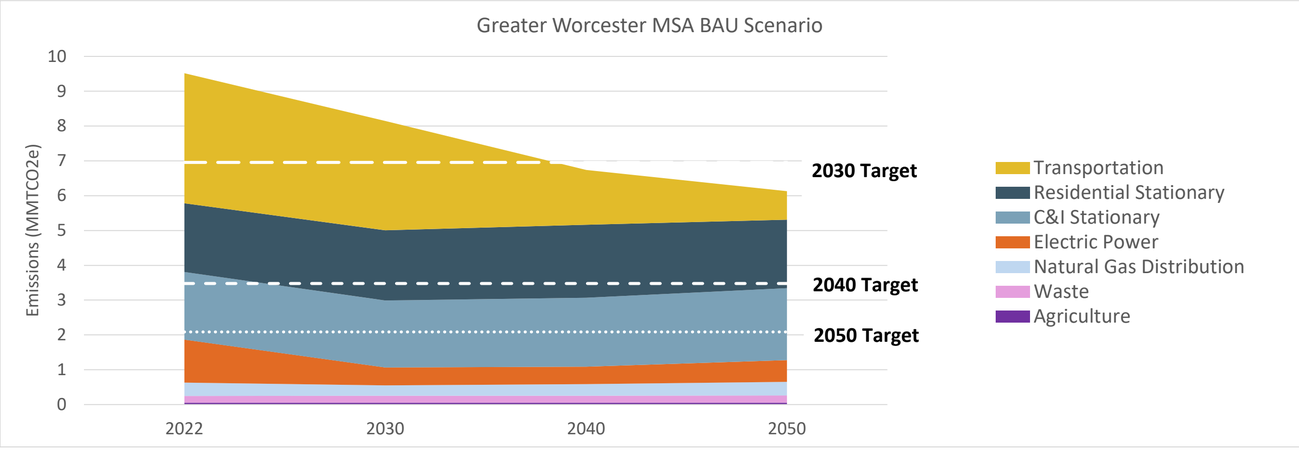
*Values to make target lines in graph*

| State Targets | | |
|---|---|---|
| 2030 | 2040 | 2050 |
| 50% | 75% | 85% |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |




| Scaled to MSA | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Gross Total | Residential Stationary | C&I Stationary | Electric Power | Natural Gas Distribution | Transportation | Waste | Agriculture | Natural & Working Lands | Net Total |
| | | | | | | | | | |
| **9.52** | **1.97** | **1.94** | **1.24** | **0.38** | **3.74** | **0.19** | **0.05** | **-2.83** | 6.69 |
| 8.15 | 2.02 | 1.92 | 0.51 | 0.30 | 3.14 | 0.20 | 0.05 | -2.83 | 5.32 |
| 6.74 | 2.10 | 1.98 | 0.50 | 0.33 | 1.57 | 0.20 | 0.05 | -2.83 | 3.91 |
| 6.13 | 1.97 | 2.07 | 0.62 | 0.39 | 0.82 | 0.21 | 0.05 | -2.83 | 3.30 |



| Year | MA DEP GHG Inventory Data (see hidden sheet called "State Emissions Data") Total | Residential Stationary | C&I Stationary | Electric Power | Electric T&D | Natural Gas System (Leaks) | Transportation | Solid Waste | Wastewater | Agriculture & Land Use |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 90.8 | 15.314 | 13.864 | 25.351 | 0.388 | 1.868 | 29.582 | 3.299 | 0.662 | 0.446 |
| 1991 | 89.5 | 14.519 | 13.778 | 26.383 | 0.372 | 1.846 | 28.008 | 3.515 | 0.639 | 0.398 |
| 1992 | 91.0 | 16.637 | 15.227 | 24.890 | 0.372 | 1.833 | 27.563 | 3.464 | 0.636 | 0.402 |
| 1993 | 88.0 | 16.765 | 14.475 | 22.399 | 0.351 | 1.754 | 27.772 | 3.467 | 0.636 | 0.417 |
| 1994 | 88.4 | 16.580 | 14.451 | 22.717 | 0.328 | 1.698 | 28.043 | 3.514 | 0.636 | 0.385 |
| 1995 | 85.9 | 14.981 | 13.869 | 21.811 | 0.297 | 1.664 | 28.705 | 3.502 | 0.637 | 0.390 |
| 1996 | 87.5 | 14.783 | 13.939 | 23.072 | 0.268 | 1.585 | 29.563 | 3.305 | 0.640 | 0.385 |
| 1997 | 91.7 | 14.565 | 14.428 | 27.182 | 0.245 | 1.534 | 29.898 | 2.848 | 0.644 | 0.380 |
| 1998 | 89.5 | 13.355 | 12.827 | 27.758 | 0.204 | 1.475 | 30.181 | 2.736 | 0.648 | 0.361 |
| 1999 | 88.4 | 14.185 | 11.678 | 26.316 | 0.209 | 1.416 | 30.790 | 2.758 | 0.653 | 0.355 |
| 2000 | 90.2 | 15.873 | 12.139 | 25.380 | 0.205 | 1.378 | 31.934 | 2.518 | 0.433 | 0.358 |
| 2001 | 89.2 | 16.199 | 12.250 | 24.779 | 0.206 | 1.308 | 31.431 | 2.271 | 0.438 | 0.348 |
| 2002 | 91.3 | 16.120 | 12.289 | 26.372 | 0.195 | 1.271 | 31.575 | 2.634 | 0.436 | 0.401 |
| 2003 | 93.2 | 16.601 | 11.461 | 27.831 | 0.193 | 1.218 | 31.976 | 3.148 | 0.437 | 0.354 |
| 2004 | 91.0 | 15.197 | 10.778 | 26.685 | 0.187 | 1.203 | 33.215 | 2.945 | 0.438 | 0.345 |
| 2005 | 92.6 | 15.027 | 11.181 | 28.010 | 0.180 | 1.110 | 33.176 | 3.071 | 0.451 | 0.368 |
| 2006 | 83.9 | 12.930 | 9.344 | 24.233 | 0.162 | 1.070 | 32.288 | 2.983 | 0.442 | 0.466 |
| 2007 | 86.6 | 13.614 | 9.585 | 25.973 | 0.150 | 1.027 | 32.542 | 2.812 | 0.445 | 0.455 |
| 2008 | 83.6 | 14.492 | 9.503 | 22.953 | 0.148 | 1.011 | 31.540 | 3.128 | 0.444 | 0.338 |
| 2009 | 77.9 | 13.996 | 8.992 | 20.388 | 0.132 | 0.960 | 29.588 | 3.104 | 0.448 | 0.310 |
| 2010 | 79.4 | 13.738 | 10.393 | 20.785 | 0.115 | 0.963 | 29.777 | 2.901 | 0.411 | 0.325 |
| 2011 | 74.0 | 13.770 | 10.159 | 17.154 | 0.103 | 0.800 | 29.714 | 1.613 | 0.416 | 0.301 |
| 2012 | 67.6 | 11.922 | 8.513 | 14.737 | 0.089 | 0.799 | 29.129 | 1.659 | 0.414 | 0.291 |
| 2013 | 71.5 | 12.428 | 10.224 | 15.272 | 0.085 | 0.784 | 30.369 | 1.615 | 0.416 | 0.302 |
| 2014 | 69.6 | 13.737 | 10.532 | 13.671 | 0.086 | 0.760 | 28.527 | 1.595 | 0.416 | 0.305 |
| 2015 | 71.2 | 13.637 | 10.947 | 14.468 | 0.075 | 0.789 | 28.936 | 1.606 | 0.419 | 0.284 |
| 2016 | 67.4 | 11.391 | 10.149 | 13.500 | 0.077 | 0.768 | 29.271 | 1.592 | 0.421 | 0.230 |
| 2017 | 67.1 | 12.355 | 10.584 | 12.446 | 0.075 | 0.735 | 28.686 | 1.507 | 0.412 | 0.266 |
| 2018 | 67.8 | 13.401 | 11.145 | 10.970 | 0.070 | 0.720 | 29.325 | 1.509 | 0.416 | 0.258 |
| 2019 | 66.8 | 13.743 | 11.434 | 9.637 | 0.080 | 0.716 | 29.078 | 1.409 | 0.417 | 0.249 |
| 2020 | 60.1 | 12.204 | 10.387 | 11.642 | 0.076 | 0.741 | 22.943 | 1.454 | 0.425 | 0.212 |
| 2021 | 63.0 | 12.587 | 10.672 | 11.265 | 0.077 | 0.715 | 25.607 | 1.428 | 0.419 | 0.194 |
| 2022 | 62.1 | 13.001 | 8.154 | 11.928 | 0.077 | 0.734 | 26.189 | 1.428 | 0.419 | 0.180 |
| 2023 | | | | | | | | | | |
| 2024 | | | | | | | | | | |
| 2025 | | | | | | | | | | |
| 2026 | | | | | | | | | | |
| 2027 | | | | | | | | | | |
| 2028 | | | | | | | | | | |
| 2029 | | | | | | | | | | |
| 2030 | | | | | | | | | | |
| 2031 | | | | | | | | | | |
| 2032 | | | | | | | | | | |
| 2033 | | | | | | | | | | |
| 2034 | | | | | | | | | | |
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| 2039 | | | | | | | | | | |
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| 2041 | | | | | | | | | | |
| 2042 | | | | | | | | | | |
| 2043 | | | | | | | | | | |
| 2044 | | | | | | | | | | |
| 2045 | | | | | | | | | | |
| 2046 | | | | | | | | | | |
| 2047 | | | | | | | | | | |
| 2048 | | | | | | | | | | |
| 2049 | | | | | | | | | | |
| 2050 | | | | | | | | | | |

| MA DEP Inventory Sectors/Sources Organized (combined multiple sources into a single source for Electric and Waste) Gross Total | Residential Stationary | C&I Stationary | Electric Power | Natural Gas Distribution | Transportation | Waste | Agriculture |
|---|---|---|---|---|---|---|---|
| 90.8 | 15.314 | 13.864 | **25.738** | 1.868 | 29.582 | **3.960** | 0.446 |
| 89.5 | 14.519 | 13.778 | **26.755** | 1.846 | 28.008 | **4.154** | 0.398 |
| 91.0 | 16.637 | 15.227 | **25.262** | 1.833 | 27.563 | **4.100** | 0.402 |
| 88.0 | 16.765 | 14.475 | **22.750** | 1.754 | 27.772 | **4.103** | 0.417 |
| 88.4 | 16.580 | 14.451 | **23.044** | 1.698 | 28.043 | **4.150** | 0.385 |
| 85.9 | 14.981 | 13.869 | **22.108** | 1.664 | 28.705 | **4.139** | 0.390 |
| 87.5 | 14.783 | 13.939 | **23.340** | 1.585 | 29.563 | **3.945** | 0.385 |
| 91.7 | 14.565 | 14.428 | **27.428** | 1.534 | 29.898 | **3.493** | 0.380 |
| 89.5 | 13.355 | 12.827 | **27.963** | 1.475 | 30.181 | **3.384** | 0.361 |
| 88.4 | 14.185 | 11.678 | **26.525** | 1.416 | 30.790 | **3.411** | 0.355 |
| 90.2 | 15.873 | 12.139 | **25.885** | 1.378 | 31.934 | **2.951** | 0.358 |
| 89.2 | 16.199 | 12.250 | **24.985** | 1.308 | 31.431 | **2.709** | 0.348 |
| 91.3 | 16.120 | 12.289 | **26.567** | 1.271 | 31.575 | **3.070** | 0.401 |
| 93.2 | 16.601 | 11.461 | **28.024** | 1.218 | 31.976 | **3.585** | 0.354 |
| 91.0 | 15.197 | 10.778 | **26.872** | 1.203 | 33.215 | **3.383** | 0.345 |
| 92.6 | 15.027 | 11.181 | **28.190** | 1.110 | 33.176 | **3.522** | 0.368 |
| 83.9 | 12.930 | 9.344 | **24.395** | 1.070 | 32.288 | **3.425** | 0.466 |
| 86.6 | 13.614 | 9.585 | **26.123** | 1.027 | 32.542 | **3.257** | 0.455 |
| 83.6 | 14.492 | 9.503 | **23.100** | 1.011 | 31.540 | **3.572** | 0.338 |
| 77.9 | 13.996 | 8.992 | **20.520** | 0.960 | 29.588 | **3.552** | 0.310 |
| 79.4 | 13.738 | 10.393 | **20.899** | 0.963 | 29.777 | **3.312** | 0.325 |
| 74.0 | 13.770 | 10.159 | **17.256** | 0.800 | 29.714 | **2.029** | 0.301 |
| 67.6 | 11.922 | 8.513 | **14.826** | 0.799 | 29.129 | **2.073** | 0.291 |
| 71.5 | 12.428 | 10.224 | **15.356** | 0.784 | 30.369 | **2.031** | 0.302 |
| 69.6 | 13.737 | 10.532 | **13.756** | 0.760 | 28.527 | **2.011** | 0.305 |
| 71.2 | 13.637 | 10.947 | **14.543** | 0.789 | 28.936 | **2.025** | 0.284 |
| 67.4 | 11.391 | 10.149 | **13.577** | 0.768 | 29.271 | **2.013** | 0.230 |
| 67.1 | 12.355 | 10.584 | **12.521** | 0.735 | 28.686 | **1.919** | 0.266 |
| 67.8 | 13.401 | 11.145 | **11.041** | 0.720 | 29.325 | **1.925** | 0.258 |
| 66.8 | 13.743 | 11.434 | **9.716** | 0.716 | 29.078 | **1.827** | 0.249 |
| 60.1 | 12.204 | 10.387 | **11.718** | 0.741 | 22.943 | **1.878** | 0.212 |
| 63.0 | 12.587 | 10.672 | **11.342** | 0.715 | 25.607 | **1.847** | 0.194 |
| 62.1 | 13.001 | 8.154 | **12.005** | 0.734 | 26.189 | **1.847** | 0.180 |

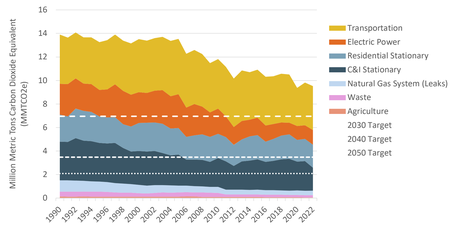
| Greater Worcester Estimated Historic Emissions (Step 1) Ratios with historic values Total | Residential Stationary | C&I Stationary | Electric Power | Natural Gas System (Leaks) | Transportation | Waste | Agriculture | SUM |
|---|---|---|---|---|---|---|---|---|
| 13.91 | 2.32 | 3.30 | 2.65 | 0.98 | 4.22 | 0.41 | 0.13 | 14.02 |
| 13.71 | 2.20 | 3.28 | 2.75 | 0.96 | 3.99 | 0.44 | 0.12 | 13.75 |
| 13.95 | 2.52 | 3.63 | 2.60 | 0.96 | 3.93 | 0.43 | 0.12 | 14.19 |
| 13.49 | 2.54 | 3.45 | 2.34 | 0.92 | 3.96 | 0.43 | 0.13 | 13.77 |
| 13.54 | 2.52 | 3.44 | 2.37 | 0.89 | 4.00 | 0.43 | 0.12 | 13.77 |
| 13.16 | 2.27 | 3.30 | 2.27 | 0.87 | 4.09 | 0.43 | 0.12 | 13.37 |
| 13.42 | 2.24 | 3.32 | 2.40 | 0.83 | 4.22 | 0.41 | 0.12 | 13.54 |
| 14.06 | 2.21 | 3.44 | 2.82 | 0.80 | 4.26 | 0.37 | 0.11 | 14.02 |
| 13.72 | 2.03 | 3.06 | 2.88 | 0.77 | 4.30 | 0.35 | 0.11 | 13.50 |
| 13.83 | 2.41 | 2.89 | 2.63 | 0.72 | 4.55 | 0.31 | 0.11 | 13.62 |
| 13.67 | 2.46 | 2.92 | 2.57 | 0.68 | 4.48 | 0.28 | 0.11 | 13.50 |
| 13.99 | 2.45 | 2.93 | 2.73 | 0.66 | 4.50 | 0.32 | 0.12 | 13.72 |
| 14.29 | 2.52 | 2.73 | 2.88 | 0.64 | 4.56 | 0.38 | 0.11 | 13.81 |
| 13.94 | 2.31 | 2.57 | 2.77 | 0.63 | 4.74 | 0.35 | 0.10 | 13.46 |
| 14.19 | 2.28 | 2.66 | 2.90 | 0.58 | 4.73 | 0.37 | 0.11 | 13.64 |
| 12.86 | 1.96 | 2.23 | 2.51 | 0.56 | 4.61 | 0.36 | 0.14 | 12.36 |
| 13.27 | 2.07 | 2.28 | 2.69 | 0.54 | 4.64 | 0.34 | 0.14 | 12.69 |
| 12.80 | 2.20 | 2.26 | 2.38 | 0.53 | 4.50 | 0.37 | 0.10 | 12.34 |
| 11.94 | 2.12 | 2.14 | 2.11 | 0.50 | 4.22 | 0.37 | 0.09 | 11.56 |
| 12.17 | 2.08 | 2.48 | 2.15 | 0.50 | 4.25 | 0.35 | 0.10 | 11.91 |
| 11.34 | 2.09 | 2.42 | 1.78 | 0.42 | 4.24 | 0.21 | 0.09 | 11.24 |
| 10.35 | 1.81 | 2.03 | 1.53 | 0.42 | 4.15 | 0.22 | 0.09 | 10.24 |
| 10.96 | 1.89 | 2.44 | 1.58 | 0.41 | 4.33 | 0.21 | 0.09 | 10.95 |
| 10.67 | 2.08 | 2.51 | 1.42 | 0.40 | 4.07 | 0.21 | 0.09 | 10.78 |
| 10.90 | 2.07 | 2.61 | 1.50 | 0.41 | 4.13 | 0.21 | 0.09 | 11.01 |
| 10.33 | 1.73 | 2.42 | 1.40 | 0.40 | 4.17 | 0.21 | 0.07 | 10.40 |
| 10.28 | 1.87 | 2.52 | 1.29 | 0.38 | 4.09 | 0.20 | 0.08 | 10.44 |
| 10.39 | 2.03 | 2.65 | 1.14 | 0.38 | 4.18 | 0.20 | 0.08 | 10.66 |
| 10.23 | 2.09 | 2.72 | 1.00 | 0.37 | 4.15 | 0.19 | 0.08 | 10.60 |
| 9.21 | 1.85 | 2.47 | 1.21 | 0.39 | 3.27 | 0.20 | 0.06 | 9.45 |
| 9.65 | 1.91 | 2.54 | 1.17 | 0.37 | 3.65 | 0.19 | 0.06 | 9.90 |
| **9.52** | **1.97** | **1.94** | **1.24** | **0.38** | **3.74** | **0.19** | **0.05** | 9.52 |

| Greater Worcester Estimated Historic Emissions (Step 2) Adjusted to correct sum and filled gaps between 2030, 2040, and 2050 with linear forecast Total | Residential Stationary | C&I Stationary | Electric Power | Natural Gas System (Leaks) | Transportation | Waste | Agriculture |
|---|---|---|---|---|---|---|---|
| **13.91** | 2.31 | 3.28 | 2.63 | 0.97 | 4.19 | 0.41 | 0.13 |
| **13.71** | 2.19 | 3.26 | 2.73 | 0.96 | 3.96 | 0.43 | 0.12 |
| **13.95** | 2.51 | 3.60 | 2.58 | 0.95 | 3.90 | 0.43 | 0.12 |
| **13.49** | 2.52 | 3.42 | 2.32 | 0.91 | 3.93 | 0.43 | 0.13 |
| **13.54** | 2.50 | 3.42 | 2.35 | 0.88 | 3.97 | 0.43 | 0.12 |
| **13.16** | 2.26 | 3.28 | 2.26 | 0.86 | 4.06 | 0.43 | 0.12 |
| **13.42** | 2.23 | 3.29 | 2.38 | 0.82 | 4.18 | 0.41 | 0.12 |
| **14.06** | 2.19 | 3.41 | 2.80 | 0.80 | 4.23 | 0.36 | 0.11 |
| **13.72** | 2.01 | 3.03 | 2.86 | 0.76 | 4.27 | 0.35 | 0.11 |
| **13.54** | 2.14 | 2.75 | 2.71 | 0.73 | 4.36 | 0.35 | 0.11 |
| **13.83** | 2.39 | 2.87 | 2.61 | 0.71 | 4.52 | 0.31 | 0.11 |
| **13.67** | 2.44 | 2.90 | 2.55 | 0.68 | 4.45 | 0.28 | 0.10 |
| **13.99** | 2.43 | 2.90 | 2.71 | 0.66 | 4.47 | 0.32 | 0.12 |
| **14.29** | 2.50 | 2.71 | 2.86 | 0.63 | 4.52 | 0.37 | 0.11 |
| **13.94** | 2.29 | 2.55 | 2.74 | 0.62 | 4.70 | 0.35 | 0.10 |
| **14.19** | 2.26 | 2.64 | 2.88 | 0.58 | 4.69 | 0.37 | 0.11 |
| **12.86** | 1.95 | 2.21 | 2.49 | 0.55 | 4.57 | 0.36 | 0.14 |
| **13.27** | 2.05 | 2.27 | 2.67 | 0.53 | 4.61 | 0.34 | 0.14 |
| **12.80** | 2.18 | 2.25 | 2.36 | 0.52 | 4.46 | 0.37 | 0.10 |
| **11.94** | 2.11 | 2.13 | 2.10 | 0.50 | 4.19 | 0.37 | 0.09 |
| **12.17** | 2.07 | 2.46 | 2.13 | 0.50 | 4.21 | 0.34 | 0.10 |
| **11.34** | 2.07 | 2.40 | 1.76 | 0.41 | 4.20 | 0.21 | 0.09 |
| **10.35** | 1.80 | 2.01 | 1.51 | 0.41 | 4.12 | 0.22 | 0.09 |
| **10.96** | 1.87 | 2.42 | 1.57 | 0.41 | 4.30 | 0.21 | 0.09 |
| **10.67** | 2.07 | 2.49 | 1.40 | 0.39 | 4.04 | 0.21 | 0.09 |
| **10.90** | 2.05 | 2.59 | 1.48 | 0.41 | 4.09 | 0.21 | 0.09 |
| **10.33** | 1.72 | 2.40 | 1.39 | 0.40 | 4.14 | 0.21 | 0.07 |
| **10.28** | 1.86 | 2.50 | 1.28 | 0.38 | 4.06 | 0.20 | 0.08 |
| **10.39** | 2.02 | 2.63 | 1.13 | 0.37 | 4.15 | 0.20 | 0.08 |
| **10.23** | 2.07 | 2.70 | 0.99 | 0.37 | 4.11 | 0.19 | 0.07 |
| **9.21** | 1.84 | 2.45 | 1.20 | 0.38 | 3.25 | 0.20 | 0.06 |
| **9.65** | 1.90 | 2.52 | 1.16 | 0.37 | 3.62 | 0.19 | 0.06 |
| **9.52** | **1.97** | **1.94** | **1.24** | **0.38** | **3.74** | **0.19** | **0.05** |
| **9.35** | 1.98 | 1.94 | 1.15 | 0.37 | 3.66 | 0.19 | 0.05 |
| **9.17** | 1.98 | 1.94 | 1.05 | 0.36 | 3.59 | 0.19 | 0.05 |
| **9.00** | 1.99 | 1.94 | 0.96 | 0.35 | 3.51 | 0.20 | 0.05 |
| **8.83** | 1.99 | 1.93 | 0.87 | 0.34 | 3.44 | 0.20 | 0.05 |
| **8.66** | 2.00 | 1.93 | 0.78 | 0.33 | 3.36 | 0.20 | 0.05 |
| **8.49** | 2.01 | 1.93 | 0.69 | 0.32 | 3.29 | 0.20 | 0.05 |
| **8.32** | 2.01 | 1.93 | 0.60 | 0.31 | 3.22 | 0.20 | 0.05 |
| **8.15** | **2.02** | **1.92** | **0.51** | **0.30** | **3.14** | **0.20** | **0.05** |
| **8.01** | 2.02 | 1.93 | 0.51 | 0.30 | 2.98 | 0.20 | 0.05 |
| **7.87** | 2.03 | 1.94 | 0.51 | 0.30 | 2.83 | 0.20 | 0.05 |
| **7.72** | 2.04 | 1.94 | 0.51 | 0.31 | 2.67 | 0.20 | 0.05 |
| **7.58** | 2.05 | 1.95 | 0.51 | 0.31 | 2.51 | 0.20 | 0.05 |
| **7.44** | 2.06 | 1.95 | 0.51 | 0.31 | 2.36 | 0.20 | 0.05 |
| **7.30** | 2.06 | 1.96 | 0.51 | 0.32 | 2.20 | 0.20 | 0.05 |
| **7.16** | 2.07 | 1.96 | 0.51 | 0.32 | 2.04 | 0.20 | 0.05 |
| **7.02** | 2.08 | 1.97 | 0.51 | 0.32 | 1.88 | 0.20 | 0.05 |
| **6.88** | 2.09 | 1.98 | 0.51 | 0.32 | 1.73 | 0.20 | 0.05 |
| **6.74** | **2.10** | **1.98** | **0.50** | **0.33** | **1.57** | **0.20** | **0.05** |
| **6.68** | 2.08 | 1.99 | 0.52 | 0.33 | 1.50 | 0.20 | 0.05 |
| **6.62** | 2.07 | 2.00 | 0.53 | 0.34 | 1.42 | 0.20 | 0.05 |
| **6.55** | 2.06 | 2.01 | 0.54 | 0.35 | 1.35 | 0.20 | 0.05 |
| **6.49** | 2.04 | 2.02 | 0.55 | 0.35 | 1.27 | 0.21 | 0.05 |
| **6.43** | 2.03 | 2.02 | 0.56 | 0.36 | 1.20 | 0.21 | 0.05 |
| **6.37** | 2.02 | 2.03 | 0.57 | 0.37 | 1.12 | 0.21 | 0.05 |
| **6.31** | 2.01 | 2.04 | 0.59 | 0.37 | 1.05 | 0.21 | 0.05 |
| **6.25** | 1.99 | 2.05 | 0.60 | 0.38 | 0.97 | 0.21 | 0.05 |
| **6.19** | 1.98 | 2.06 | 0.61 | 0.39 | 0.90 | 0.21 | 0.05 |
| **6.13** | **1.97** | **2.07** | **0.62** | **0.39** | **0.82** | **0.21** | **0.05** |

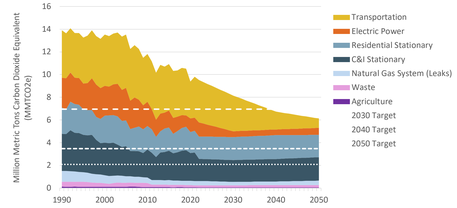
*Values to make target lines in graph*

| State Targets 2030 | 2040 | 2050 |
|---|---|---|
| 50% | 75% | 85% |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |
| 7.0 | 3.5 | 2.1 |

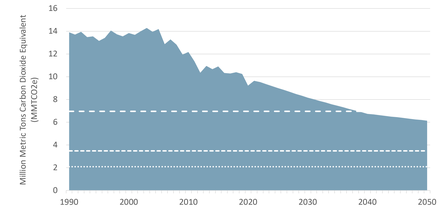
Greater Worcester Estimated Historic Emissions




Greater Worcester Estimated Historic and Future Emissions (BAU)




Greater Worcester Estimated Historic and Future Emissions (BAU)



| Sector | Number | Measure | 2030 | 2040 | 2050 | Total by Sector 2030 | Total by Sector 2040 | Total by Sector 2050 |
|---|---|---|---|---|---|---|---|---|
| Waste and Materials Management | WMM1. Organics Waste Diversion | By 2050 Divert 95% of all organic waste produced within the MSA from landfilling and into composting or anerobic digestion. This will be started through an elementary, middle and high school climate program to educate students on waste prevention, reduction, recycling, and reuse, as well as sutainable degrowth practices that can be implemented at an individual level. This educational strategy will focus on all aspects of climate change throughout the childs time within the school system. In conjuction with this educational program schools will also establish policies and procedures for internal waste seperation as part of this holistic education (leading by example by seperating food waste from cafeteria from general trash, as well as recyclable waste) as well as establishing school or school district composting or anerobic digestion program to accept school organic waste or from students bringing from home compostables/organic waste with them and school gardens that accept the compost/digestate from offsite or onsight facilities This will foster a whole of society approch and response | 286 | | 5,440 | | | |
| Waste and Materials Management | WMM2. Anerobic Digestion | By 2050 Divert power generation away from fossil fuels through installation of anerobic digesters at municipal facilities such as wastewater treatment plants, technical schools, technical colleges, and other public institutions as well as and other urban and rural agricultural projects that generate energy for 10% of electricity/power use in the region in 2050. | 13,537 | | 96,704 | | | |
| Waste and Materials Management | WMM3. Comprehensive Extended Producer Responsibilities Legislation | Extended Producer Responsibilities (EPR) Legislation That tackles all aspects of producer responsibility for end of life of products sold in the MSA including: A ban on single use plastics; packaging and plastic waste directives that set targets for recovery and recycling of 95% of plastic waste produced in the MSA by 2050, requireing the use of 100% recycled and recylable/compostable materials in single use objects, requiring packaging comply with essential requirements minimizing packaging volume and weight, as well as design to to permit its reuse and recovery following the model of the European Packaging and Waste Directive 94/62/EC and/ or California's Plastic Pollution Prevention and Packaging Producer Responsibility Act (SB 54) | 553 | | 10,498 | | | |
| Waste and Materials Management | WMM4. Comprehensive Unit Based Pricing Legislation | Unit Based Pricing (UBP) or Pay-As-You-Throw (PAYT) Program Adoption throughout the MSA for Residential, Municipal, Commercial, and Industrial waste producers would reduce between 40-60% of the waste generated in the MSA, and utilize existing transfer stations for sortation, reducing Vehicle Miles Traveled by a corresponding amount through Co-Collection (where seperately bagged organics/compostables, recyclables, single use plastics, glass, and MSW are collected on the same day from the same bin) and transported to the transfer stations to be sorted, creating valuble feedstocks for a circular economy. By 2050 have full adoption across the MSA. | 8,102 | | 14,182 | 22,772 | - | 132,115 |
| Waste and Materials Management | WMM5. Regional Resource Recovery Network | Build and manage a MSA wide resource recovery network of facilities that can fulfil the following functions: operate as a regionwide end point or points for organic materials utilizing Anerobic Digestion capable of processing 350,000 tons or organic waste and food waste per year; that can intake MSW or recyclable/ recoverable materials of varying levels of contamination from transfer stations across the MSA and the northeast region at one end and decontaminate, seperate, and process that waste into reusable products or products that can be shipped elsewhere for further processing into reusable products or final disposal at the other end; municipally supported re-use stores for deconstructed materials and bulky recoverable/reusable goods like furniture and appliances; glass grinding facilities to make ground glass pozzolans for green concrete; electric smelting facilities to turn scrap metals into recycled materials to be resold locally, and other materials recovery facilities and other processes not listed here. By creating this localized nework for these waste streams we can reduce VMT by utilizing existing tansfer stations across the MSA to the ship to these facilities within the MSA and by leverageing shortend distances to these facilities and existing and new frieght rail service with the goal to reduce vehicle miles travelled by waste haulers by 25-50% by 2050.This network of facilities should create a usable end source material for a variety of products based on their inputs: Seperated scrap metal and aluminum to recycled steel and aluminum stock produced locally; from spent single use and old batteries recoverable rare metals to make into new batteries; from organic waste anerobic digestion for onsite power generation and heating and organic fertilizer produced locally; particle board, chip board, and engineered lumber products from wood waste and C+D materials produced locally; This network should act as a laboratory for innovation in waste reuse, recycling and recovery. By utilizing locally recovered materials we can reduce the | 294 | | 5,291 | | | |
| Electricity Generation and/or Use | EGU1. Solar Power Generation | Divert power generation away from fossil fuels through installation of 11.882441TWh of solar generation and storage systems over already-paved or underutilized surfaces (including parking lot canopies, brownfields, landfills, and rooftops) that generate energy for 10% of electricity/power use in the region in 2050. | | | | | | |
| Electricity Generation and/or Use | EGU2. Wind Power Generation | Divert power generation away from fossil fuels through expanding onshore wind energy production; install 20.585784 TWh of onshore wind turbine systems which generate energy for 15% of electricity/power use in the region in 2050. Tap the MSA into offshore wind production which is from the broader northeast USA region that generates energy for 20% of electricity/power use in the MSA in 2050, with wind power in total making up 35% of the total power utilized in the region. Promotion Statewide? | | | | | | |
| Electricity Generation and/or Use | EGU3. Nuclear Power Generation | If proven feasible, install 1 small-scale modular nuclear reactors which generate energy for 7% of electricity/power use in the region in 2050. Tap the MSA into nuclear energy production which is from the broader northeast USA region that generates energy for 13% of electricity/power use in the MSA in 2050. | 446,717 | 1,003,201 | 1,837,374 | 446,717 | 1,003,201 | 1,837,374 |
| Electricity Generation and/or Use | EGU4. Battery Energy Storage Systems | Support the diversion of power generation away from fossil fuels by installing battery storage systems that store power produced by intermittent renewable energy sources such as solar and wind by 2050. The goal would be to store 1% of the regions power needs, reducing reliance on external power needs. Additionally, utilized pumped water energy storage systems paired with hydro to store an additional 1% of the region's power needs. Quantification of emissions reductions for this strategy is covered by the solar, wind, and hydro strategies. | | | | | | |
| Electricity Generation and/or Use | EGU5. Hydro-Power Solutions | Divert power generation away from fossil fuels through installing 0.520588 TWh of additional hydropower and micro-hydropower systems that generate energy for 1% of electricity/power use in the region in 2050, using dams along rivers and old mill ponds to generate electricity. Tap the MSA into hydropower which is from the broader northeast North America region which generates energy for 25% of electricity/power use in the MSA in 2050. This would in total account for 26% of all power utilized in the region. | | | | | | |

| Total MMTCO2e Reductions | | | | |
|---|---|---|---|---|
| Total | 2030 | 1.9 | 2050 | 5.4 |
| Total excluding existing carbon sequestration | 2030 | 1.9 | 2050 | 5.3 |
| **Values Below Used in Projection Graph** | | | | |
| **Emissions reductions (excluding all sequestration)** | **2030** | **1.7** | **2050** | **4.8** |
| **Carbon Sequestration Total** | **2030** | **0.2** | **2050** | **0.6** |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Transportation | T1. Alternatives to Personal Vehicle Usage | Implement e-bike and bike share programs; expand the network of separated and safe bike lanes; improve sidewalks, crosswalks, and intersections for all road users, especially along corridors in high-crash locations; expand bike racks and bike facilities in the region and fill needed gaps; address network gaps to accomodate bicycle and pedestrian modes; expand shared-use paths to improve first- and last-mile trips; and expand efforts on Safe Routes to School and Complete Streets projects.<br><br>Electrify all transit buses in each RTA by 2050; continue or begin funding fare-free for all users in each RTA by 2050; implement Bus Rapid Transit (BRT) in the City of Worcester; install bike racks on all buses by 2050 and related infrastructure at transit hubs; expand and electrify VIA micro-transit options and similar micro-transit options in the region.<br><br>Support the development of Compass Rail and other MBTA passenger rail systems; support the expansion and improvement of Union Station to support passenger rail capacity and user experience/accessibility; improve, expand, and electrify intercity bus services in the region (i.e., Peter Pan between Worcester to Providence). | 133,323 | | 266,646 | 663,737 | | 1,275,788 |
| Transportation | T2. Expand and Improve Public Transit | Support the full electrification of transit buses and either continue or begin the funding of fare-free transit for all users. Implement a Bus Rapid Transit (BRT) system in the City of Worcester to offer fast, more reliable service to help further reduce car dependency. Fully electrify micro-transit services, such as on-demand shuttles and senior van services, to provide convenient alternatives to personal vehicles.<br><br>Support the investment in regional passenger rail, including Compass Rail and other MBTA passenger rail systems, in the Greater Worcester region. In addition, continue to make improvements and modernizations of the WRTA Union Station to support rail capacity, user experience, and accessibility. Moreover, electrify intercity bus routes (i.e., Peter Pan) to offer efficient, low-emission travel between cities. | 3,155 | 343 | 15,829 | | | |
| Transportation | T3. Alternative Fuel Charging Infrastructure | Expansion of public charging infrastructure at municipally-owned buildings and identify other public EV charging locations near multifamily housing and commercial centers, especially in LIDAC and rural communities. Municipalities must develop a regional EV charging network strategy or plan to identify suitable locations for EV charging stations; identify EVSE companies and utilities to build and operate the charging infrastructure; explore incentives and funding programs install, operate, and maintain charging infrastructure; and educate residents about how to use EV chargers and clearly communicate guidelines for using public chargers. Municipalities must determine grid upgrades, as necessary, in order to install the necessary chargers at each location. This could and should be done within the strategy or plan. | 521,092 | | 959,370 | | | |
| Transportation | T4. Adoption of Zero Emission Light-Duty Vehicles | Increase the adoption of zero emission passenger and light-duty municipal vehicles. About 100% of municipal passenger and light-duty vehicle fleet converts to all-electric by 2050. At the end of useful life, all converted electric vehicles must be replaced with similar zero-emission vehicles. Steps to take include education, identifying incentives and rebates, technical assistance, identifying EVSE companies and utilities to work with, and developing dashboards that identify charging infrastructure locations. | 3,971 | | 22,466 | | | |
| Transportation | T5. Adoption of Zero Emission Medium- and Heavy-Duty Vehicles | Increase the adoption of zero emission medium- and heavy-duty municipal vehicles, as able. Municipalities must convert at least 75% all medium- and heavy-duty fleet to all-electric or an alternative fuel vehicle (i.e., bio-diesel, propane, CNG) by 2050. At the end of useful life, all converted alternative fuel vehicles must be replaced with similar alternative fuel vehicles. Steps to take include education, identifying incentives and rebates, technical assistance and support, identifying EVSE companies and utilities to work with, garage infrastructure upgrades, and workforce development. | 2,196 | | 11,477 | | | |
| Agricultural/Natural/Working Lands | ANWL1. Establish an urban tree and shrub planting program | Establish an ongoing program to support native tree and shrub planting in urban communities in the MSA. Focus on planting native species that require little maintenance or may be better suited for the local environment. Prioritize planting 5% additional tree cover in public areas with little native tree and shrub coverage in Fitchburg, Gardner, Leominster, Southbridge, Webster, and Worcester in MA, as well as Windham in CT. | 3,186 | | 23,897 | | | |
| Agricultural/Natural/Working Lands | ANWL2. Permanently protect 300 acres of forestland in MA and CT by 2050 | Permanently protect 300 acres of forestland in MA and CT by 2050 through the use of Conservation Restrictions in MA and Conservation Easements in CT. Encourage additional limited protections of forestland in MA through the use of the Chapter 61 program. | 16,545 | | 66,180 | | | |
| Agricultural/Natural/Working Lands | ANWL3. Establish a Resiliency Garden Program for private homeowners to convert portions of their yard into climate-smart gardens | Convert 1,000 acres of privately-owned manicured lawn through the establishment of a Resiliency Garden Program that enables homeowners to convert portions of their yard into climate-smart gardens. Offer rebates and technical guidance to residents who install and maintain qualifying gardens. Gardens supported may include: (1) Food Gardens, which will promote local food production to reduce emissions from food transportation, packaging, and storage; (2) Rain Gardens, which will manage stormwater on-site, reduce runoff and flooding, and limit energy-intensive water treatment; and (3) Pollinator Gardens; which will support biodiversity, sequester carbon in soil and perennial plants, and reduce lawn mowing emissions. | 1,113 | | 5,565 | 201,165 | - | 638,823 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Agricultural/Natural/Working Lands | ANWL4. Develop a Municipal Resiliency Pocket initiative that transforms underutilized municipal lands into multifunctional green spaces | Convert 2,000 acres of municipally-owned pavement and/or manicured lawn through the development of a regional Municipal Resiliency Pocket initiative tthat transforms underutilized municipal lands into multifunctional green spaces. Recaliam vacant, degraded, or underutilized municipal land in the MSA into a network of small-scale ecological pockets to sequester carbon, reduce urban heat, absorb stormwater, and promote biodiversity. Types of resiliency pockets might include: (1) Mini-forests with dense, fast-growing native trees to support carbon capture and biodiversity; (2) Food forests with edible perennial landscapes accessible to the public to promote carbon-smart local food; (3) Parks with native grasses and flowers that require minimal maintenance and promote high ecological value; and (4) Rain gardens and bioswales planted in buffers to municipal lots and rights-of-way to reduce runoff and urban flooding. | 176,763 | - | 530,290 | | | |
| Agricultural/Natural/Working Lands | ANWL5. Reduce Synthetic Pesticide and Fertilizer Usage | Reduce the usage of synthetic pesticides and fertilizers on 5,000 acres of municipal, commercial, and residential land by 2050.<br>Encourage farms in the MSA to adopt regenerative practices that reduce nitrogen fertilizer use and eliminate pesticide applications, and partner with MDAR, CTDOA, Mounth Wachusett Community College, Central Mass Grown, and other similar organizations/programs to provide technical and financial assistance on regenerative farming practices. Establish training and technical support programs to encourage municipalities, schools, and public landowners to adopt Integrated Pest Management policies. Support the adoption of a statewide ban on synthetic pesticide use on non-agricultural residential and commercial properties to protect ecological value, reduce GHG emissions, and restore natural carbon sinks in soil and plant communities. Advocate for state legislation that bans or strictly regulates synthetic pesticide use on lawns, gardens, ornamental landscapes, schoolyards and recreational fields, golf courses, and business parks. | 3,557 | | 12,891 | | | |
| Commercial and Residential Buildings | CRB1. | Mixed-Use Zoning + Transit-Oriented Development (TOD) in relevant areas like town and village centers, transportation corridors and other designated districts: Compact, walkable development reduces both VMT and building emissions. Smart growth zoning can reduce per capita emissions by 20–40% (EPA Smart Growth Reports). Rail-served communities like Worcester, Grafton, and Fitchburg are key targets for such reforms. The region can aim to work with 25% of municipalities in the MSA which have ready or moderate levels of infrastructural preparedness by 2035 and all remaining/relevant municipal or village centers (another estimated 30%) by 2050.<br>Emphasize Brownfield clean-up/redevelopment and limit access to open spaces and conservation land for any new development: This strategy focuses on encouraging compact growth through cluster development, transfer of development rights (TDR), and growth boundaries. The goal is to have 50% of towns in the MSA adopt these reforms by 2040 and reach an optimum state by 2050. Preserving forests, farmland, and open spaces is crucial in Worcester County, where nearly 75% of the land remains undeveloped. Protecting these areas helps maintain important natural carbon sinks, reduces emissions from new infrastructure expansion, and limits vehicle miles traveled by encouraging denser, more compact development patterns. | 16,607 | | 32,168 | | | |
| Commercial and Residential Buildings | CRB2. | Use retro-commissioning, deep retrofits, and replacement of heating/cooling systems to optimize the use of energy. Aim to upgrade local and state-owned facilities in the next 25 years, prioritizing high energy and high usage buildings (for example, emergency operation centers and school buildings). Also, incentivize and target optimization for all remaining buildings by 2050, prioritizing the larger facilities first, creating strong incentive mechanisms to promote this transition. The aim is to get most of the high energy usage facilities to net zero, using distributed energy costs, and adding microgrids/renewable energy generation as a part of the process. | 22,497 | | 64,275 | | | |
| Commercial and Residential Buildings | CRB3. | Encourage the reuse and upgrading of existing facilities to minimize demolition waste, reduce embodied carbon, and avoid unnecessary new construction. Promote deconstruction and the recycling of building materials to build a local circular construction economy. Some key actions include: Require all demolitions to submit adaptive reuse justifications and materials reuse plan by 2030; Pilot deconstruction/demolition consideration bylaws for non-historic buildings in 5 towns by 2035; Provide tax credits and incentives for adaptive reuse projects and build the necessary local infrastructure like regional permit centers and material recovery hubs (explore/adopt public-private partnerships to establish regional reuse markets and sustainable material recovery facilities). Some tangible success parameters could be: all major demolition projects would have to have an adaptive reuse/deconstruction strategy, reduce demolition waste by 40% by 2040; build the public and private ecosystem that facilitates adaptive reuse, circular construction and cradle to door - aiming for at least 3-4 regional hubs in the target area. | 588 | | 2,939 | 554,046 | - | 1,463,470 |
| Commercial and Residential Buildings | CRB4. | Accelerate the adoption of sustainable materials and building practices by reforming procurement, educating stakeholders, and creating the necessary market demand. Prioritize carbon-smart, locally sourced, and circular materials in public and private construction. Key actions include:<br>Integrate green concrete, recycled aggregates, and low-carbon materials into 30 % of municipally or state-owned projects by 2035; 100% of municipally or state-owned projects by 2050. Develop local pilot programs for porous pavement, recycled lumber, fly ash concrete, and passive cooling/green roofs. Work with state agencies to incentivize the use of tested materials like green concrete (e.g., via DOT and public construction specs).<br>Reduce embodied emissions of new construction by 40% by 2045.<br>Update local procurement policies in 30 towns to favor sustainable and/or recycled materials by 2035.<br>Educate engineers and architects about material performance, pricing, and code compatibility. | 2,322 | | 9,288 | | | |
| Commercial and Residential Buildings | CRB5. | Build a supportive ecosystem for sustainable development by aligning building codes, incentives, and public awareness efforts with net-zero goals. Make sustainable design the default through flexible code adoption, energy modeling, community education, and a culture of collaboration. Work with the local municipalities in MA for 100% adoption of the stretch energy code by 2035, and 100% adoption of the specialized opt-in stretch code by 2050. Work with local municipalities in CT to advocate for the adoption of a stretch energy code that reflects the best practices and strategies for new buildings to meet high efficiency standards. Require energy/BEM modeling for large developments (>10,000 sq. ft.) with public disclosure by 2035; emphasize strategies like passive heating/cooling in all constructions; create flexible permitting incentives for passive and net-zero designs via point-based development bonuses. Reduce total building energy demand through behavioral and systems strategies by 15% by 2030 and 40% by 2050. Ensure 100% of lighting sales are high-efficiency by 2030; 100% of new residential appliances are electric by 2035; 100% for commercial appliances by 2045. | 512,032 | | 1,354,800 | | | |
| Industry | I1. | Develop and implement a mandatory greenhouse gas emissions reporting and reduction framework | 1,209 | 2,822 | 3,225 | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Industry | I2. | Develop a Worcester-CT MSA cradle-to-cradle industrial ecosystem that minimizes material waste, maximizes reuse, and leverages green technology innovations. By 2030, launch an MSA-wide industrial circularity accelerator program in partnership with the local Chambers of Commerce, institutions, and industrial leaders in the MSA, and conduct comprehensive industrial waste/waste flow audits. By 2040, build capacity and physical networks to facilitate the reuse/exchange of materials and equipment, collaborative procurement of sustainable/recycled materials, and shared use of waste processing technologies. Incentivize participation in the industrial material efficiency and waste circularity network through the establishment of tax credits for verified material diversion from landfills and grants to assist with adopting cradle-to-cradle systems. Using these mechanisms, divert 60% of solid waste from landfill/incineration from industrial facilities in the Worcester-CT MSA by 2050.<br>In case of large campuses/industrial corridors and clusters, create overlay zoning guidelines that encourage the integration of green systems and create zones where integrated energy systems (microgrids and other energy production and supply systems) reduce energy peak demand, reduce wastewater generation, and expand treatment and create circular systems, aiming to create net-zero neighborhoods zones where possible. This strategic development could model best practices in the region, even while reducing the overall energy consumption and greenhouse gas emissions by an additional 5 percent. | 469 | | 2,812 | 13,773 | | 38,290 |
| Industry | I3. | Accelerate the transition of industrial facilities to low-carbon energy systems, focusing on electrification, energy efficiency, and zero-emission mobility. Utilizing rebates for electric heat pump installations, smart controls, and occupancy-based heating/cooling/lighting, electrify 60% of large industrial facilities (greater than 15,000 sq ft.), and reduce energy usage by 35% by 2040. Require electric vehicle charging infrastructure in all new industrial facilities greater than 20,000 sq ft. starting in 2030, and 15,000 sq ft. starting in 2035. Electrify industrial fleets to the extent possible, and promote idle-reduction retrofits and low-carbon fuels where full electrification isn't yet feasible. Electrify or utilize alternative fuel in 50% industrial light-duty vehicles and 15% medium-duty vehicles by 2040, aiming for 100% electrification/alternative fuels of industrial light-duty vehicles and 30% medium-duty vehicles by 2050. | 12,095 | 28,221 | 32,252 | | | |

**Reference Table**
**Waste Characterization Data Used in 2022 GHG Inventory**

| Table 4. Overall Waste Composition By Detailed Material Category Mapped to GPC Waste Categories | | |
|---|---|---|
| **Waste Category/Sub-category** | **Weighted Average** | **GPC Waste Category** |
| **Paper** | | |
| Uncoated Corrugated Cardboard/Kraft Paper | 5.80% | Paper |
| Waxed Cardboard | 0.50% | Paper |
| High Grade Office Paper | 0.50% | Paper |
| Magazines/Catalogs | 0.40% | Paper |
| Newsprint | 0.30% | Paper |
| Other Recyclable Paper | 3.90% | Paper |
| Compostable Paper | 7.20% | Paper |
| Remainder/Composite Paper | 3.20% | Paper |
| **Plastic** | | |
| PET Beverage Containers (non-MA deposit containers) | 0.80% | Other |
| PET Containers other than Beverage Containers | 0.50% | Other |
| Plastic MA Deposit Beverage Containers | 0.10% | Other |
| HDPE Bottles, colored and natural | 0.60% | Other |
| Plastic Tubs and lids (HDPE, PP, etc.) | 0.40% | Other |
| #5 PP Bottles & Containers | 0.90% | Other |
| Plastic Containers #3-#7 (which originally contained non-hazardous material) | 0.90% | Other |
| Other Plastic Bottles & Containers | 0.30% | Other |
| Expanded Polystyrene Food Grade | 0.40% | Other |
| Expanded Polystyrene Non-food Grade | 0.20% | Other |
| Bulk Rigid Plastic Items | 1.80% | Other |
| Film (non-bag clean commercial and industrial packaging film) | 1.00% | Other |
| Grocery and other Merchandise Bags | 0.30% | Other |
| Other Film means plastic film | 5.70% | Other |
| Remainder/Composite Plastic | 2.50% | Other |
| **Metal** | | |
| Aluminum Beverage Containers (non-MA deposit containers) | 0.10% | Other |
| Aluminum MA Deposit Beverage Containers | 0.30% | Other |
| Tin/Steel Containers | 0.80% | Other |
| Other Aluminum | 0.40% | Other |
| Other Ferrous and non-ferrous | 1.60% | Other |
| White Goods | 0.10% | Other |
| Remainder/Composite Metal | 1.50% | Other |
| **Glass** | | |
| Glass Beverage Containers (non-MA deposit containers) | 0.80% | Other |
| Other Glass Packaging Containers (non-MA deposit containers) | 0.50% | Other |
| Glass MA Deposit Beverage Containers | 0.40% | Other |
| Remainder/Composite Glass | 0.50% | Other |
| **Organic Materials** | | |
| Food Waste | 21.60% | Food |
| Branches and Stumps | 0.40% | Waste and Plant Debris |
| Prunings, Trimmings, Leaves and Grass | 1.30% | Waste and Plant Debris |
| Manures | 0.20% | Waste and Plant Debris |
| Remainder/Composite Organic | 6.00% | Waste and Plant Debris |
| **Construction and Demolition (in the MSW stream)** | | |
| Asphalt Pavement, Brick, and Concrete | 0.10% | Other |
| Aggregates, Stone, Rock | 0.60% | Other |
| Wood – Treated | 3.40% | Wood |
| Wood – Untreated | 3.00% | Wood |
| Asphalt Roofing | 0.30% | Other |
| Drywall/Gypsum Board | 0.90% | Other |
| Carpet and Carpet Padding | 1.80% | Other |
| Remainder/Composite Construction and Demolition | 2.10% | Other |
| **Household Hazardous Waste** | | |
| Ballasts, CFLs, and Other Fluorescents | 0.00% | Other |
| Batteries – Lead Acid | 0.00% | Other |
| Batteries – Other | 0.10% | Other |
| Paint | 0.10% | Other |
| Bio-Hazardous | 3.50% | Other |
| Vehicle and Equipment Fluids | 0.00% | Other |
| Empty Metal, Glass, and Plastic Containers | 0.10% | Other |
| Other Hazardous or Household Hazardous Waste | 0.10% | Other |
| **Electronics** | | |
| Computer-related Electronics | 0.10% | Other |
| Other "brown goods" | 0.20% | Other |
| Televisions and Computer Monitors | 0.00% | Other |
| **Other Materials** | | |
| Tires and other rubber | 0.40% | Other |
| Textiles | 5.20% | Textiles |
| Bulky Materials | 2.20% | Other |
| Mattresses | 0.10% | Other |
| Restaurant Fats, Oils and Grease | 0.00% | Food |
| Other Miscellaneous | 2.30% | Other |
| **Total** | 100% | |

**Reference Table**
**2022 Total Tons MSA Wide CMRPC GHG Inventory**

| Subsector | Est. Total Waste to Landfill (short tons) | Est. Mass of Waste Incinerated (short tons) | Est. Mass of Organics Sent to Compositing Facility (short tons) | Est. Mass of Organics Sent to Anaerobic Digester (short tons) | Total MTCO2e |
|---|---|---|---|---|---|
| Solid Waste Disposal | **137,483** | | | | 31,610 |
| Biological Treatment of Waste | | | 3,202 | 32,100 | 1,939 |
| Incineration and Open Burning | | **684,925** | | | 16,278 |
| Wastewater Treatment and Discharge | | | | | 146,719 |
| | | | | | **196,546** |

**Reference Table**

| Percent of Waste to Disposal Type | |
|---|---|
| Total Waste | 822,408 |
| Fraction of Landfill | 17% |
| Fraction of Incineration | 83% |

| Waste Characterization Study Allocation to Measures | | | |
|---|---|---|---|
| **Measure** | **Percent** | **Type of Waste** | **Notes** |
| WM1* | 21.6% | Organic Waste Percent | |
| WM2 | | | Quantified in Electricity All Measures And/Or Supported by replication of PCAP method |
| WM3* | 17.2% | Recycling Percent | |
| WM4 | | | No tons necessary from there - pay as you throw |
| WM5* | 18.3% | Percentage to "C&D/Reuse" | |
| Circular construction | 9.15% | | |

| Measure | Total Waste From Landfill/Incineration | By 2050 | Action |
|---|---|---|---|
| WM1* | 177,640 | 95% | Diverted to AD/Compost |
| WM2 | | | |
| WM3* | 141,454 | 95% | Recycled/reused |
| WM4 | | | |
| WM5* | 150,501 | 95% | Reuse/Recovered |

**=Requires Waste Characterization percentage*

| | |
|---|---|
| Total Waste Compost/Anae | 42,262 |
| Compost tons | 11,163 |
| Anaerobic tons | 32,100 |
| Fraction of Compost | 26.41% |
| Fraction of Anerobic Diges | 75.95% |

**Emissions Reduction Summary Table**
**Tons and Emissions by Sector**

| WMM 1 Tons | WM1 MTCO2e | WM3 Tons | WM3 CO2e | WM5 Tons | WM5 CO2e | WM4 Tons | WM4 CO2e | I2 Tons | I2 CO2e |
|---|---|---|---|---|---|---|---|---|---|
| 177,640 | 5,726 | 141,454 | 11,051 | 71,488 | 5,585 | 181,533 | 14,182 | 36,000 | 3,281 |

| Comparison with 2022 GHG Inventory | | Difference |
|---|---|---|
| MEASURES Total Emissions (MTCO2e) | 39,826 | 8,062 |
| INVENTORY Total Emissions (MTCO2e) | 47,888 | |
| MEASURES Total Waste (Short Tons) | 608,115 | 214,293 |
| INVENTORY Total Waste (Short Tons) | 822,408 | |

| | |
|---|---|
| The above data is from the Massachusetts's Department of Environmental Protection (DEP) "Summary of Waste Combustor Class II Recycling Program Waste Characterization Studies (Includes 2010, 2013, 2016, 2019, and 2022 Data)". Data from the "2022 Detailed Fall & Winter" tab of the workbook was used. For data that was entered as "N/A" in 2022, the 2019 Spring/Summer value was used. This data provides a weighted average composition by material category based on the amount of waste that each incineration facility burned in calendar year 2022. | https://www.mass.gov/guides/solid-waste-master-plan#-waste-characterization-&-capacity-studies- |

| WMM1 Organics Waste Diversion | | |
|---|---|---|
| ***Measure WMM1*** | ***By 2050 Divert 95% of all organic waste produced within the MSA from landfilling and into composting or anerobic digestion. This will be started through an elementary, middle and high school climate program to educate students on waste prevention, reduction, recycling, and reuse, as well as sustainable degrowth practices that can be implemented at an individual level. This educational strategy will focus on all aspects of climate change throughout the childs time within the school system. In conjunction with this educational program schools will also establish policies and procedures for internal waste separation as part of this holistic education (leading by example by separating food waste from cafeteria from general trash, as well as recyclable waste) as well as establishing school or school district composting or anerobic digestion program to accept school organic waste or from students bringing from home compostables/organic waste with them and school gardens that accept the compost/digestate from offsite or on-site facilities This will foster a whole of society approach and response to climate change.*** | |
| ***2030*** | ***286*** | ***MTCO2e*** |
| ***2050*** | ***5,440*** | ***MTCO2e*** |
| Methodology Description: The estimated quantity of organic waste generated in the MSA and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. A percentage of this organic waste was assumed to be diverted in 2030 and 2050 to composting and anaerobic digestion. The emissions associated with composting are subtracted from the total emissions reduction and anaerobic digestion was assumed to have a methane capture rate of 100% and therefore no emissions associated with the process. | | |

| WMM3 Comp Extended Producer | | |
|---|---|---|
| ***Measure WMM3*** | ***Extended Producer Responsibilities (EPR) Legislation that tackles all aspects of producer responsibility for end of life of products sold in the MSA including: A ban on single use plastics; packaging and plastic waste directives that set targets for recovery and recycling of 95% of plastic waste produced in the MSA by 2050, requiring the use of 100% recycled and recyclable/compostable materials in single use objects, requiring packaging comply with essential requirements minimizing packaging volume and weight, as well as design to permit its reuse and recovery following the model of the European Packaging and Waste Directive 94/62/EC and/ or California's Plastic Pollution Prevention and Packaging Producer Responsibility Act (SB 54)*** | |
| ***2030*** | ***553*** | ***MTCO2e*** |
| ***2050*** | ***10,498*** | ***MTCO2e*** |
| Methodology Description: The estimated quantity of recyclable plastics and papers generated in the MSA and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. A percentage of this was assumed to be diverted in 2030 and 2050. | | |

| WMM5 Regional Resource Recovery |
|---|

| | |
|---|---|
| ***Measure WMM5*** | ***Build and manage a MSA wide resource recovery network of facilities that can fulfil the following functions: operate as a regionwide end point or points for organic materials utilizing Anerobic Digestion capable of processing 350,000 tons or organic waste and food waste per year; that can intake MSW or recyclable/ recoverable materials of varying levels of contamination from transfer stations across the MSA and the northeast region at one end and decontaminate, separate, and process that waste into reusable products or products that can be shipped elsewhere for further processing into reusable products or final disposal at the other end; municipally supported re-use stores for deconstructed materials and bulky recoverable/reusable goods like furniture and appliances; glass grinding facilities to make ground glass pozzolans for green concrete; electric smelting facilities to turn scrap metals into recycled materials to be resold locally, and other materials recovery facilities and other processes not listed here. By creating this localized network for these waste streams we can reduce VMT by utilizing existing transfer stations across the MSA to the ship to these facilities within the MSA and by leveraging shortened distances to these facilities and existing and new freight rail service with the goal to reduce vehicle miles travelled by waste haulers by 25-50% by 2050.This network of facilities should create a usable end source material for a variety of products based on their inputs: Separated scrap metal and aluminum to recycled steel and aluminum stock produced locally; from spent single use and old batteries recoverable rare metals to make into new batteries; from organic waste anerobic digestion for onsite power generation and heating and organic fertilizer produced locally; particle board, chip board, and engineered lumber products from wood waste and C+D materials produced locally; This network should act as a laboratory for innovation in waste reuse, recycling and recovery. By utilizing locally recovered materials we can reduce the embodied carbon of shipped virgin materials as well as create an end point for waste that is also a beginning point for a circular economy. The ultimate goal of this strategy would be to divert 95% of all waste away from landfilling and towards the production of green materials.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***294*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***5,291*** | ***MTCO2e*** |

Methodology Description: The estimated quantity of construction and demolition, electronics, and bulky material waste generated in the MSA and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. A percentage of this was assumed to be diverted in 2030 and 2050.

**Measure: WMM1 Organics Waste Diversion**

[value] **Total Estimated Landfilled/Incinerated Waste in MSA**

822,408 (Short Ton *Source: 2022 GHG Inventory*

[input] **Percentage of Organic Waste sent to Landfills/Incinerators**

| | | | |
|---|---|---|---|
| | 21.6% | (%) | Source: MassDEP Summary of Waste Combustor Class II Recycling Program Waste Characterization https://www.mass.gov/guides/solid-waste-master-plan#-waste-characterization-&-capacity-studies- |

[calc] **Total Estimated Short Tons of Organic Waste in Landfills and Incinerators**

177,640 (Short Tons)

[input] **Target Diversion Percent by 2030**

5.0% (%) *Assumption*

[input] **Target Diversion Percent by 2050**

95% (%) *Assumption*

[calc] **Target Diversion in Short Tons by 2030**

8,882 (Short Tons)

[calc] **Target Diversion In Short Tons by 2050**

168,758 (Short Tons)

[values] **Waste disposal by type**

| | | | |
|---|---|---|---|
| Landfill | 17% | (%) | *Source: 2022 GHG Inventory* |
| Incineration | 83% | (%) | |

[values] **Landfill CH4 Emissions Variables**

| | | |
|---|---|---|
| Lo | 0.08 | *Source: 2022 GHG Inventory* |
| frec | 0.85 | |
| Ox | 0.10 | |

[calc] **Landfill Methane Emissions Reduced by 2030**

16 (MTCH4)

[calc] **Landfill Methane Emissions Reduced by 2050**

303 (MTCH4)

[values] **Incineration CO2, CH4, and N2O Emissions Variables**

| | | | |
|---|---|---|---|
| Eq 8.6 | 0.6% | | *Source: 2022 GHG Inventory, GPC Equation 8.6* |
| Carbon ratio | 3.67 | | |
| Conversion | 0.000001 | | |
| CH4 | 0.20 | (g CH4/ton) | |
| N2O | 50 | (g N2O/ton) | |
| CH4 GWP | 28 | | *AR5* |
| N2O GWP | 265 | | *AR5* |

| | | |
|---|---|---|
| [calc] | **Incineration CO2, CH4, N2O emissions 2030** | |
| CO2 | 150 | (MTCO2e) |
| CH4 | 0.04 | (MTCO2e) |
| N2O | 98 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **Incineration CO2, CH4, N2O emissions 2050** | |
| CO2 | 2,843 | (MTCO2e) |
| CH4 | 0.8 | (MTCO2e) |
| N2O | 1,862 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2030 Total Emissions Reduced from Incineration** | |
| | 248 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2030 Total Emissions Reduced from Landfill** | |
| | 446 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2050 Total Emissions Reduced from Incineration** | |
| | 4,706 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2050 Total Emissions Reduced from Landfill** | |
| | 8,478 | (MTCO2e) |

| | | |
|---|---|---|
| [summary] | **2030 and 2050 Diversion in Short Tons** | |
| 2030 | 8,882 | (Short tons) |
| 2050 | 168,758 | (Short tons) |

**Measure WMM1 Organic Waste Diversion Pt. 2 - Allocation to Composting and Associated Emissions**

| | | | |
|---|---|---|---|
| [calc] | **Percentage of waste allocation to compost versus anerobic calculation** | | |
| Total | 42,262 | (Short tons | *Source: 2022 GHG Inventory* |
| Compost | 11,163 | (Short tons) | |
| AD | 32,100 | (Short tons) | |
| Compost | 26% | (%) | |
| AD | 76% | (%) | |
| | **No emissions associated with anerobic digestion due to 100% methane capture** | | |

| | | |
|---|---|---|
| [input] | **Conversions** | |
| | 907 | Short Ton to Kg |
| | 0.000001 | gram to kg |

| | | |
|---|---|---|
| [calc] | **Diversion to Compost** | |
| 2030 | 2,128,324 | (kg) |
| 2050 | 40,438,163 | (kg) |

| | | | |
|---|---|---|---|
| [value] | **Emissions Factors for CH4 and N2O** | | |
| | 4 | (g CH4 / kg | *Source: 2022 GHG Inventory* |
| | 0.3 | (g N2O/kg waste) | |

[calc] **2030 CH4 Emissions Excluding Methane Capture (Not applicable)**

| | | |
|---|---|---|
| 9 | (MTCH4) | *Source: 2022 GHG Inventory* |
| 28 | GWP | |
| 1 | (MTN2O) | |
| 265 | GWP | |
| **408** | **Total MTCO2e Compost** | |

[calc] **2050 CH4 Emissions excluding Methane Capture (Not applicable)**

| | | |
|---|---|---|
| 162 | (MTCH4) | *Source: 2022 GHG Inventory* |
| 28 | GWP | |
| 12 | (MTN2O) | |
| 265 | GWP | |
| **7,744** | **Total MTCO2e Compost** | |

[FINAL] **2030 Annual GHG Emissions Reduced**

286 (MTCO2e)

*Includes associated emissions with compost, no emissions associated with anaerobic digestion given a 100% methane capture*

[FINAL] **2050 Annual GHG emissions reduced**

5,440 (MTCO2e)

*Includes associated emissions with compost, no emissions associated with anaerobic digestion given a 100% methane capture*

## WMM3. Comp Extended Producer

[value] **Total Estimated Landfilled/Incinerated Waste in MSA**

822,408 (Short Ton *Source: 2022 GHG Inventory*

[input] **Estimated Percentage of Recyclables sent to Landfills/Incinerations**

17.2% (%) Source: MassDEP Summary of Waste Combustor Class II Recycling Program Waste Characterization https://www.mass.gov/guides/solid-waste-master-plan#-waste-characterization-&-capacity-studies-

[calc] **Total Estimated Short Tons of Recyclables in Landfills/Incinerators**

141,454 (Short Tons)

[input] **Target Diversion Percent by 2030**

5.0% (%) *Assumption*

[input] **Target Diversion Percent by 2050**

95% (%) *Assumption*

| | | | |
|---|---|---|---|
| [calc] | **Target Diversion in Short Tons by 2030** | | |
| | 7,073 | (Short Tons) | |
| [calc] | **Target Diversion in Short Tons by 2050** | | |
| | 134,381 | (Short Tons) | |
| [values] | **Waste disposal by type** | | |
| Landfill | 17% | (%) | *Source: 2022 GHG Inventory* |
| Incineration | 83% | (%) | |
| [values] | **Landfill CH4 Emissions Variables** | | |
| Lo | 0.08 | | *Source: 2022 GHG Inventory* |
| frec | 0.85 | | |
| Ox | 0.10 | | |
| [calc] | **Landfill Methane Emissions Reduced by 2030** | | |
| | 12.69 | (MTCH4) | |
| [calc] | **Landfill Methane Emissions Reduced by 2050** | | |
| | 241.11 | (MTCH4) | |
| [values] | **Incineration CO2, CH4, and N2O Emissions Variables** | | |
| | 0.6% | | *Source: 2022 GHG Inventory, GPC Equation* |
| | 3.67 | | *8.6* |
| conversion | 0.000001 | | |
| CH4 | 0.20 | (g CH4/ton) | |
| N2O | 50 | (g N2O/ton) | |
| CH4 GWP | 28 | | *AR5* |
| N2O GWP | 265 | | *AR5* |
| [calc] | **Incineration CO2, CH4, N2O emissions 2030** | | |
| CO2 | 119 | (MTCO2e) | |
| CH4 | 0.0 | (MTCO2e) | |
| N2O | 78 | (MTCO2e) | |
| [calc] | **Incineration CO2, CH4, N2O emissions 2050** | | |
| CO2 | 2,264 | (MTCO2e) | |
| CH4 | 0.6 | (MTCO2e) | |
| N2O | 1,483 | (MTCO2e) | |
| [calc] | **2030 Total Emissions Reduced from Incineration** | | |
| | 197 | (MTCO2e) | |
| [calc] | **2030 Total Emissions Reduced from Landfill** | | |
| | 355 | (MTCO2e) | |
| [FINAL] | **2030 Annual GHG emissions reduced** | | |
| | 553 | (MTCO2e) | |
| [calc] | **2050 Total Emissions Reduced from Incineration** | | |

3,747 (MTCO2e)

[calc] **2050 Total Emissions Reduced from Landfill**
6,751 (MTCO2e)

[FINAL] **2050 Annual GHG emissions reduced**
10,498 (MTCO2e)

## WMM5. Regional Resource Recovery

[value] **Total Estimated Landfilled/Incinerated Waste in MSA**
822,408 (Short Ton *Source: 2022 GHG Inventory*

[input] **Estimated Percentage of Recyclables Sent to Landfills/Incinerations**
9.2% (%) Source: MassDEP Summary of Waste Combustor Class II Recycling Program Waste Characterization https://www.mass.gov/guides/solid-waste-master-plan#-waste-characterization-&-capacity-studies-

[calc] **Total Estimated Short Tons of Recyclables in Landfills/Incinerators**
75,250 (Short Tons)

[input] **Target Diversion Percent by 2030**
5.0% (%) *Assumption*

**Target Diversion Percent by 2050**
[input]
90% (%) *Assumption*

[calc] **Target Diversion by 2030**
3,763 (Short Tons)

[calc] **Target Diversion by 2050**
67,725 (Short Tons)

[values] **Waste disposal by type**

| | | | |
|---|---|---|---|
| Landfill | 17% | (%) | *Source: 2022 GHG Inventory* |
| Incineration | 83% | (%) | |

[values] **Landfill CH4 Emissions Variables**

| | | |
|---|---|---|
| Lo | 0.08 | *Source: 2022 GHG Inventory* |
| frec | 0.85 | |
| Ox | 0.10 | |

[calc] **Landfill Methane Emissions Reduced by 2030**
6.75 (MTCH4)

[calc] **Landfill Methane Emissions Reduced by 2050**
121.52 (MTCH4)

| | | | |
|---|---|---|---|
| [values] | **Incineration CO2, CH4, and N2O Emissions Variables** | | |
| Eq 8.6 | 0.6% | | *Source: 2022 GHG Inventory, GPC Equation 8.6* |
| Carbon ratic | 3.67 | | |
| conversion | 0.000001 | | |
| CH4 | 0.20 | (g CH4/ton) | |
| N2O | 50 | (g N2O/ton) | |
| CH4 GWP | 28 | | *AR5* |
| N2O GWP | 265 | | *AR5* |

| | | |
|---|---|---|
| [calc] | **Incineration CO2, CH4, N2O emissions 2030** | |
| CO2 | 63 | (MTCO2e) |
| CH4 | 0.0 | (MTCO2e) |
| N2O | 42 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **Incineration CO2, CH4, N2O emissions 2050** | |
| CO2 | 1,141 | (MTCO2e) |
| CH4 | 0.3 | (MTCO2e) |
| N2O | 747 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2030 Total Emissions Reduced from Incineration** | |
| | 105 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2030 Total Emissions Reduced from Landfill** | |
| | 189 | (MTCO2e) |

| | | |
|---|---|---|
| [FINAL] | **2030 Annual GHG Emissions Reduced** | |
| | 294 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2050 Total Emissions Reduced from Incineration** | |
| | 1,889 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **2050 Total Emissions Reduced from Landfill** | |
| | 3,402 | (MTCO2e) |

| | | |
|---|---|---|
| [FINAL] | **2050 Annual GHG emissions reduced** | |
| | 5,291 | (MTCO2e) |

| | | |
|---|---|---|
| [summary] | **WMM 1, 3 and 5 Annual GHG Emissions Reduced in 2030** | |
| | 1,133 | (MTCO2e) |

| | | |
|---|---|---|
| [summary] | **WMM 1, 3 and 5 Annual GHG Emissions Reduced in 2050** | |
| | 21,230 | (MTCO2e) |

| | | |
|---|---|---|
| [summary] | **Total Tons Diverted 2030 & 2050** | |
| 2030 | 19,717 | (Short Tons) |
| 2050 | 370,865 | (Short Tons) |

**Co pollutants**

**Measure 1**

**Landfill Co-Pollutants**

*Source: EPA Landfill Gas Emissions Model (LandGEM) Version 3.1 User Manual*

[value] **Conversion for Landfill gas (LFG) generated per ton of waste**

1.98E-08 ppmv × ft³ × MW = lb

7,063 ft³/ton

| Pollutant | ppmv | MW | *EF (lb/ton)* | *Waste (tons) 2030* | *Waste (tons) 2050* | *Emissions (Metric Tons) 2030* | *Emissions (Metric Tons) 2050* |
|---|---|---|---|---|---|---|---|
| **Benzene** | 39 | 78 | *0.4260* | *11,228* | *213,334* | *2* | *45* |
| **Toluene** | 170 | 92 | *2.1903* | *11,228* | *213,334* | *12* | *234* |
| **Vinyl chloride** | 7.3 | 63 | *0.0638* | *11,228* | *213,334* | *0* | *7* |
| **Carbon monoxide** | 110 | 28 | *0.4309* | *11,228* | *213,334* | *2* | *46* |
| **Methylene chloride** | 5.8 | 85 | *0.0689* | *11,228* | *213,334* | *0* | *7* |
| **Chloroform** | 0.3 | 119 | *0.0057* | *11,228* | *213,334* | *0* | *1* |
| **Carbon tetrachloride** | 0.0 | 154 | *0.0000* | *11,228* | *213,334* | *0* | *0* |
| **Ethylbenzene** | 4.6 | 106 | *0.0683* | *11,228* | *213,334* | *0* | *7* |
| **Trichloroethylene** | 2.8 | 131 | *0.0515* | *11,228* | *213,334* | *0* | *5* |
| **Perchloroethylene** | 2.1 | 166 | *0.0487* | *11,228* | *213,334* | *0* | *5* |
| | | | | *[FINAL]* | ***Total 2030*** | ***19*** | ***(MT Co-Pollutants)*** |
| | | | | *[FINAL]* | ***Total 2050*** | ***358*** | ***(MT Co-Pollutants)*** |

**Measure 3**

**Landfill Co-Pollutants**

*Source: EPA Landfill Gas Emissions Model (LandGEM) Version 3.1 User Manual*

[value] **Conversion for Landfill gas (LFG) generated per ton of waste**

1.98E-08 ppmv × ft³ × MW = lb

7,063 ft³/ton

| Pollutant | ppmv | MW | *EF (lb/ton)* | *Waste (tons) 2030* | *Waste (tons) 2050* | *Emissions (Metric Tons) 2030* | *Emissions (Metric Tons) 2050* |
|---|---|---|---|---|---|---|---|
| **Benzene** | 39 | 78 | *0.4260* | *7,073* | *134,381* | *2* | *29* |
| **Toluene** | 170 | 92 | *2.1903* | *7,073* | *134,381* | *8* | *147* |
| **Vinyl chloride** | 7.3 | 63 | *0.0638* | *7,073* | *134,381* | *0* | *4* |
| **Carbon monoxide** | 110 | 28 | *0.4309* | *7,073* | *134,381* | *2* | *29* |
| **Methylene chloride** | 5.8 | 85 | *0.0689* | *7,073* | *134,381* | *0* | *5* |
| **Chloroform** | 0.3 | 119 | *0.0057* | *7,073* | *134,381* | *0* | *0* |
| **Carbon tetrachloride** | 0.0 | 154 | *0.0000* | *7,073* | *134,381* | *0* | *0* |
| **Ethylbenzene** | 4.6 | 106 | *0.0683* | *7,073* | *134,381* | *0* | *5* |
| **Trichloroethylene** | 2.8 | 131 | *0.0515* | *7,073* | *134,381* | *0* | *3* |
| **Perchloroethylene** | 2.1 | 166 | *0.0487* | *7,073* | *134,381* | *0* | *3* |
| | | | | *[FINAL]* | ***Total 2030*** | ***12*** | ***(MT Co-Pollutants)*** |
| | | | | *[FINAL]* | ***Total 2050*** | ***225*** | ***(MT Co-Pollutants)*** |

**Measure 5**

**Landfill Co-Pollutants**

*Source: EPA Landfill Gas Emissions Model (LandGEM) Version 3.1 User Manual*

[value] **Conversion for Landfill gas (LFG) generated per ton of waste**

1.98E-08 ppmv × ft³ × MW = lb

7,063 ft³/ton

| Pollutant | ppmv | MW | *EF (lb/ton)* | *Waste (tons) 2030* | *Waste (tons) 2050* | *Emissions (Metric Tons) 2030* | *Emissions (Metric Tons) 2050* |
|---|---|---|---|---|---|---|---|
| **Benzene** | 39 | 78 | *0.4260* | *3,763* | *67,725* | *1* | *14* |
| **Toluene** | 170 | 92 | *2.1903* | *3,763* | *67,725* | *4* | *74* |
| **Vinyl chloride** | 7.3 | 63 | *0.0638* | *3,763* | *67,725* | *0* | *2* |
| **Carbon monoxide** | 110 | 28 | *0.4309* | *3,763* | *67,725* | *1* | *15* |
| **Methylene chloride** | 5.8 | 85 | *0.0689* | *3,763* | *67,725* | *0* | *2* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Chloroform** | 0.3 | 119 | *0.0057* | *3,763* | *67,725* | *0* | *0* |
| **Carbon tetrachloride** | 0.0 | 154 | *0.0000* | *3,763* | *67,725* | *0* | *0* |
| **Ethylbenzene** | 4.6 | 106 | *0.0683* | *3,763* | *67,725* | *0* | *2* |
| **Trichloroethylene** | 2.8 | 131 | *0.0515* | *3,763* | *67,725* | *0* | *2* |
| **Perchloroethylene** | 2.1 | 166 | *0.0487* | *3,763* | *67,725* | *0* | *2* |
| | | | | *[FINAL]* | ***Total 2030*** | ***6*** | ***(MT Co-Pollutants)*** |
| | | | | *[FINAL]* | ***Total 2050*** | ***114*** | ***(MT Co-Pollutants)*** |

| Multiple Measures | By 2050 Divert power generation away from fossil fuels through installation of anerobic digesters at municipal facilities such as wastewater treatment plants, technical schools, technical colleges, and other public institutions as well as and other urban and rural agricultural projects that generate energy for 10% of electricity/power use in the region in 2050. |
|---|---|

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***13,537*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***96,704*** | ***MTCO2e*** |

Methodology Description: A 1.8% average annual percent increase in net electricity was used to calculated the projected electricity in 2030, 2040, and 2050 based on ISO New England data. The share of electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. It was assumed that anaerobic digestion would be the source of 0%, 3% and 5% of the MSA's electricity in 2030, 2040, and 2050, respectively.

[value] **2022 Electricity Emissions**

1,145,804 (MTCO2e) Source: 2022 GHG Inventory

[value] **2022 Transmission & Distribution (T&D) Emissions**

56,855 (MTCO2e) Source: 2022 GHG Inventory

[value] **Average Annual Percent Increase in Net Electricity Use**

1.8% Source: ISO New England New England's Electricity Demand Forecast https://www.iso-ne.com/about/key-stats/electricity-use#:~:text=Net%20electricity%20use%20is%20expected,to%2026%2C897%20MW%20in%202034.

[value] **Number of years from 2022 to 2030, 2040, 2050**

| | |
|---|---|
| 8 | (years) |
| 18 | (years) |
| 28 | (years) |

[calc] **Estimated Increase in Net Electricity Use in MSA (compound growth)**

| | |
|---|---|
| 2030 | 7,750,674,641 |
| 2040 | 9,264,399,755 |
| 2050 | 11,073,758,968 |

[value] **Total 2022 Electricity Consumption in MSA by Type**

| Type | Electricity (kWh) | EV Adjustment (kWh) | Adjusted Electricity (kWh) | Percent of Total | Emissions factors (MTCO2e/kWh) |
|---|---|---|---|---|---|
| CT IOU | 800,847,265 | (6,772,384) | 794,074,881 | 12% | 0.0002467 |
| MA IOU | 4,738,634,423 | (11,396,183) | 4,727,238,240 | 70% | 0.0001700 |
| MA CCA | 439,731,577 | | 439,731,577 | 7% | 0.0000901 |
| MA MLP | 758,769,768 | | 758,769,768 | 11% | 0.0001773 |
| ***TOTAL*** | *6,737,983,033* | *(18,168,567)* | *6,719,814,466* | | |

Source: 2022 GHG Inventory

[value] **Total Electricity T&D Losses in MSA by Type**

| Type | T&D Losses (kWh) |
|---|---|
| CT IOU | 28,505,406 |
| MA IOU | 237,493,662 |
| MA CCA | 22,091,855 |
| MA MLP | 35,842,551 |
| ***TOTAL*** | 323,933,474 |

Source: 2022 GHG Inventory

[calc] **Weighted Electricity Emissions Factor**

0.000175

[calc] **Projected Electricity Emissions with Increased Electricity Demand and No Additional Renewable Energy**

| | | |
|---|---|---|
| 2030 | 1,353,687 | (MTCO2e) |
| 2040 | 1,618,066 | (MTCO2e) |
| 2050 | 1,934,078 | (MTCO2e) |

[value] **Emissions Factor for Electricity from Renewable Sources**

0.00 (MTCO2e/kWh)

Source: GHG Protocol https://ghgprotocol.org/scope-2-frequently-asked-questions#question%20two

[input] **2030 Electricity Generation Sources**

1% Anaerobic Digestion

[input] **2040 Electricity Generation Sources**

3% Anaerobic Digestion

[input] **2050 Electricity Generation Sources**

5% Anaerobic Digestion

[calc] **2030 Electricity Emissions**

1,340,150 (MTCO2e)

[calc] **2040 Electricity Emissions**

1,569,524 (MTCO2e)

[calc] **2050 Electricity Emissions**
1,837,374 (MTCO2e)

[calc] **2030 Electricity Emissions Reduction**
13,537 (MTCO2e)

[calc] **2040 Electricity Emissions Reduction**
48,542 (MTCO2e)

[calc] **2050 Electricity Emissions Reduction**
96,704 (MTCO2e)

**Co-Pollutants**

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from anaerobic digestion.

[calc] **2030 Total kWh**
77,506,746 kWh
77,507 MWh

[calc] **2050 Total kWh Consumption (Projected)**
553,687,948 kWh
553,688 MWh

[input] **Conversion Lbs to Metric Ton**
2,204.62 Lbs/Metric Ton

[calc] **AVERT-derived Emission Rates and associated Total Co-Pollutant Emissions**

| Emission Factor | | **2030** | **2050** | **Unit** |
|---|---|---|---|---|
| 0.03 | SO2 (lb/MWh) | 0.98 | 7.03 | MT SO2 |
| 0.15 | NOX (lb/MWh) | 5.17 | 36.92 | MT NOX |
| 0.03 | PM2.5 (lb/MWh) | 0.98 | 7.03 | MT PM2.5 |
| 0.01 | VOCs (lb/MWh) | 0.39 | 2.76 | MT VOCs |
| 0.02 | NH3 (lb/MWh) | 0.60 | 4.27 | MT NH3 |
| | Total | 8 | 58 | MT Co-Pollutants |

| | |
|---|---|
| ***Measure*** | ***Develop a Worcester-CT MSA cradle-to-cradle industrial ecosystem that minimizes material waste, maximizes reuse, and leverages green technology innovations. By 2030, launch an MSA-wide industrial circularity accelerator program in partnership with the local Chambers of Commerce, institutions, and industrial leaders in the MSA, and conduct comprehensive industrial waste/waste flow audits. By 2040, build capacity and physical networks to facilitate the reuse/exchange of materials and equipment, collaborative procurement of sustainable/recycled materials, and shared use of waste processing technologies. Incentivize participation in the industrial material efficiency and waste circularity network through the establishment of tax credits for verified material diversion from landfills and grants to assist with adopting cradle-to-cradle systems. Using these mechanisms, divert 60% of solid waste from landfill/incineration from industrial facilities in the Worcester-CT MSA by 2050.***<br><br>***In case of large campuses/industrial corridors and clusters, create overlay zoning guidelines that encourage the integration of green systems and create zones where integrated energy systems (microgrids and other energy production and supply systems) reduce energy peak demand, reduce wastewater generation, and expand treatment and create circular systems, aiming to create net-zero neighborhoods zones where possible. This strategic development could model best practices in the region, even while reducing the overall energy consumption and greenhouse gas emissions by an additional 5 percent.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***469*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***2,812*** | ***MTCO2e*** |

Limited data was available to indicate the sources of waste generated in the MSA, therefore, a quantity of waste and a percent reduction were assumed to be associated with industrial activities. The emissions associated with this reduction were calculated assuming the same ratio of waste landfilled and incinerated in the MSA as used in the 2022 GHG Inventory.

[input] **Total Estimated Waste from Industrial Sector**
60,000 (short tons) *Assumption*

[input] **2030 Percent of Industrial Waste Diversion From Landfills/Incinerators**
10% (%) *Assumption*

[calc] **2030 Waste Reduced**
6,000 (short tons)

[input] **2050 Percent of Industrial Waste Diversion From Landfills/Incinerators**
60% (%) *Assumption*

| | | | |
|---|---|---|---|
| [calc] | **2050 Waste Reduced** | | |
| | 36,000 | (short tons) | |
| [input] | **Waste Diversion Allocations and Total Tons per** | | |
| | 17% | Fraction of Landfill | |
| | 83% | Fraction of Incineration | |
| [calc] | **Tons by Disposal Location** | | |
| 2030 | 1,003 | (short tons for landfill) | |
| 2030 | 4,997 | (short tons for incinerator) | |
| 2050 | 6,018 | (short tons for landfill) | |
| 2050 | 29,982 | (short tons for incinerator) | |
| [values] | **Landfill CH4 Emissions Variables** | | |
| Lo | 0.08 | | *Source: 2022 GHG Inventory* |
| frec | 0.85 | | |
| Ox | 0.10 | | |
| [calc] | **Landfill Methane Emissions Reduced by 2030** | | |
| | 11 | (MTCH4) | |
| | 301.43 | (MTCO2e) | *AR5* |
| [calc] | **Landfill Methane Emissions Reduced by 2050** | | |
| | 65 | (MTCH4) | |
| | 1,809 | (MTCO2e) | *AR5* |
| [values] | **Incineration CO2, CH4, and N2O Emissions Variables** | | |
| | 0.6% | | *Source: 2022 GHG Inventory, GPC* |
| | 3.67 | | *Equation 8.6* |
| conversion | 0.000001 | | |
| CH4 | 0.20 | (g CH4/ton) | |
| N2O | 50 | (g N2O/ton) | |
| CH4 GWP | 28 | | *AR5* |
| N2O GWP | 265 | | *AR5* |
| [calc] | **Incineration CO2, CH4, N2O emissions 2030** | | |
| CO2 | 101 | (MTCO2e) | |
| CH4 | 0.0 | (MTCO2e) | |
| N2O | 66 | (MTCO2e) | |
| | **167** | **Total MTCO2e Incineration 2030** | |
| [calc] | **Incineration CO2, CH4, N2O emissions 2050** | | |
| CO2 | 606 | (MTCO2e) | |
| CH4 | 0.2 | (MTCO2e) | |
| N2O | 397 | (MTCO2e) | |
| | **1,004** | **Total MTCO2e Incineration 2050** | |

[calc] **Total Emission Reduction 2030 and 2050 (Landfill + Incineration)**

| | | |
|---|---|---|
| 2030 | 469 | (MTCO2e) |
| 2050 | 2,812 | (MTCO2e) |

**Co-Pollutants**

**Landfill Co-Pollutants**

*Source: EPA Landfill Gas Emissions Model (LandGEM) Version 3.1 User Manual*

[value] **Conversion for Landfill gas (LFG) generated per ton of waste**

1.98E-08 ppmv × ft³ × MW = lb

7,063 ft³/ton

| Pollutant | ppmv | MW | *EF (lb/ton)* | *Waste (tons) 2030* | *Waste (tons) 2050* | *Emissions (Metric Tons) 2030* | *Emissions (Metric Tons) 2050* |
|---|---|---|---|---|---|---|---|
| **Benzene** | 39 | 78 | *0.4260* | *6,000* | *36,000* | *1* | *8* |
| **Toluene** | 170 | 92 | *2.1903* | *6,000* | *36,000* | *7* | *39* |
| **Vinyl chloride** | 7.3 | 63 | *0.0638* | *6,000* | *36,000* | *0* | *1* |
| **Carbon monoxide** | 110 | 28 | *0.4309* | *6,000* | *36,000* | *1* | *8* |
| **Methylene chloride** | 5.8 | 85 | *0.0689* | *6,000* | *36,000* | *0* | *1* |
| **Chloroform** | 0.3 | 119 | *0.0057* | *6,000* | *36,000* | *0* | *0* |
| **Carbon tetrachloride** | 0.0 | 154 | *0.0000* | *6,000* | *36,000* | *0* | *0* |
| **Ethylbenzene** | 4.6 | 106 | *0.0683* | *6,000* | *36,000* | *0* | *1* |
| **Trichloroethylene** | 2.8 | 131 | *0.0515* | *6,000* | *36,000* | *0* | *1* |
| **Perchloroethylene** | 2.1 | 166 | *0.0487* | *6,000* | *36,000* | *0* | *1* |
| | | | | *[FINAL]* | ***Total 2030*** | ***10*** | ***(MT Co-Pollutants)*** |
| | | | | *[FINAL]* | ***Total 2050*** | ***60*** | ***(MT Co-Pollutants)*** |

**Industrial Waste Toolkit/Worksheet**

Pg. 64 https://www.un-page.org/static/78555adf7da006a2fd945b6424a14b3d/industrial-waste-management-cost-structure-review-report-2021.pdf

| | |
|---|---|
| ***Measure*** | ***Unit Based Pricing (UBP) or Pay-As-You-Throw (PAYT) Program Adoption throughout the MSA for Residential, Municipal, Commercial, and Industrial waste producers would reduce between 40-60% of the waste generated in the MSA, and utilize existing transfer stations for sortation, reducing Vehicle Miles Traveled by a corresponding amount through Co-Collection (where separately bagged organics/compostables, recyclables, single use plastics, glass, and MSW are collected on the same day from the same bin) and transported to the transfer stations to be sorted, creating valuable feedstocks for a circular economy. By 2050 have full adoption across the MSA.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***8,102*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***14,182*** | ***MTCO2e*** |

The population in the MSA which is not already served by a Pay-As-You-Throw/SMART program was estimated and an assumed 0.9 short tons per person per year was used to calculate the estimated baseline waste, aligned with the approach used in the 2022 GHG Inventory. A percent reduction of waste was assumed for 2030 and 2050 for increased participation in PAYT/SMART programs.

**GHG Reductions**

[input] **Total Population MA portion of MSA**
860,801 (people)

[input] **MA Portion of MSA enrolled in PAYT/SMART**

508,729 (people) *Source: Census 2022 population (consistent with GHG inventory)*

*PAYT/SMART communities list from MassDEP 2024 Municipal Solid Waste & Recycling Survey Responses https://www.mass.gov/lists/recycling-solid-waste-data-for-massachusetts-cities-towns*

[input] **MA Portion of MSA Without PAYT/SMART**
352,072 (people)

[input] **Tons per capita**
0.9 (Short Tons/Capita) Source: 2022 GHG Inventory

[calc] **Estimated Waste for Communities Not Participating in PAYT/SMART**
302,555 (Short Tons)

[input] **2030 Percent Reduction of Waste**
20% (%) *Assumption*

| | | | | |
|---|---|---|---|---|
| [input] | **2050 Percent Reduction of Waste** | | | |
| | | 60% | Reduction | *Assumption* |
| [calc] | **Tons of Waste Reduced** | | | |
| | 2030 | 60,511.02 | Total Short Tons | |
| | 2050 | 181,533 | | |
| [input] | **Waste Disposal Percentages** | | | |
| | | 17% | Landfilled | |
| | | 83% | Incinerated | |
| [calc] | **Tons of Waste Diverted by Type** | | | |
| | 2030 | 10,116 | (Short Tons Landfilled) | |
| | 2030 | 151,186 | (Short Tons Incinerated) | |
| | 2050 | 30,347 | (Short Tons Landfilled) | |
| | 2050 | 151,186 | (Short Tons Incinerated) | |
| [input] | **Waste Disposal Percentages** | | | |
| | | 17% | Fraction of Landfill | |
| | | 83% | Fraction of Incineration | |
| [values] | **Landfill CH4 Emissions Variables** | | | |
| Lo | | 0.08 | | *Source: GHG Inventory, GPC Equation 8.3* |
| frec | | 0.85 | | |
| Ox | | 0.10 | | |
| [calc] | **Landfill Methane Emissions Reduced by 2030** | | | |
| | | 109 | (MTCH4) | |
| | | 3,040 | (MTCO2e) | *AR5* |
| [calc] | **Landfill Methane Emissions Reduced by 2050** | | | |
| | | 326 | (MTCH4) | |
| | | 9,120 | (MTCO2e) | *AR5* |
| [values] | **Incineration CO2, CH4, and N2O Emissions Variables** | | | |
| Eq 8.6 | | | | |
| | | 0.6% | | *Source: 2022 GHG Inventory, GPC Equation 8.6* |
| Carbon ratio | | 3.67 | | |
| conversion | | 0.000001 | | |
| CH4 | | 0.20 | (g CH4/ton) | |
| N2O | | 50 | (g N2O/ton) | |
| CH4 GWP | | 28 | | *AR5* |
| N2O GWP | | 265 | | *AR5* |
| [calc] | **Incineration CO2, CH4, N2O emissions 2030** | | | |
| CO2 | | 3,058 | (MTCO2e) | |

| | | |
|---|---|---|
| CH4 | 0.8 | (MTCO2e) |
| N2O | 2,003 | (MTCO2e) |
| | **5,062** | **Total MTCO2e Incineration 2030** |

[calc] **Incineration CO2, CH4, N2O emissions 2050**

| | | |
|---|---|---|
| CO2 | 3,058 | (MTCO2e) |
| CH4 | 0.8 | (MTCO2e) |
| N2O | 2,003 | (MTCO2e) |
| | **5,062** | **Total MTCO2e Incineration 2050** |

[FINAL] **Total Emission Reduction 2030 and 2050 (Landfill + Incineration)**

| | | |
|---|---|---|
| 2030 | 8,102 | (MTCO2e) |
| 2050 | 14,182 | (MTCO2e) |

**Co-Pollutants**

**Landfill Co-Pollutants**

*Source: EPA Landfill Gas Emissions Model (LandGEM) Version 3.1 User Manual*

[value] **Conversion for Landfill gas (LFG) generated per ton of waste**

1.98E-08 ppmv × ft³ × MW = lb

7,063 ft³/ton

| **Pollutant** | **ppmv** | **MW** | ***EF (lb/ton)*** | ***Waste (tons) 2030*** | ***Waste (tons) 2050*** | ***Emissions (Metric Tons) 2030*** | ***Emissions (Metric Tons) 2050*** |
|---|---|---|---|---|---|---|---|
| **Benzene** | 39 | 78 | *0.4260* | *60,511* | *181,533* | *13* | *39* |
| **Toluene** | 170 | 92 | *2.1903* | *60,511* | *181,533* | *66* | *199* |
| **Vinyl chloride** | 7.3 | 63 | *0.0638* | *60,511* | *181,533* | *2* | *6* |
| **Carbon monoxide** | 110 | 28 | *0.4309* | *60,511* | *181,533* | *13* | *39* |
| **Methylene chloride** | 5.8 | 85 | *0.0689* | *60,511* | *181,533* | *2* | *6* |
| **Chloroform** | 0.3 | 119 | *0.0057* | *60,511* | *181,533* | *0* | *1* |
| **Carbon tetrachloride** | 0.0 | 154 | *0.0000* | *60,511* | *181,533* | *0* | *0* |
| **Ethylbenzene** | 4.6 | 106 | *0.0683* | *60,511* | *181,533* | *2* | *6* |
| **Trichloroethylene** | 2.8 | 131 | *0.0515* | *60,511* | *181,533* | *2* | *5* |
| **Perchloroethylene** | 2.1 | 166 | *0.0487* | *60,511* | *181,533* | *1* | *4* |
| | | | | *[FINAL]* | ***Total 2030*** | ***101*** | ***(MT Co-Pollutant*** |
| | | | | *[FINAL]* | ***Total 2050*** | ***304*** | ***(MT Co-Pollutants)*** |

**Links to data sources:**

| Multiple Measures | Electricity Use | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***446,717*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2040*** | ***1,003,201*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***1,837,374*** | ***MTCO2e*** |

Methodology Description: A 1.8% average annual percent increase in net electricity was used to calculate the projected electricity in 2030, 2040, and 2050 based on ISO New England data. The share of electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. Emissions reductions associated with anaerobic digestion are excluded from the calculations below and shown in the waste sector measures.

**Electricity Consumption Data and Supplemental Data**

[value] **2022 Electricity Emissions**

1,145,804 (MTCO2e) *Source: 2022 GHG Inventory*

[value] **2022 Transmission & Distribution (T&D) Emissions**

56,855 (MTCO2e) *Source: 2022 GHG Inventory*

[value] **Average Annual Percent Increase in Net Electricity Use**

1.8% *Source: ISO New England's 10-Year Electricity Demand Forecast https://www.iso-ne.com/about/key-stats/electricity-use#:~:text=Net%20electricity%20use%20is%20expected,to%2026%2C897%20MW%20in%202034.*

[value] **Number of years from 2022 to 2030, 2040, 2050**

8 (years)
18 (years)
28 (years)

[calc] **Estimated Increase in Net Electricity Use in MSA (compound growth)**

| | |
|---|---|
| 2030 | 7,750,674,641 |
| 2040 | 9,264,399,755 |
| 2050 | 11,073,758,968 |

[value] **Total 2022 Electricity Consumption in MSA by Type**

| Type | Electricity (kWh) | EV Adjustment (kWh) | Adjusted Electricity (kWh) | Percent of Total | Emissions Factor (MTCO2e/kWh) |
|---|---|---|---|---|---|
| CT IOU | 800,847,265 | (6,772,384) | 794,074,881 | 12% | 0.000247 |
| MA IOU | 4,738,634,423 | (11,396,183) | 4,727,238,240 | 70% | 0.000170 |
| MA CCA | 439,731,577 | | 439,731,577 | 7% | 0.000090 |
| MA MLP | 758,769,768 | | 758,769,768 | 11% | 0.000177 |
| ***TOTAL*** | *6,737,983,033* | *(18,168,567)* | *6,719,814,466* | | |

*Source: 2022 GHG Inventory*

[value] **Total Electricity T&D Losses in MSA by Type**

| Type | T&D Losses (kWh) |
|---|---|
| CT IOU | 28,505,406 |
| MA IOU | 237,493,662 |
| MA CCA | 22,091,855 |
| MA MLP | 35,842,551 |
| **TOTAL** | **323,933,474** |

*Source: 2022 GHG Inventory*

[calc] **2022 Weighted Electricity Emissions Factor**

0.000175

[calc] **Projected Electricity Emissions with Increased Electricity Demand and No Additional Renewable Energy**

| | | |
|---|---|---|
| 2030 | 1,353,687 | (MTCO2e) |
| 2040 | 1,618,066 | (MTCO2e) |
| 2050 | 1,934,078 | (MTCO2e) |

[value] **Emissions Factor for Eletricity from Renewable Sources**

0.0000 (MTCO2e/kWh)

*Source: GHG Protocol https://ghgprotocol.org/scope-2-frequently-asked-questions#question%20two*

[input] **2030 Electricity Generation Sources**

| | |
|---|---|
| 15% | Solar |
| 4% | Wind |
| 8% | Nuclear |
| 1% | Storage |
| 5% | Hydro |
| 1% | Anaerobic Digestion |
| *66%* | *Remaining* |

*Anaerobic Digestion is accounted for in Waste Sector Measures but has been shown here to show overall percent composition of clean energy.*

[input] **2040 Electricity Generation Sources**

| | |
|---|---|
| 20% | Solar |
| 12% | Wind |
| 10% | Nuclear |
| 3% | Storage |

*2040 is optional to include*

17% Hydro
3% Anaerobic Digestion
*35% Remaining*

[input] **2050 Electricity Generation Sources**
25% Solar
18% Wind
25% Nuclear
5% Storage
22% Hydro
5% Anaerobic Digestion
*0% Remaining*

[calc] **2030 Electricity Emissions**
906,970 (MTCO2e)

[calc] **2040 Electricity Emissions**
614,864.90 (MTCO2e)

[calc] **2050 Electricity Emissions**
96,704 (MTCO2e)

[FINAL] **2030 Electricity Emissions Reduction**
446,717 (MTCO2e)

[calc] **2040 Electricity Emissions Reduction**
1,003,201 (MTCO2e)

[FINAL] **2050 Electricity Emissions Reduction**
1,837,374 (MTCO2e)

[calc] ***Percent to allocate emission reductions***

| Source | 2030 | 2040 | 2050 |
|---|---|---|---|
| Solar | 44% | 31% | 25% |
| Wind | 12% | 18% | 18% |
| Nuclear | 24% | 15% | 25% |
| Storage | 3% | 5% | 5% |
| Hydro | 15% | 26% | 22% |
| Anaerobic Digestion | 3% | 5% | 5% |

[calc] ***GHG emissions reduction allocated to each source (MTCO2e)***

| | | | |
|---|---|---|---|
| Solar | 197,081 | 308,677 | 459,343 |
| Wind | 52,555 | 185,206 | 330,727 |
| Nuclear | 105,110 | 154,339 | 459,343 |
| Storage | 13,139 | 46,302 | 91,869 |
| Hydro | 65,694 | 262,376 | 404,222 |
| Anaerobic Digestion | 13,139 | 46,302 | 91,869 |
| Totals (check) | 446,717 | 1,003,201 | 1,837,374 |

## Co-Pollutants

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from renewable sources.

[calc] **2030 Total kWh From Renewable Sources**

2,635,229,378 kWh
2,635,229 MWh

[calc] **2050 Total kWh From Renewable Sources**

11,073,758,968 kWh
11,073,759 MWh

[input] **Conversion Lbs to Metric Ton**

2,204.62 Lbs/Metric Ton

[calc]

**AVERT-derived Emission Rates and associated Total Co-Pollutant Emissions**

| Emission Factor | | 2030 | 2050 | Unit |
|---|---|---|---|---|
| 0.03 | SO2 (lb/MWh) | 33.47 | 140.64 | MT SO2 |
| 0.15 | NOX (lb/MWh) | 175.71 | 738.38 | MT NOX |
| 0.03 | PM2.5 (lb/MWh) | 33.47 | 140.64 | MT PM2.5 |
| 0.01 | VOCs (lb/MWh) | 13.15 | 55.25 | MT VOCs |
| 0.02 | NH3 (lb/MWh) | 20.32 | 85.39 | MT NH3 |
| **Total** | | **276** | **1,160** | **MT Co-Pollutants** |

[calc] **Co-pollutant reduction allocated to each source (MT Co-Pollutant)**

| Source | 2030 | 2050 |
|---|---|---|
| Solar | 122 | 290 |
| Wind | 32 | 209 |
| Nuclear | 65 | 290 |
| Storage | 8 | 58 |
| Hydro | 41 | 255 |
| Anaerobic Digestion | 8 | 58 |
| Totals (check) | 276 | 1,160 |

| Measure | Expand and improve regional bicycle and pedestrian networks by making them safety, more accessible, and well-connected to help reduce car dependency, increased health benefits, and more economic opportunities. Implement more e-bike and bike-share programs in urban areas and across the region where feasible. Expand bike racks and bicycle facilities where needed. Expand shared-use paths for first- and last-mile trips to support the movement and connectivity of bicyclists and pedestrians to origins/destinations and transit stations/stops | |
|---|---|---|
| Annual GHG emissions reduced in 2030 | 133,323 | MTCO2e |
| Annual GHG emissions reduced in 2050 | 266,646 | MTCO2e |

Data from the Greater Worcester Regional GHG Inventory for 2022 was used to calculate a reduction in vehicle miles traveled (VMT) of passenger gasoline vehicles that could be associated with the elements described in the measure. It was assumed that VMT would be reduced by 5% by 2030 and 10% by 2050.

**MA VMT Reduction**

[input] **MA Gasoline Passenger Miles Traveled and Fuel Consumption in 2022**

| | | |
|---|---|---|
| 6,313,785,072 | Miles | Source: 2022 GHG Inventory |
| 275,277,035 | Gallons | |

[calc] **MA Average Fuel Efficiency**

22.9 (mile/gal)

[input] **Percentage of MA VMT Reductions**

| | | |
|---|---|---|
| 2030 | 5% | Assumption - CT has a 5% VMT reduction goal for 2050 |
| 2050 | 10% | Assumption |

[calc] **MA VMT Reduction**

| | |
|---|---|
| 2030 | 315,689,254 |
| 2050 | 631,378,507 |

[calc] **MA Fuel Reduced**

| | |
|---|---|
| 2030 | 13,763,852 |
| 2050 | 27,527,703 |

[value] **Gasoline and Diesel Emission Factor - CO2e**

| | | |
|---|---|---|
| 0.0089 | (Gasoline) | Source: 2022 GHG Inventory |
| 0.0103 | (Diesel) | |

[calc] **MA Estimated Emissions Reduction**

| | | |
|---|---|---|
| 2030 | 122,075 | (MTCO2e) |
| 2050 | 244,149 | (MTCO2e) |

## CT VMT Reduction

[input] **CT Gasoline Passenger Miles Traveled and Fuel Consumption in 2022**

| | | |
|---|---|---|
| 634,116,832 | Miles | Source: 2022 GHG Inventory |
| 25,364,673 | Gallons | |

[calc] **CT Average Fuel Efficiency**

| | |
|---|---|
| 25.0 | (mile/gal) |

[input] **Percentage of CT VMT Reductions**

| | |
|---|---|
| 2030 | 5% |
| 2050 | 10% |

[calc] **CT VMT Reduction**

| | |
|---|---|
| 2030 | 31,705,842 |
| 2050 | 63,411,683 |

[calc] **CT Fuel Reduced**

| | |
|---|---|
| 2030 | 1,268,234 |
| 2050 | 2,536,467 |

[calc] **CT Estimated Emissions Reduction**

| | | |
|---|---|---|
| 2030 | 11,248 | (MTCO2e) |
| 2050 | 22,496 | (MTCO2e) |

## Total Emissions Reduction From VMT (MA + CT)

[calc] **Total Emissions Reduction From VMT Reduction**

| | | |
|---|---|---|
| 2030 | 133,323 | (MTCO2e) |
| 2050 | 266,646 | (MTCO2e) |

## Total VMT Emissions Reductions

[FINAL] **Annual GHG emissions reduced in 2030**

(MTCO2e) *133,323*

[FINAL] **Annual GHG emissions reduced in 2050**

(MTCO2e) *266,646*

## Co-Pollutants

**Methodology:** The Federal Highway Administration's CMAQ Emissions Calculator Bicycle, Pedestrian, and Micromobility Emissions Tool was used to quantify co pollutants in relation to a reduction in VMT. A 2 to 1 ratio was input into the calculator and the year was set to 2030 to obtain the total kg/day/trip co-pollutants reduction. The co-pollutants reduction output is applied to the number of trips allocated to walking and biking as part of the vehicles trips reduced. The same was done for 2050 but the year is set to 2040 in place of 2050 because that is the furthest year the tool is able to evaluate.

[value] **Average trip distance**
2.0129 (miles/trip) *Default value*

[calc] **MA VMT Reduction**
2030 315,689,254 (miles)
2050 631,378,507 (miles)

[calc] **CT VMT Reduction**
2030 31,705,842 (miles)
2050 63,411,683 (miles)

[input] **Percent allocated to walking or biking**
5%

[calc] **Number of Trips Reduced**
2030 8,629,219 (trips)
2050 17,258,438 (trips)

| 2030 | | | |
|---|---|---|---|
| **Pollutant** | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** |
| Carbon Monoxide (CO) | 0.00466 | 0.0017001 | 14,670 |
| Particulate Matter ≤2.5 µm | 0.00002 | 0.0000066 | 57 |
| Particulate Matter ≤10 µm | 0.00009 | 0.0000324 | 280 |
| Nitrogen Oxides (NOx) | 0.00015 | 0.0000541 | 467 |
| Volatile Organic | 0.00016 | 0.0000571 | 493 |
| **2050** | | | |
| **Pollutant** | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** |
| Carbon Monoxide (CO) | 0.00289 | 0.0010549 | 18,207 |
| Particulate Matter ≤2.5 µm | 0.00002 | 0.0000059 | 102 |
| Particulate Matter ≤10 µm | 0.00009 | 0.0000317 | 548 |
| Nitrogen Oxides (NOx) | 0.00006 | 0.0000205 | 353 |
| Volatile Organic | 0.00012 | 0.0000421 | 727 |

[calc] **2030 Total Co-Pollutant Reductions**
15,967 (MT Co-Pollutants)
[calc] **2050 Total Co-Pollutant Reductions**
19,937 (MT Co-Pollutants)

**Cost**

Cost estimates for this measure include the development of shared use paths and bike share programs. The Shared Use Path Design Guide Cost Estimator available from MA EEA was used to determine an example cost for a shared use path. A value of approximately $2.5 million per mile of path was used, with assumptions that 10 miles and 20 miles of path would be developed by 2030 and 2050, respectively. The costs for bike share programs were derived from recent examples within Massachusetts, including the Minuteman, ValleyBike, and Newburyport bike share programs. The three year program costs range from $187,450 to $2.3 million, representing a variety of programs including those for a single community and up to as many as ten communities, and programs with regular bikes and e-bikes. It was assumed that by 2030 three small scale and one large scale bike share programs would be established and by 2050, 12 small scale and 4 large scale programs would be established (in addition to the programs started by 2030).

**Shared Use Path Cost**

*Source: MA EEA Shared Use Path Design Guide Cost Estimator https://www.mass.gov/guides/shared-use-path-planning-and-design-guide*

[input] **Path Length**
1000 (ft)

[input] **Path Width**
12 (ft)

[input] **Number of Segments**
1.00

[input] **Other Assumptions:**
Construction to begin in 2026
Includes design and traffic control costs
Existing conditions: roadway
Roadway Side Path type
Porous pavement
Grass shoulder
No equestrian path
Moderate landscape restoration and enhancements
No parking spaces
No lighting required
15% contingency cost

[calc] **Cost Summary**

| | | |
|---|---|---|
| $ | 295,800.00 | Path |
| $ | 20,700.00 | Structures |
| $ | 57,300.00 | Landscaping |
| $ | 14,790.00 | Traffic Control |
| $ | 446,878.50 | Construction cost (w/ contingency) |
| | | |
| $ | 14,200.00 | Survey |
| $ | 69,630.00 | Design |
| **$** | **530,708.50** | **Toal Cost Per 1000 ft** |
| **$** | **2,464,970.00** | **Total Cost Per Mile** |

| | | | | |
|---|---|---|---|---|
| [input] | **Miles of Path To be Constructed** | | | |
| 2030 | | 10 | (miles) | |
| 2050 | | 20 | (miles) | |
| | | | | |
| [calc] | **Total Cost for Path Construction** | | | |
| 2030 | $ | 24,649,700.00 | | |
| 2050 | $ | 49,299,400.00 | | |
| | | | | |
| | **Bike Share Programs** | | | |
| [value] | **Minuteman Bike Share** | | | |
| | $ | 187,450 | (2024 dollars) Three year cost | |
| | | 42.00 | (bikes) | |
| | $ | 1,800.00 | ($/bike) | |
| | | 7 | (stations) | *Sources: The Concord Bridge article https://concordbridge.org/index.php/2025/03/25/minuteman-bike-share-expands-to-neighboring-towns-after-state-grant/* <br><br> *Town of Acton Capital Improvement Plan FY26-27 https://www.acton-ma.gov/DocumentCenter/View/10112/2024-12-16-FY2026-2035-CIP?bidId=* |
| [value] | **Newburyport Bike Share** | | | |
| | $ | 288,800 | (2024 dollars) Three year cost | |
| | | 33 | (bikes) | *Source: City of Newburyport https://www.cityofnewburyport.com/sites/g/files/vyhlif12211/f/uploads/comm00574_09_09_2024_amended_bike_share.pdf* |
| | | 6 | (stations) | |
| | $ | 2,200 | ($/bike) | |
| | | | | |
| [value] | **ValleyBike Bike Share** | | | |
| | $ | 2,300,000 | (2024 dollars) Three year cost | *Source: City of Northampton https://archive.northamptonma.gov/WebLink/DocView.aspx?id=828651&dbid=0&repo=CityOfNorthampton* |
| | | 10 | (municipalities) | |
| | | 300 | (existing bikes) | |
| | | 50 | (new e-bikes) | |
| | $ | 2,250 | ($/e-bike) | |
| | | | | |
| [value] | **Consumer Price Index Conversion 2024 to 2025 Dollars** | | | |
| | | $1.05 | (dollar conversion) | *Source: US Bureau of Labor Statistics CPI Inflation Calculator https://www.bls.gov/data/inflation_calculator.htm* |

| | | | |
|---|---|---|---|
| [calc] | **Average of Small Program Three Year Costs** | | |
| | $ | 250,031 | (2025 dollars) |
| [calc] | **Average Annual Small Program Cost** | | |
| | $ | 83,344 | (2025 dollars) |
| [calc] | **Average Annual Large Program Cost** | | |
| | $ | 805,000 | (2025 dollars) |
| [input] | **Number of Single Community/Small Regional Programs** | | |
| 2030 | | 3.00 | *Assumption* |
| 2050 | | 12.00 | *Assumption* |
| [input] | **Number of Large Regional Programs** | | |
| 2030 | | 1.00 | *Assumption* |
| 2050 | | 4.00 | *Assumption* |
| [input] | **Time Programs In Place** | | |
| | | 23 | (years) |
| | | 10 | (years) |
| [calc] | **Bike Share Program Cost** | | |
| 2030 | $ | 3,050,094 | *Assuming in operation for 3 years (2027-2030)* |
| 2050 | $ | 66,466,969 | *Includes ongoing cost for programs started by 2030* |
| [calc] | **Total Cost for Shared Use Paths and Bike Share** | | |
| 2030 | $ | 27,699,794 | |
| 2050 | $ | 115,766,369 | |

| | |
|---|---|
| ***Measure*** | ***Expansion of public charging infrastructure at municipally-owned buildings and identify other public EV charging locations near multifamily housing and commercial centers, especially in LIDAC and rural communities. Municipalities must develop a regional EV charging network strategy or plan to identify suitable locations for EV charging stations; identify EVSE companies and utilities to build and operate the charging infrastructure; explore incentives and funding programs install, operate, and maintain charging infrastructure; and educate residents about how to use EV chargers and clearly communicate guidelines for using public chargers. Municipalities must determine grid upgrades, as necessary, in order to install the necessary chargers at each location. This could and should be done within the strategy or plan.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***521,092*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***959,370*** | ***MTCO2e*** |

GHG reductions associated with electric vehicle charging were quantified by using the Electric Vehicle Infrastructure Coordinating Council Initial Assessment to the General Couty report which identifies the charging demand required to meet the MA 2030 statewide EV adoption goal. This report includes the number of charging ports by type which were scaled down to the MA portion of the MSA by population.

**Emissions Reductions from Expanding EV Charging**

| | | | | |
|---|---|---|---|---|
| [value] | **Percent of state population in MA (MSA)** | | | |
| | | 12% | (%) | *Source: 2022 GHG Inventory (Census)* |
| [value] | **EVs to port ratio for level 2 multifamily home chargers** | | | |
| | | 16 | (EVs/port) | *Source: Table 4.2 EVICC* |
| [value] | **Multifamily residential ports projected statewide to meet 2030 targets** | | | |
| | | 15,000 | (ports) | *Source: Table 4.2 EVICC* |
| [calc] | **Multifamily residential ports projected for MSA to meet 2030 targets** | | | |
| | | 1,800 | (ports) | |
| [input] | **Percent increase needed beyond 2030 chargers for 2050** | | | |
| 2050 | | 50% | (%) | *Assumption* |
| [calc] | **Multifamily residential ports assumed for 2050** | | | |
| 2050 | | 2,700 | **(ports)** | |
| [value] | **EVs to port ratio for level 2 commercial chargers** | | | |
| | | 29.4 | (EVs/port) | *Source: Table 4.2 EVICC* |
| [value] | **Commercial ports projected statewide to meet 2030 targets** | | | |

33,000 (ports)

[calc] **Commercial ports projected for MSA to meet 2030 targets**
3,960 (ports)

[input] **Percent increase in chargers for 2050**
2050 50% (%) *Assumption*

[calc] **Commercial ports assumed for 2050**
2050 5,940

[value] **EVs to port ratio for level 2 public chargers**
28.0 (EVs/port) *Source: Table 4.2 EVICC*

[value] **Public ports projected statewide to meet 2030 targets**
35,000 (ports)

[calc] **Public ports projected for MSA to meet 2030 targets**
4,200 (ports)

[input] **Percent increase needed beyond 2030 chargers**
2050 50% (%) *Assumption*

[calc] **Public ports assumed for 2050**
2050 6,300

[calc] **Average miles traveled per year per vehicle (VMT/registrations) for 2022 in MA**
10,984.57 (miles/yr) *Source: Explore DOT state statistical https://explore.dot.gov/views/StateStatisticalAbstracts_16699101653250/DashboardALT?%3Aembed=y&%3Aiid=1&%3AisGuestRedirectFromVizportal=y*

[input]
**Average miles/gal for passenger vehicles for gasoline vehicles**
23.2 (miles/gal) *Source: GHG Inventory (MA_Passenger_Vehicles!B2 / C3)*

[calc] **Gallons gasoline saved per port per year if fully utilized**
7,585 (gallons)

[value] **Gasoline Emissions Factors**
0.00878 ($MTCO_2$/gal) *Source: EPA Emissions Factor Hub*
0.0000004 ($MTCH_4$/gal) *28* *GWP*
0.0000001 ($MTN_2O$/gal) *265* *CO2*

[calc] **MTCO2e saved per port fully utilized per year (not including elec increase)**
66.84 (MTCO2e)

| | | | |
|---|---|---|---|
| [input] | **Average kW output** | | |
| | 14 | (kW) | *Source: USDOT Charging Forward Toolkit https://www.transportation.gov/rural/ev/toolkit* |
| [value] | **Hours per year** | | |
| | 8,760 | (hrs/year) | |
| [calc] | **Electricity used per year per port** | | |
| | 122,640 | (kWh) | |
| [value] | **Future Electricity emissions factor** | | |
| 2030 | 0.000118 | ($MTCO_2e$/kWh) | *Source: MA EEA via Climate Leader Community Guidance* |
| 2050 | 0.0000000 | ($MTCO_2e$/kWh) | |
| [calc] | **MTCO2e/year increased from EV charging** | | |
| 2030 | 15 | (MTCO2e/year) | |
| 2050 | 0 | (MTCO2e/year) | *Assumed all electricity will be from renewable sources in 2050* |
| [calc] | **Net GHG emissions savings per port per year** | | |
| 2030 | 52 | (MTCO2e/year) | |
| 2050 | 67 | (MTCO2e/year) | |
| [calc] | **Emissions reduction from vehicles supported by multifamily residential EV chargers** | | |
| 2030 | 94,173 | (MTCO2e/year) | |
| 2050 | 141260 | (MTCO2e/year) | |
| [calc] | **Emissions reduction from vehicles supported by commercial EV chargers** | | |
| 2030 | 207,181 | (MTCO2e/yea | |
| 2050 | 397,024 | (MTCO2e/year) | |
| [calc] | **Emissions reduction from vehicles supported by public EV chargers** | | |
| 2030 | 219,738 | (MTCO2e/year) | |
| 2050 | 421,086 | (MTCO2e/year) | |
| [FINAL] | **Annual GHG emissions reduced in 2030** | | |
| | 521,092 | (MTCO2e) | |
| [FINAL] | **Annual GHG emissions reduced in 2050** | | |
| | 959,370 | (MTCO2e) | |
| [calc] | **Number EVs supported** | | |
| 2030 | 262,824 | (EVs) | |
| 2050 | 394,236 | (EVs) | |

**Co-pollutants**

**Methodology:** The Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure tool is used to quantify the co pollutants. The co-

pollutants reduction is based on the number of EV's supported by charging infrustructure.

**2030 Gasoline Co-pollutants Reduction**

| Type | kg/day | MT/year |
|---|---|---|
| Carbon Monoxide (CO) | 20,307.268 | 7,412.2 |
| Nitrogen Oxide (NOx) | 410.370 | 149.8 |
| Particulate Matter <2.5 µm (PM2.5) | 33.646 | 12.3 |
| Particulate Matter <10 µm (PM10) | 38.035 | 13.9 |
| Volatile Organic Compounds (VOC) | 1,008.942 | 368.3 |
| | **Total** | **7,956** |

*Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure*

*Inputs: 2030, Passenger Car, 2018, Gasoline, 262,824 EV vehicle population, model 2027*

**2050 Gasoline**

| Type | kg/day | MT/year |
|---|---|---|
| Carbon Monoxide (CO) | 20,591.948 | 7,516.1 |
| Nitrogen Oxide (NOx) | 221.314 | 80.8 |
| Particulate Matter <2.5 µm (PM2.5) | 50.192 | 18.3 |
| Particulate Matter <10 µm (PM10) | 56.739 | 20.7 |
| Volatile Organic Compounds (VOC) | 1,774.136 | 647.6 |
| | **Total** | **8,283** |

*Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV*

*Charging Infrastructure*

*Inputs: 2040, Passenger car, 2025, Gasoline,394,236 EV vehicle population, 2040*

[FINAL] **Total Co-Pollutant Reduction**

| | | |
|---|---|---|
| 2030 | 7,956 | (MT co-pollutants) |
| 2050 | 8,283 | (MT co-pollutants) |

**Cost**

The EPA CCAP Cost Estimating Resource identified the cost of a level 2 charger as $7,500 (2015 dollars). This was converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator and multiplied by the number of charging ports. The number of ports was determined in the GHG reduction calculations for 2030 and 2050 based on statewide projected charging port needs, scaled to the MSA by population.

[value] **Consumer Price Index Conversion 2015 to 2025 Doll**

$1.38 (dollar conversion) *Source: US Bureau of Labor Statistics CPI Inflation Calculator*

**Average Cost for a Level 2 Charger**

[value] $7,500 (2015 dollars) *Source: EPA CCAP estimation resource*

[calc] $10,350 (2025 dollars)

[calc] **Estimated Ports Needed by sector (Public/Com/MultiFam) by 2030 based on Statewide Targets**

| | |
|---|---|
| 1,800 | Multiresidential |
| 3,960 | Commercial |
| 4,200 | Public |

[calc] **Estimated Cost by sector (Public/Com/MultiFam) by 2030 based on Statewide Targets**

| | | |
|---|---|---|
| $ | 18,630,000 | Multiresidential |
| $ | 40,986,000 | Commercial |
| $ | 43,470,000 | Public |

[calc] **Estimated Ports Needed by sector (Public/Com/MultiFam) by 2050 based on Statewide Targets**

| | |
|---|---|
| 2,700 | Multiresidential |
| 5,940 | Commercial |
| 6,300 | Public |

[calc] **Estimated Cost by sector (Public/Com/MultiFam) by 2050 based on Statewide Targets**

| | | |
|---|---|---|
| $ | 27,945,000 | Multiresidential |
| $ | 61,479,000 | Commercial |

| | | |
|---|---|---|
| | $ 65,205,000 | Public |

[FINAL]

| | |
|---|---|
| | **Estimated Total Costs for all EV Chargers in 2030 and 2050** |
| 2030 | $ 103,086,000 |
| 2050 | $ 154,629,000 |

| | | | |
|---|---|---|---|
| ***Measure T4.*** | ***Increase the adoption of zero emission passenger and light-duty municipal vehicles. About 100% of municipal passenger and light-duty vehicle fleet converts to all-electric by 2050. At the end of useful life, all converted electric vehicles must be replaced with similar zero-emission vehicles. Steps to take include education, identifying incentives and rebates, technical assistance, identifying EVSE companies and utilities to work with, and developing dashboards that identify charging infrastructure locations.*** | | |
| ***Annual GHG emissions reduced in 2030*** | ***3,971*** | ***MTCO2e*** | |
| ***Annual GHG emissions reduced in 2050*** | ***22,466*** | ***MTCO2e*** | |

The 2022 Greater Worcester Regional GHG Inventory data was used to identify the gasoline usage by municipal vehicles and calculate an emissions reduction associated with electrifying 20% of the fleet vehicles by 2030 and 100% by 2050. The MA DOER Climate Leader Community Program identified 20% by 2030 as a fleet electrification target for MA municipalities, this was also applied to CT fleet vehicles. The increase in electricity associated with the use of EVs was accounted for in 2030, but in 2050 an electricity emissions factor of zero was used as it was assumed that electricity to charge vehicles will be from renewable sources.

| | | | |
|---|---|---|---|
| ***Measure T5.*** | ***Increase the adoption of zero emission medium- and heavy-duty municipal vehicles, as able. Municipalities must convert at least 75% all medium- and heavy-duty fleet to all-electric or an alternative fuel vehicle (i.e., bio-diesel, propane, CNG) by 2050. At the end of useful life, all converted alternative fuel vehicles must be replaced with similar alternative fuel vehicles. Steps to take include education, identifying incentives and rebates, technical assistance and support, identifying EVSE companies and utilities to work with, garage infrastructure upgrades, and workforce development.*** | | |
| ***Annual GHG emissions reduced in 2030*** | ***2,196*** | ***MTCO2e*** | |
| ***Annual GHG emissions reduced in 2050*** | ***11,477*** | ***MTCO2e*** | |

The 2022 Greater Worcester Regional GHG Inventory data was used to identify the diesel usage by municipal vehicles and calculate an emissions reduction associated with electrification of 20% of the fleet vehicles by 2030 and 75% by 2050. The MA DOER Climate Leader Community Program identified 20% by 2030 as a fleet electrification target for MA municipalities, this was also applied to CT fleet vehicles. The increase in electricity associated with the use of EVs was accounted for in 2030, but in 2050 an electricity emissions factor of zero was used as it was assumed that electricity to charge vehicles will be from renewable sources.

***Support the full electrification of transit buses and either continue or begin the funding of fare-free transit for all users. Implement a Bus Rapid Transit (BRT) system in the City of Worcester to offer fast, more reliable service to help further reduce car dependency. Fully electrify micro-transit services,***

| | |
|---|---|
| ***Measure T2*** | ***such as on-demand shuttles and senior van services, to provide convenient alternatives to personal vehicles.***<br><br>***Support the investment in regional passenger rail, including Compass Rail and other MBTA passenger rail systems, in the Greater Worcester region. In addition, continue to make improvements and modernizations of the WRTA Union Station to support rail capacity, user experience, and accessibility. Moreover, electrify intercity bus routes (i.e., Peter Pan) to offer efficient, low-emission travel between cities.*** |

| | | | |
|---|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***3,155*** | ***MTCO2e*** | |
| ***Annual GHG emissions reduced in 2050*** | ***15,829*** | ***MTCO2e*** | |

Senior van services are provided both by municipalities and by Regional Transit Authorities (RTAs), therefore, data for electrifying vehicles used in the operations of both were included in the measure quantification. The fuel usage, mileage, and fuel efficiency data for RTA vehicles for demand response was obtained from the Federal Transit Administration 2022 Fuel and Energy Datasets and from previous coordination with RTAs directly (data collected during PCAP). Emissions reductions were calculated assuming a 20% reduction in fuel usage by 2030 and 100% electrification by 2050 for both municipal vehicles and RTA vehicles. To avoid double counting of vans in municipal fleets, the emissions reduction was subtracted from Measures T4 and T5.

**T4. Zero Emission Light Duty**

Includes Municipal Gas, Plug in, Flex Fuel, Electric

[input] **Percent of Municipal Vehicles Transitioned to Electric for CT**

| | | | |
|---|---|---|---|
| 2030 | 20% | (percent) | |
| 2050 | 100% | (percent) | |

[value] **Electricity Emissions Factors**

| | | | |
|---|---|---|---|
| 2030 | 0.00012 | (MTCO2e/kW | *Source: MA EEA via MA Climate Leader Community Municipal Decarbonization Commitment and Roadmap Guidance page 8* |
| 2050 | 0.0 | (MTCO2e/kW | *Assumption: All electricity for charging from renewable sources in 2050* |

[value] **Gasoline Emissions Factor**

0.008869223 (MTCO2e) *Source: EPA Emissions Factor Hub*

[value] **Diesel Emissions Factor**

0.010316074 (MTCO2e) *Source: EPA Emissions Factor Hub*

[value] **Electric Vehicle Fuel Efficiency**

0.40 (kwh/mile) *Source: 2022 GHG Inventory*

CT Municipal Vehicles

[value] **CT Municipal Gasoline Vehicle Count and Fuel Consumption**

655,777 (Gallons) *Source: 2022 GHG Inventory*

1,203 (Vehicles)

[calc] **CT Municipal Gasoline Vehicle Estimated Miles traveled**

| | | |
|---|---|---|
| 28 | (mile/gal) | *Source: 2022 GHG Inventory* |
| 18,361,756 | (miles) | |
| 15,263 | (miles/vehicle) | |

[value] **CT Gasoline Vehicles Total 2022 Emissions**

| | | |
|---|---|---|
| 5,816 | (MTCO2e) | *Source: 2022 GHG Inventory* |

[calc] **CT 2030 Gasoline & Emissions Reduction**

| | |
|---|---|
| 131,155 | (gallons) |
| 1,163 | (MTCO2e) |

[calc] **CT 2030 Electric Vehicle Usage & Emissions**

| | | |
|---|---|---|
| 3,672,351 | (miles) | *Miles traveled by EVs* |
| 176 | (MTCO2e) | *Emissions associated with increased electricity* |

[calc] **CT 2030 Net Emissions Reduction**

| | |
|---|---|
| 987 | (MTCO2e) |

[calc] **CT 2050 Electric Vehicle Usage & Emissions**

| | |
|---|---|
| 18,361,756 | (miles) |
| 7,344,702 | (kWh) |
| 0 | (MTCO2e) |

[calc] **CT Total Emissions Reductions**

| | | |
|---|---|---|
| 2030 | 987 | (MTCO2e) |
| 2050 | 5,816 | (MTCO2e) |

MA Municipal Vehicles

[value] **MA Gasoline Municipal Vehicle Count and Fuel Consumption**

| | | |
|---|---|---|
| 31,017,028 | (miles) | *Source: 2022 GHG Inventory* |
| 1,693,132 | (gallons gas) | |
| 18.3 | (average miles/gal) | |

[value] **MA Flex Fuel Municipal Vehicle Count and Fuel Consumption**

| | | |
|---|---|---|
| 2,917,007 | (miles) | *Source: 2022 GHG Inventory* |
| 162,270 | (gallons gas) | |
| 18 | (average miles/gal) | |

[value] **MA Hybrid Municipal Vehicle Count and Fuel Consumption**

| | | |
|---|---|---|
| 1,187,778 | (miles) | *Source: 2022 GHG Inventory* |
| 51,106 | (gallons gas) | |
| 23.2 | (average miles/gal) | |

[value] **MA Plug In Municipal Vehicle Count and Fuel Consumption**

| | | |
|---|---|---|
| 8,969.0 | (miles) | *Source: 2022 GHG Inventory* |
| 174.0 | (gallons gas) | |
| 51.5 | (average miles/gal) | |

[value] **2022 Emissions associated with Gasoline, Flex Fuel, Hybrid and Plug Ins**

| | | |
|---|---|---|
| 16,991 | (MTCO2e) | *Source: 2022 GHG Inventory* |

| | | | |
|---|---|---|---|
| [calc] | **MA Summary of all Vehicle Types** | | |
| | 1,906,682 | (gallons gas) | |
| | 35,130,782 | (miles) | |
| | 18.4 | (average miles/gal) | |
| [calc] | **MA 2030 Gasoline Reduction** | | |
| | 7,026,156 | (miles) | |
| | 381,336 | (gallons) | *Gallons of gasoline saved* |
| [calc] | **MA 2030 Emissions Reduction From Gasoline Reduction** | | |
| | 3,382 | (MTCO2e) | |
| [calc] | **MA 2030 Electric Vehicle Usage & Emissions** | | |
| | 7,026,156 | (miles) | *Miles traveled by EVs* |
| | 337 | (MTCO2e) | *Emissions associated with increased electricity* |
| [calc] | **MA 2030 Net Emissions Reduction From Gasoline Reduction** | | |
| | 3,045 | (MTCO2e) | |
| [calc] | **MA 2050 Electric Vehicle Usage & Emissions** | | |
| | 35,130,782 | (miles) | *Miles traveled by EVs* |
| | 0 | (MTCO2e) | *Emissions associated with increased electricity* |
| [calc] | **MA Total MTCO2e Reductions** | | |
| | 3,045 | **2030 Emission Reductions (MTCO2e)** | |
| | 16,991 | **2050 Emission Reductions (MTCO2e)** | |
| | MSA (CT + MA) Light duty Municipal Vehicles | | |
| [calc] | **MSA WIDE Total Emissions Reductions** | | |
| 2030 | 4,032 | (MTCO2e) | |
| 2050 | 22,807 | (MTCO2e) | |
| [calc] | **Senior Van Electrification (Measure T5 below)** | | |
| 2030 | 60 | (MTCO2e) | |
| 2050 | 341 | (MTCO2e) | |
| [FINAL] | **MSA WIDE (MA & CT) in Total Emissions Reductions** | | |
| 2030 | 3,971 | (MTCO2e) | |
| 2050 | 22,466 | (MTCO2e) | |

*Excludes municipally-owned senior vans which are accounted for in Measure T2.*

| | | | |
|---|---|---|---|
| | **T5. Zero Emission Medium/Heavy Duty** | | |
| | Includes Municipal Diesel Vehicles | | |
| [input] | **Percent of Municipal Vehicles Transitioned to Electric** | | |
| 2030 | 20% | (percent) | |
| 2050 | 75% | (percent) | |
| [value] | Electric Vehicle Fuel Efficiency | | |
| | 0.40 | kwh/mile | |
| | **CT Medium & Heavy Duty Municipal Vehicles** | | |

| | | | |
|---|---|---|---|
| [value] | **CT Municipal Diesel Vehicle Count and Fuel Consumption** | | |
| | 356,644 | Gallons | *Source: 2022 GHG Inventory* |
| | 655 | Vehicle Count | |
| [calc] | **CT Municipal Diesel Vehicle estimated Miles traveled** | | |
| | 17 | (miles/gallon) | *Source: 2022 GHG Inventory* |
| | 5,920,295 | (miles) | |
| | 9,036 | (miles/vehicle) | |
| [value] | **CT Municipal Diesel Vehicle Emissions 2022** | | |
| | 3,679 | 2022 MTCO2e | *Source: 2022 GHG Inventory* |
| [calc] | **CT 2030 Diesel & Emissions Reduction** | | |
| | 71,329 | (gallons) | *Gallons saved* |
| | 633 | (MTCO2e) | |
| [calc] | **CT 2030 Electric Vehicle Usage & Emissions** | | |
| | 1,184,059 | (miles) | *Miles traveled by EVs* |
| | 473,624 | (kWh) | *Increased electricity usage* |
| | 57 | (MTCO2e) | *Emissions associated with increased electricity* |
| [calc] | **CT 2030 Net Emissions Reductions** | | |
| | 576 | (MTCO2e) | |
| [calc] | **CT 2050 Diesel & Emissions Reduction** | | |
| | 267,483 | (gallons) | *Gallons saved* |
| | 2,759 | (MTCO2e) | |
| [calc] | **CT 2050 Electric Vehicle Usage & Emissions** | | |
| | 4,440,221 | (miles) | *Miles traveled by EVs* |
| | 1,776,089 | (kWh) | *Increased electricity usage* |
| | 0 | (MTCO2e) | *Emissions associated with increased electricity* |
| [calc] | **CT Total MTCO2e Reductions** | | |
| 2030 | 576 | **(MTCO2e)** | |
| 2050 | 2,759 | **(MTCO2e)** | |

**MA Medium & Heavy Duty Municipal Vehicles**

| | | | |
|---|---|---|---|
| [value] | **MA Municipal Diesel Vehicle Count, Total Miles Traveled, and Total Fuel Usage** | | |
| | 13,184,216 | (miles) | *Source: GHG Inventory* |
| | 858,895 | (gallons) | |
| | 15.35 | (average miles/gallon) | |
| [calc] | **MA Municipal Diesel Vehicle Emissions 2022** | | |
| | 8,860 | 2022 MTCO2e | *Source: GHG Inventory* |
| [calc] | **MA 2030 Diesel Fuel & Emissions Reductions** | | |
| | 2,636,843 | (miles) | |
| | 171,779 | (gallons) | *Gallons saved* |

1,772 (MTCO2e)

[calc] **MA 2030 Electric Vehicle Usage & Emissions**

| | | |
|---|---|---|
| 2,636,843 | (miles) | *Miles traveled by EVs* |
| 1,054,737 | (kWh) | *Increased electricity usage* |
| 127 | (MTCO2e) | *Emissions associated with increased electricity* |

[calc] **MA 2030 Net Emissions Reduction**

1,646 (MTCO2e)

[calc] **MA 2050 Diesel Fuel & Emissions Reductions**

| | | |
|---|---|---|
| 9,888,162 | (miles) | |
| 644,171 | (gallons) | *Gallons saved* |
| 6,645 | (MTCO2e) | |

[calc] **MA 2050 Electric Vehicle Usage & Emissions**

| | | |
|---|---|---|
| 9,888,162 | (miles) | *Miles traveled by EVs* |
| 3,955,265 | (kWh) | *Increased electricity usage* |
| 0 | (MTCO2e) | *Emissions associated with increased electricity* |

[calc] **MA Total Emissions Reductions**

| | | |
|---|---|---|
| 2030 | 1,646 | (MTCO2e) |
| 2050 | 8,860 | (MTCO2e) |

MSA (CT + MA) Municipal Vehicles

[calc] **MSA WIDE (MA & CT) Total Emissions Reductions**

| | | |
|---|---|---|
| 2030 | 2,221 | (MTCO2e) |
| 2050 | 11,620 | (MTCO2e) |

[calc] **Senior Van Electrification (Measure T5 below)**

| | | |
|---|---|---|
| 2030 | 25 | (MTCO2e) |
| 2050 | 142 | (MTCO2e) |

[calc] **MSA WIDE (MA & CT) in Total MTCO2e Reductions**

| | | |
|---|---|---|
| 2030 | 2,196 | (MTCO2e) |
| 2050 | 11,477 | (MTCO2e) |

*Excludes municipally-owned senior vans which are accounted for in Measure T2.*

**T2. Expand and Improve Public Transit**

[input] **Senior Van Percent of Light Duty Fleet**

1.50% (percent) *Assumption: Andover, MA and Easthampton, MA have COA vans which make up about 2.5% of their total fleets.*

[input] **Senior Van Percent of Medium/Heavy Duty Fleet**

1.50% (percent) *Assumption: Andover, MA and Easthampton, MA have COA vans which make up about 2.5% of their total fleets.*

| | | |
|---|---|---|
| [input] | **Senior Van Percent Electric Vehicles** | |
| 2030 | 20% | (percent) |
| 2050 | 100% | (percent) |

**Light Duty Vehicles**

| | | |
|---|---|---|
| [calc] | **CT Light Duty Vehicles Allocated to Senior Vans** | |
| | 18.05 | (vehicles) |
| | 275,426 | (miles) |
| | 9,837 | (gallons) |
| [calc] | **CT Light Duty Gallons Gasoline Reduced by Transitioning to Electric** | |
| 2030 | 1,967 | (gallons) |
| 2050 | 9,837 | (gallons) |
| [calc] | **CT Light Duty Emissions Reduction** | |
| 2030 | 17.45 | (MTCO2e) |
| 2050 | 87.24 | (MTCO2e) |
| [calc] | **MA Light Duty Vehicles Allocated to Senior Vans** | |
| | 28,600 | (gallons) |
| | 526,962 | (miles) |
| [calc] | **MA Light Duty Gallons Gasoline Reduced by Transitioning to Electric** | |
| 2030 | 5,720 | (gallons) |
| 2050 | 28,600 | (gallons) |
| [calc] | **MA Light Duty Emissions Reduction** | |
| 2030 | 50.73 | (MTCO2e) |
| 2050 | 253.66 | (MTCO2e) |
| [calc] | **2030 Increased Electricity Use & Emissions From EVs** | |
| | 64,191 | (kWh) |
| | 7.70 | (MTCO2e) |
| [calc] | **2050 Increased Electricity Use & Emissions From EVs** | |
| | 320,955 | (kWh) |
| | 0.00 | (MTCO2e) |
| [calc] | **Total Light Duty Emissions Reduction** | |
| 2030 | 60.48 | (MTCO2e) |
| 2050 | 340.91 | (MTCO2e) |

**Medium/Heavy Duty Vehicles**

| | | |
|---|---|---|
| [calc] | **CT Med/Heavy Duty Vehicles Allocated to Senior Vans** | |
| | 10 | (vehicles) |
| | 88,804 | (miles) |
| | 3,172 | (gallons) |
| [calc] | **CT Med/Heavy Duty Gallons Gasoline Reduced by Transitioning to Electric** | |

| | | | |
|---|---|---|---|
| 2030 | 634 | (gallons) | |
| 2050 | 3,172 | (gallons) | |
| | | | |
| [calc] | **CT Med/Heavy Duty Emissions Reduction** | | |
| 2030 | 5.63 | (MTCO2e) | |
| 2050 | 28.13 | (MTCO2e) | |
| | | | |
| [calc] | **MA Med/Heavy Vehicles Allocated to Senior Vans** | | |
| | 12,883 | (gallons) | |
| | 237,378 | (miles) | |
| | | | |
| [calc] | **MA Med/Heavy Gallons Gasoline Reduced by Transitioning to Electric** | | |
| 2030 | 2,577 | (gallons) | |
| 2050 | 12,883 | (gallons) | |
| | | | |
| [calc] | **MA Med/Heavy Emissions Reduction** | | |
| 2030 | 23 | (MTCO2e) | |
| 2050 | 114 | (MTCO2e) | |
| | | | |
| [calc] | **2030 Increased Electricity Use & Emissions From EVs** | | |
| | 26,095 | (kWh) | |
| | 3 | (MTCO2e) | |
| | | | |
| [calc] | **2050 Increased Electricity Use & Emissions From EVs** | | |
| | 5,407 | (kWh) | |
| | 0.00 | (MTCO2e) | |
| | | | |
| [calc] | **Total Med/Heavy Duty Emissions Reduction** | | |
| 2030 | 25 | (MTCO2e) | |
| 2050 | 142 | (MTCO2e) | |
| | | | |
| | **Regional Transit Authority Vehicle Electrification (Demand response)** | | |
| [value] | **Worcester Regional Transit Authority Demand Response** | | |
| | *Vehicle Type 1* | | |
| Usage | 29,991 | (gallon gas) | *Source: 2022 - 2023 NTD Annual Data - Fuel and Energy* |
| Miles | 1,040,237 | (miles) | *https://data.transportation.gov/Public-Transit/2022-2023-* |
| MPG | 34.68 | (miles/gal) | *NTD-Annual-Data-Fuel-and-Energy/8ehq-7his/about_data* |
| | *Vehicle Type 2* | | |
| Usage | 63,826 | (gallon gas) | |
| Miles | 508,180 | (miles) | |
| MPG | 7.96 | (miles/gal) | |
| | | | |
| [value] | **Montachusett Regional Transit Authority Demand Response** | | |
| Usage | 226,774 | (gallon gas) | |
| Miles | 1,880,572 | (miles) | *Source: 2022 - 2023 NTD Annual Data - Fuel and Energy* |
| MPG | 8.29 | (miles/gal) | *https://data.transportation.gov/Public-Transit/2022-2023-* |
| | | | *NTD-Annual-Data-Fuel-and-Energy/8ehq-7his/about_data* |
| [value/calc] | **Windham Region Transit District Demand Response (partial)** | | |
| Miles | 128,240 | (miles) | *Source: Phillip Johnson at WRTD via email on 3/12/24* |
| Average M | 8.13 | (miles/gal) | |

| | | | |
|---|---|---|---|
| Usage | 15,783 | (gal gas) | |
| [inputs] | **Percent Reduction in RTA Gasoline Usage From Electrification** | | |
| 2030 | 20% | | *Assumption* |
| 2050 | 100% | | *Assumption* |
| [calc] | **Reduction in Gasoline From Electrification** | | |
| 2030 | 54,510 | | |
| 2050 | 272,548 | | |
| [calc] | **Emissions Reductions for RTAs** | | |
| 2030 | 483 | | |
| 2050 | 2,417 | | |

**Regional Transit Authority Vehicle Electrification (Fixed Route)**

| | | | |
|---|---|---|---|
| [value] | **Worcester Regional Transit Authority Fixed Route (2022)** | | |
| | *Diesel* | | *Source: WRTA Bus data from 2022 - 2023 NTD Annual Data* |
| | 388,637 | (gal diesel) | |
| | 1,817,367 | (miles) | |
| | 4.68 | (miles/gal) | |
| | *Gasoline* | | |
| | 29,326 | (gal gas) | *Only miles included in source, fuel usage calculated* |
| | 99,708 | (miles) | |
| | 3.40 | (miles/gal) | *Source: DOE Alternative Fuels Data Center* |
| [value] | **Montachusett Regional Transit Authority Fixed Route (2022)** | | |
| | *Diesel* | | *Data View - Fuel and Energy (by Agency)* |
| | 85,904 | (gal diesel) | |
| | 452,598 | (miles) | |
| | 5.27 | (miles/gal) | |
| | *Gasoline* | | *on-demand fuel usage so this was subtracted form the total to calculate* |
| | 44,641 | (gal gas) | |
| | 288,833 | (miles) | |
| | 6.47 | (miles/gal) | |
| [value] | **Windham Region Transit District Fixed Route (2023)** | | |
| | 155,177 | (miles) | *Source: Phillip Johnson at WRTD via email on 3/12/24* |
| *diesel* | 50% | (%) | |
| *gas* | 50% | (%) | |
| | *Diesel* | | |
| | *4.97* | (miles/gal) | *Only mileage data provided the for communities in MSA. Used average MPG from other two RTAs.* |
| | 385,950 | (gal diesel) | |
| | 77,588 | (miles) | |
| | *Gasoline* | | |
| | 4.94 | (miles/gal) | *Only mileage data provided the for communities in MSA. Used average* |
| | 382,904 | (gal gas) | |
| | 77,588 | (miles) | |
| [input] | **Percent Reduction in Fuel Usage From Electrification** | | |
| 2030 | 20% | (%) | *Assumption* |

2050 100% (%) *Assumption*

[calc] **Reduction in Diesel Usage**
2030 172,098 (gal)
2050 860,491 (gal)

[calc] **Reduction in Gasoline Usage**
2030 91,374 (gal)
2050 456,871 (gal)

[calc] **Emissions Reductions from Diesel Reduction**
2030 1,775 MTCO2e
2050 8,877 MTCO2e

[calc] **Emissions Reductions from Gasoline Reduction**
2030 810 MTCO2e
2050 4,052 MTCO2e

**Total Emissions Reductions - Municipal Vehicles and RTAs**

[calc] **2030 Total Emissions Reductions**
3,155 (MTCO2e)

[calc] **2050 Total Emissions Reductions**
15,829 (MTCO2e)

**Co-pollutants**

**T4. Zero Emission Light Duty**

The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Electric Vehicles and EV Charging Infrastructure tool was used to quantify the co-pollutants. The co-pollutants reduction is based on EV miles traveled by municipal vehicles that were previously gasoline powered vehicles.

[calc] **2030 Total Miles Traveled by Municipal Electric Vehicles (previously gasoline)**

10,698,508 (EV miles)

| 2030 Gasoline Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 84.71 | 30.9 |
| Nitrogen Oxide (NOx) | 2.26 | 0.8 |
| Particulate Matter <2.5 µm | 0.19 | 0.1 |
| Particulate Matter <10 µm | 0.22 | 0.1 |
| Volatile Organic Compounds | 3.86 | 1.4 |
| | **Total** | **33.3** |

*Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure*

*Inputs: 2030, Passenger Truck, 2018, Gasoline, 10,693,217 VMT traveled by electric fleet annually, model 2027*

[calc] **2050 Total Miles Traveled by Municipal Electric Vehicles (previously gasoline)**

53,492,538 (EV miles)

| 2050 Gasoline Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 279.29 | 101.9 |
| Nitrogen Oxide (NOx) | 3.81 | 1.4 |
| Particulate Matter <2.5 µm (PM2.5) | 0.74 | 0.3 |
| Particulate Matter <10 µm (PM10) | 0.84 | 0.3 |
| Volatile Organic Compounds (VOC) | 24.03 | 8.8 |
| | **Total** | **112.7** |

*Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure*

*Inputs: 2040, Passenger Truck, 2025, Gasoline, 53,492,538 VMT traveled by electric fleet annually, model 2040*

| [FINAL] | **Total Co-Pollutant Reduction** |
|---|---|
| 2030 | 33 (MT co-pollutants) |
| 2050 | 113 (MT co-pollutants) |

**T5. Zero Emission Medium/Heavy Duty**

The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Electric Vehicles and EV Charging Infrastructure tool is used to quantify the co-pollutants. The co-pollutants reduction is based on the EV miles traveled by municipal vehicles that were previously diesel powered vehicles.

[calc] **2030 Total Miles Traveled by Municipal Electric Vehicles (previously diesel)**

3,820,902 (EV miles)

| 2030 Diesel Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 17.128 | 6.3 |
| Nitrogen Oxide (NOx) | 4.184 | 1.5 |

| | | |
|---|---|---|
| Particulate Matter <2.5 µm (PM2.5) | 0.039 | 0.0 |
| Particulate Matter <10 µm (PM10) | 0.087 | 0.0 |
| Volatile Organic Compounds (VOC) | 0.544 | 0.2 |
| | **Total** | **8.0** |

*Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure*

*Inputs: 2030, Passenger Truck, 2018, Diesel, 3,820,902 VMT traveled by electric fleet annually, model 2027*

[calc] **2050 Total Miles Traveled by Municipal Electric Vehicles (previously diesel)**

14,328,383 (EV miles)

| 2050 Disel Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 47.387 | 17.3 |
| Nitrogen Oxide (NOx) | 9.903 | 3.6 |
| Particulate Matter <2.5 µm (PM2.5) | 0.129 | 0.0 |
| Particulate Matter <10 µm (PM10) | 0.305 | 0.1 |
| Volatile Organic Compounds (VOC) | 2.047 | 0.7 |
| | **Total** | **21.8** |

*Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure*

*Inputs: 2040, Passenger Truck, 2025, Diesel, 14,328,383 VMT traveled by electric fleet annually, model 2040*

[FINAL] **Total Co-Pollutant Reduction**

2030 8 (MT co-pollutants)

2050 22 (MT co-pollutants)

**T2. Expand and Improve Public Transit**

The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Electric Vehicles and EV Charging Infrastructure tool was used to quantify the co-pollutants of heavy and light dusty senior vans. The co-pollutants reduction is based on the EV miles traveled by municipal vehicles that were previously gasoline and diesel powered vehicles. The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Non-EV Bus Replacement was used to quantify RTA co-pollutant reductions by applying mileage to be driven by electric buses.

[calc] **2030 Total Miles Traveled by EV Senior Vans That Transitioned From Gasoline**

160,478 (EV miles)

| 2030 Gasoline Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 1.271 | 0.5 |
| Nitrogen Oxide (NOx) | 0.034 | 0.0 |
| Particulate Matter <2.5 µm (PM2.5) | 0.003 | 0.0 |
| Particulate Matter <10 µm (PM10) | 0.003 | 0.0 |
| Volatile Organic Compounds (VOC) | 0.058 | 0.0 |
| | **Total** | **0.5** |

Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure

Inputs: 2030, Passenger Truck, 2018, Gasoline, 160,478 VMT traveled by electric fleet annually, model 2027

[calc] **2050 Total Miles Traveled by EV Senior Vans That Transitioned From Gasoline**

802,388 (EV miles)

| 2050 Gasoline Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 4.189 | 1.5 |
| Nitrogen Oxide (NOx) | 0.057 | 0.0 |
| Particulate Matter <2.5 µm (PM2.5) | 0.011 | 0.0 |
| Particulate Matter <10 µm (PM10) | 0.013 | 0.0 |
| Volatile Organic Compounds (VOC) | 0.360 | 0.1 |
| | **Total** | **1.7** |

Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure

Inputs: 2040, Passenger Truck, 2025, Gasoline, 802,388 VMT traveled by electric fleet annually, model 2040

[calc] **2030 Total Miles Traveled by EV Senior Vans That Transitioned From Diesel**

65,237 (EV miles)

| 2030 Diesel Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 0.292 | 0.1 |
| Nitrogen Oxide (NOx) | 0.071 | 0.0 |
| Particulate Matter <2.5 µm (PM2.5) | 0.001 | 0.0 |
| Particulate Matter <10 µm (PM10) | 0.001 | 0.0 |
| Volatile Organic Compounds (VOC) | 0.009 | 0.0 |
| **Total** | | **0.1** |

Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure

Inputs: 2030, Passenger Truck, 2018, Diesel, 63,237 VMT traveled by electric fleet annually, model 2027

[calc] **2050 Total Miles Traveled by EV Senior Vans That Transitioned From Diesel**

326,183 (EV miles)

| 2050 Diesel Co-pollutants Reduction | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 1.079 | 0.4 |
| Nitrogen Oxide (NOx) | 0.225 | 0.1 |
| Particulate Matter <2.5 µm (PM2.5) | 0.003 | 0.0 |
| Particulate Matter <10 µm (PM10) | 0.007 | 0.0 |
| Volatile Organic Compounds (VOC) | 0.047 | 0.0 |
| | **Total** | **0.5** |

Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Electric Vehicles and EV Charging Infrastructure

Inputs: 2040, Passenger Truck, 2025, Diesel, 326,283 VMT traveled by electric fleet annually, model 2040

[calc] **2030 miles traveled**

562,737 (miles)

[calc] **2050 miles traveled**

2,813,683 (miles)

| RTA Diesel and Gasoline Co-Pollutants Reduction 2030 | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 2.6064 | 1.0 |
| Nitrogen Oxide (NOx) | 0.0257 | 0.0 |
| Particulate Matter <2.5 µm (PM2.5) | 0.1584 | 0.1 |
| Particulate Matter <10 µm (PM10) | 3.4801 | 1.3 |
| Volatile Organic Compounds (VOC) | 0.0615 | 0.0 |
| | **Total** | **2.3** |

Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Transit Bus Replacement

Inputs: 2040, 2018, Diesel, Passenger Truck, 2025, Diesel, 562,737 miles traveled, model 2027, Hybrid Electric

| RTA Diesel and Gasoline Co-Pollutants Reduction 2050 | | |
|---|---|---|
| **Type** | **kg/day** | **MT/year** |
| Carbon Monoxide (CO) | 8.5028 | 3.1 |
| Nitrogen Oxide (NOx) | 0.0138 | 0.0 |
| Particulate Matter <2.5 µm (PM2.5) | 0.0097 | 0.0 |
| Particulate Matter <10 µm (PM10) | 7.7586 | 2.8 |
| Volatile Organic Compounds (VOC) | 0.0004 | 0.0 |
| **Total** | | **5.9** |

Source: Federal Highway Administration CMAQ Emissions Calculator Toolkit Transit Bus Replacement

Inputs: 2040, 2018, Diesels, Passenger Truck, 2025, Diesel, 2,813,683 miles traveled, model 2027, Hybrid Electric

| [FINAL] | **Total Co-Pollutant Reduction** |
|---|---|
| 2030 | 3 (MT Co-pollutants) |
| 2050 | 8 (MT Co-pollutants) |

**Cost**

## T4. Light Duty Vehicle Cost

The cost for transitioning light duty municipal fleet vehicles to electric was determined by assuming the cost per vehicle was $55,000 (2025 dollars) based on the EPA CCAP Cost of Measures Resource. The number of chargers needed was determined by assuming each port can support 2 vehicles and each charger has 2 ports. The cost per charger was assumed to be $7,500 (2015 dollars), also sourced from the EPA, and converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. The cost for vehicle purchasing and chargers were summed to determine the total cost.

| | | | | |
|---|---|---|---|---|
| [input] | **Average Cost of Electric Vehicle** | | | |
| | | $55,000 | (2025 Dollars) | *Source: EPA CCAP Cost of Measures Resource* |
| [calc] | **CT Light Duty Vehicles for EV Replacement** | | | |
| 2030 | | 237 | (vehicles) | *Excludes senior vans which are municipally owned (see MeasureT2)* |
| 2050 | | 948 | (vehicles) | |
| [calc] | **MA Light Duty Vehicles for EV Replacement** | | | |
| 2030 | | 709 | (vehicles) | *Excludes senior vans which are municipally owned (see MeasureT2)* |
| 2050 | | 2,836 | (vehicles) | |
| [calc] | **Vehicle Purchasing Cost** | | | |
| 2030 | | $ 52,029,670 | | |
| 2050 | | $ 208,118,680 | | |
| | **Ports Per Charger** | | | |
| [input] | | 2 | (ports/charger) | *Assumption* |
| | **EVs Per Port** | | | |
| [input] | | 2 | (vehicle/port) | *Assumption* |
| [calc] | **Evs Per Charger** | | | |
| | | 4 | (charger/vehicle) | |
| [calc] | **Number of Chargers Needed** | | | |
| 2030 | | 236 | (chargers) | |
| 2050 | | 946 | (chargers) | |
| [value] | **Consumer Price Index Conversion 2015 to 2025 Dollars** | | | |
| | | $1.38 | (dollar conversion) | *Source: US Bureau of Labor Statistics CPI Inflation Calculator* |
| | **Average Cost for a Level 2 Charger** | | | |
| [value] | | $7,500 | (2015 dollars) | *Source: EPA CCAP estimation resource* |
| [calc] | | $10,350 | (2025 dollars) | |
| [calc] | **Cost of EV Charger Installation** | | | |
| 2030 | | $ 2,447,759 | (2025 dollars) | |
| 2050 | | $ 9,791,038 | (2025 dollars) | |
| [calc] | **Cost of Vehicles and Chargers for Light Duty** | | | |

| | | | |
|---|---|---|---|
| 2030 | $ 54,477,429 | (2025 dollars) | |
| 2050 | $ 217,909,718 | (2025 dollars) | |

**T5. Medium/Heavy Duty Vehicle Cost**

The cost for transitioning light duty municipal fleet vehicles to electric was determined by assuming the cost per vehicle was $150,000. The number of chargers needed was determined by assuming each port can support two vehicles and each charger has two ports. The cost per charger was assumed to be $7,500 (2015 dollars), sourced from the EPA CCAP Cost of Measures Resource. This value was converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. The cost for vehicle purchasing and chargers were summed to determine the total cost.

| | | | |
|---|---|---|---|
| [input] | **Average cost of Electric Vehicle** | | |
| | $150,000 | (2025 Dollars) | *Assumption* |
| [calc] | **CT Med/Heavy Duty Vehicles for EV Replacement** | | |
| 2030 | 129 | (vehicles) | *Excludes senior vans which are* |
| 2050 | 355 | (vehicles) | *municipally owned (see MeasureT2)* |
| [calc] | **MA Med/Heavy Duty Vehicles for EV Replacement** | | |
| 2030 | 520 | (vehicles) | *Excludes senior vans which are* |
| 2050 | 1,430 | (vehicles) | *municipally owned (see MeasureT2)* |
| [calc] | **Vehicle Purchasing Cost** | | |
| 2030 | $ 97,372,243 | | |
| 2050 | $ 267,773,668 | | |
| | **Ports Per Charger** | | |
| [input] | 2 | (ports/charger) | *Assumption* |
| | **EVs Per Port** | | |
| [input] | 2 | (vehicle/port) | *Assumption* |
| [calc] | **Evs Per Charger** | | |
| | 4 | (charger/vehicle) | |
| [calc] | **Number of Chargers Needed** | | |
| 2030 | 162 | (chargers) | |
| 2050 | 446 | (chargers) | |
| [value] | **Consumer Price Index Conversion 2015 to 2025 Dollars** | | |
| | $1.38 | (dollar conversion) | *Source: US Bureau of Labor Statistics* |
| | | | *CPI Inflation Calculator* |
| | **Average Cost for a Level 2 Charger** | | |
| [value] | $7,500 | (2015 dollars) | *Source: EPA CCAP estimation resource* |
| [calc] | $10,350 | (2025 dollars) | |
| [calc] | **Cost of EV Charger Installation** | | |
| 2030 | $ 1,679,671 | (2025 dollars) | |

| | | | |
|---|---|---|---|
| 2050 | $ 4,619,096 | (2025 dollars) | |

| | | | |
|---|---|---|---|
| [calc] | **Cost of Vehicles and Chargers for Med/Heavy Duty** | | |
| 2030 | $ 99,051,914 | (2025 dollars) | |
| 2050 | $ 272,392,763 | (2025 dollars) | |

**T2. Public Transit Improvements**

The cost for electrification of transit buses was calculated using the number of buses in the fleet for three RTAs based on the 2022 Annual Agency Profiles from the Federal Transit Administration. The 2020 study, Financial Analysis of Battery Electric
Transit Buses, by the National Renewable Energy Laboratory, provided a cost of $887,308 per battery electric bus and cost of $50,000 for each charger. These values were converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. Similarly, cost for electrification of demand response and senior van vehicles were calculated using costs from the EPA CCAP Cost of Measures Resource values of $55,000 per vehicle and $7,500 (2015 dollars) per charger. Cost for all three vehicle types were summed to provide an overall measure cost.

| | | | |
|---|---|---|---|
| [value] | **Average Miles Traveled per Year for a Public Bus** | | |
| | 32,814 | (average miles/year) | |
| [calc] | **Estimating Total RTA Busses** | | |
| | 114 | (buses) | *Source: 2022 Annual Agency Profiles* |
| | 241 | (DR vehicles) | *Source: 2022 Annual Agency Profiles* |
| | **Buses Electrified** | | |
| 2030 | 23 | (buses) | |
| 2050 | 219 | (buses) | |
| [value] | **Consumer Price Index Conversion 2020 to 2025 Dollars** | | |
| | $1.26 | (dollar conversion) | *Source: US Bureau of Labor Statistics CPI Inflation Calculator* |
| | **Average cost of Electric Bus** | | |
| [input] | $ 887,308 | (2020 dollars) | *Source: NREL Financial Analysis of BEV Buses* |
| [calc] | $ 1,118,008 | (2025 dollars) | |
| | **Bus Purchasing Cost** | | |
| 2030 | $ 20,175,260 | (2020 dollars) | |
| 2050 | $ 244,367,904 | (2025 dollars) | |
| [value] | **Estimated cost of E-Bus Charger** | | |
| | $ 50,000 | (2020 dollars) | *Source: NREL Financial Analysis of BEV Buses (1 charger per bus)* |
| | $ 63,000 | (2025 dollars) | |
| [calc] | **Bus Charging Cost** | | |
| 2030 | $ 1,432,469 | (2025 dollars) | |
| 2050 | $ 13,770,185 | (2025 dollars) | |
| [calc] | **Demand Response Vehicles Electrified** | | |
| 2030 | 48 | (DR vehicles) | |

| | | | |
|---|---|---|---|
| 2050 | 193 | (DR vehicles) | |
| [calc] | **Senior Vans Electrified** | | |
| 2030 | 24 | (senior vans) | |
| 2050 | 97 | (senior vans) | |
| [input] | **Average Cost of Electric Vehicle** | | |
| | $55,000 | (2025 dollars) | *Source: EPA CCAP Cost of Measures Resource* |
| [calc] | **Vehicle Purchasing Cost** | | |
| 2030 | $ 3,990,465 | (2025 dollars) | |
| 2050 | $ 15,961,858 | (2025 dollars) | |
| | **Ports Per Charger** | | |
| [input] | 2 | (ports/charger) | *Assumption* |
| | **EVs Per Port** | | |
| [input] | 2 | (vehicle/port) | *Assumption* |
| [calc] | **EVs Per Charger** | | |
| | 4 | (charger/vehicle) | |
| [calc] | **Number of Chargers Needed** | | |
| 2030 | 18 | (chargers) | |
| 2050 | 73 | (chargers) | |
| [value] | **Consumer Price Index Conversion 2015 to 2025 Dollars** | | |
| | $1.38 | (dollar conversion) | *Source: US Bureau of Labor Statistics CPI Inflation Calculator* |
| | **Average Cost for a Level 2 Charger** | | |
| [value] | $7,500 | (2015 dollars) | *Source: EPA CCAP estimation resource* |
| [calc] | $10,350 | (2025 dollars) | |
| [calc] | **Cost of EV Charger Installation** | | |
| 2030 | $ 187,733 | (2015 dollars) | |
| 2050 | $ 750,933 | (2025 dollars) | |
| [calc] | **Estimated Total Cost For Buses, Demand Response, and Senior Vans** | | |
| 2030 | $ 25,785,927 | (2025 dollars) | |
| 2050 | $ 274,850,880 | (2025 dollars) | |

| Measure ANWL1 | Establish an ongoing program to support native tree and shrub planting in urban communities in the MSA. Focus on planting native species that require little maintenance or may be better suited for the local environment. Prioritize planting 15% additional tree cover in public areas with little native tree and shrub coverage in Fitchburg, Gardner, Leominster, Southbridge, Webster, and Worcester in MA, as well as Windham in CT. | |
|---|---|---|
| Annual increased carbon sequestration in 2030 | 3,186 | MTCO2e |
| Annual increased carbon sequestration in 2050 | 23,897 | MTCO2e |

Increased carbon sequestration was calculated using National Land Cover 2021 Data for total forest land in square miles for Fitchburg, Gardner, Leominster, Southbridge, Webster, and Worcester in MA, as well as Windham, CT. It was assumed that a 2% increase in land area could be achieved by 2030 and a 15% increase in 2050 and used a carbon sequestration rate of 2.23 MT C per hectare per year from the EPA Local Greenhouse Gas Inventory Tool.

**National land Cover data and Tree Cover Calculations**

[value] **Fitchburg MA total forest area**
36,722,700 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Gardner MA total forest area**
26,165,700 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Leominster MA total forest area**
32,886,900 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Southbridge MA total forest area**
32,014,800 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Webster MA total forest area**
15,277,500 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Worcester MA total forest area**
14,606,100 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Windham CT total forest area**
37,166,400 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[calc] **Total forest area for Fitchburg, Gardner, Leominster, Southbridge, Webster, Worcester, and Windham**
194,840,100 (sq m)

[input] **Percentage increase of additional land cover from 2030 to 2050**
2% (%) Increase by 2030
15% (%) Increase by 2050

[calc] **Additional area of carbon sequestering land for all towns 2030 and 2050**
2030 3,896,802 (sq m)

2050 29,226,015 (sq m)

[value] **Conversions**

0.0001 (sq m to ha) *Source: Worcester Regional GHG Inventory 2022*

2.23 (MTC/ha/yr)

[value] 3.6667 (Carbon to CO2e) *EPA LGGIT Tool*

[calc] **Additional area of carbon sequestering land for all towns 2030 and 2050**

2030 390 (ha)

2050 2,923 (ha)

[FINAL **Annual carbon sequestered fromadditional land area**

2030 3,186 (MTCO2e)

2050 23,897 (MTCO2e)

**Co-Pollutant Reduction**

Co-pollutant emissions reductions were quantified using the OurTree tool by iTree for six municipalities in the Greater Worcester region. It was assumed that co-pollutant reductions would increase by the same percent as the increase in land area, 2% and 15% for 2030 and 2050, respectively.

[value] **Baseline co-pollutant reductions (lb/year)**

| Municipality | Carbon Monoxide | Ozone | Nitrogen Dioxide | Sulfur Dioxide | PM2.5 |
|---|---|---|---|---|---|
| Fitchburg | 13,212 | 462,874 | 101,019 | 26,488 | 25,540 |
| Gardner | 11,197 | 392,249 | 85,607 | 22,446 | 21,643 |
| Leominster | 13,491 | 472,603 | 103,144 | 27,044 | 26,077 |
| Southbridge | 11,474 | 397,938 | 87,733 | 23,000 | 21,986 |
| Webster | 5,872 | 207,774 | 44,893 | 11,773 | 11,449 |
| Worcester | 10,634 | 376,250 | 81,295 | 21,319 | 20,733 |
| Windham | 11,977 | 379,065 | 8,289 | 19,688 | 15,559 |

*Source: OurTree by iTree, accessed January 2024*

[calc] **Total Baseline Annual Co-Pollutant Reduction**

3,573,335 (lb/year)

[value] **Conversion**

2,205 lb to MT

[calc] **Total Baseline Annual Co-Pollutant Reduction**

1,621 (MT Co-Pollutants)

**Percent Increase in land area for carbon sequestration**

2030 2%

2050 15%

[calc] **Total Additional Co-Pollutant Reduction**

2030 32 (MT Co-Pollutants)

2050 243 (MT Co-Pollutants)

[value] **Fitchburg MA total forest area**
36,722,700 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Gardner MA total forest area**
26,165,700 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Leominster MA total forest area**
32,886,900 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Southbridge MA total forest area**
32,014,800 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Webster MA total forest area**
15,277,500 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Worcester MA total forest area**
14,606,100 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[value] **Windham CT total forest area**
37,166,400 (sq m) *Source: Worcester Regional GHG Inventory 2022*

[calc] **Total forest area for Fitchburg, Gardner, Leominster, Southbridge, Webster, Worcester, and Windham**
194,840,100 (sq m)

| Municipality | Carbon Monoxide | Ozone | Nitrogen Dioxide | Sulfur Dioxide | PM2.5 | Total co pollutant lb/yr | |
|---|---|---|---|---|---|---|---|
| Fitchburg | 13,212 | 462,874 | 101,019 | 26,488 | 25,540 | 629,133 | 0.0171 |
| Gardner | 11,197 | 392,249 | 85,607 | 22,446 | 21,643 | 533,142 | 0.0204 |
| Leominster | 13,491 | 472,603 | 103,144 | 27,044 | 26,077 | 642,359 | 0.0195 |
| Southbridge | 11,474 | 397,938 | 87,733 | 23,000 | 21,986 | 542,131 | 0.0169 |
| Webster | 5,872 | 207,774 | 44,893 | 11,773 | 11,449 | 281,761 | 0.0184 |
| Worcester | 10,634 | 376,250 | 81,295 | 21,319 | 20,733 | 510,231 | 0.0349 |
| Windham | 11,977 | 379,065 | 8,289 | 19,688 | 15,559 | 434,578 | 0.0117 |

| | Carbon Monoxide | Ozone | Nitrogen Dioxide | Sulfur Dioxide | PM2.5 |
|---|---|---|---|---|---|
| | 0.0004 | 0.0126 | 0.0028 | 0.0007 | 0.0007 |
| | 0.0004 | 0.0150 | 0.0033 | 0.0009 | 0.0008 |
| | 0.0004 | 0.0144 | 0.0031 | 0.0008 | 0.0008 |
| | 0.0004 | 0.0124 | 0.0027 | 0.0007 | 0.0007 |
| | 0.0004 | 0.0136 | 0.0029 | 0.0008 | 0.0007 |
| | 0.0007 | 0.0258 | 0.0056 | 0.0015 | 0.0014 |
| | 0.0003 | 0.0102 | 0.0002 | 0.0005 | 0.0004 |
| Average | **0.0004** | **0.0156** | **0.0034** | **0.0009** | **0.0009** |

| |
|---|
| **Carbon Monoxide** |
| **Ozone** |
| **Nitrogen Dioxide** |
| **Sulfur Dioxide** |
| **PM2.5** |

Utilized a 2025 Carbon Sequestration study on Miyawaki Forests based on a study in South India. These forests are best for replacing degraded land in urban areas with natural benefits. Miyawaki mini forests grow up to 10 times faster and 30 times denser than traditional urban forests. These forests are also 100 times more biodiverse and have 30 times more carbon sequestration capacity for the land area than traditional forests. There is a significant potential for increasing climate mitigation in urban areas. 5 year old forests sequester four times more carbon than 2 year old forests (Vaidya, 2025). The maximum carbon sequestration rate for these forests peak at 5 years, thus a constant rate was applied for 2030 and 2050 to determine overall increase in carbon sequestration.

Sources: Turfgrass has the potential to sequester more carbon than they emit. Turfgrass can become a carbon sink, at hgme lawns can sequester anywhere from 25.4 to 204.3 $gC/m^2/year$. This is a small amount but a big difference can be made if a large amount of lawns were able to sequester carbon. Using a low input turf species increases the likelyhood of the turf area becoming a carbon sink. (low maintence grass)
The Potential of Turfgrass to Sequester Carbon and Offset Greenhouse Gas Emissions | Turfgrass Science hortsci0539S808_814 value is coming from this study (25.4-204.3)

78%
6%
11%
5%

Non grass Lawns:
**Low growing/creeping Thyme:** Only grows a few inches tall and is resilient to high traffic and pollinator friendly to bees and resistant to drought
**Chamomile lawn:** These lawns require little maintence and grow without supplemental watering, watering, or mowing
**Moss lawn:** best for shaded lawns

| Measure ANWL2 | Permanently protect 20,000 acres of forestland in MA and CT by 2050 through the use of Conservation Restrictions in MA and Conservation Easements in CT. Encourage additional limited protections of forestland in MA through the use of the Chapter 61 program. | |
|---|---|---|
| Annual GHG emissions reduced in 2030 | 16,545 | MTCO2e |
| Annual GHG emissions reduced in 2040 | 33,090 | MTCO2e |
| Annual GHG emissions reduced in 2050 | 66,180 | MTCO2e |

The continued carbon sequestration from protecting 20,000 acres of forestland was calculated using the a rate of 2.23 MT C per hectare per year from the EPA Local Greenhouse Gas Inventory Tool.

**CT and MA Forested Land Protection Supplemental Data and Calculations**

| | | | |
|---|---|---|---|
| [value] | **Protection of Forested Land Targets for 2030 and 2050** | | |
| 2030 | 5,000 | (acres) | |
| 2040 | 10,000 | (acres) | |
| 2050 | 20,000 | (acres) | |
| [value] | **Conversions & Factors** | | |
| | 0.00025 | (sq m to Acres) | *Source: Worcester Regional GHG Inventory 2022* |
| | 0.0001 | (sq m to ha) | |
| | 2.23 | (MTC/ha/yr) | *Carbon sequestration factor* |
| | 3.67 | (Carbon to CO2e) | |
| | 0.40 | (Acre to Hectare) | |
| [calc] | **Protected Forest Land 2030, 2040, 2050** | | |
| 2030 | 2,023 | (Hectare) | |
| 2040 | 4,047 | (Hectare) | |
| 2050 | 8,094 | (Hectare) | |
| [FINAL] | **Total Carbon Sequestration 2030, 2040, 2050** | | |
| 2030 | 16,545 | (MTCO2e) | |
| 2040 | 33,090 | (MTCO2e) | |
| 2050 | 66,180 | (MTCO2e) | |

**Co-Pollutants**

Co-pollutants were quantified by back calculating a factor for several pollutants from data outputs of the OurTrees tool by iTree.

| | | |
|---|---|---|
| [calc] | **Protected Land** | |
| **2030** | 20,233,904 | (sq m) |

| | | |
|---|---|---|
| **2040** | 40,467,808 | (sq m) |
| **2050** | 80,935,616 | (sq m) |

| **Pollutant** | **Emissions factor (lb/year/sq m)** | 2030 (lb/year) | 2040 (lb/year) | 2050 (lb/year) | 2030 (MT/year) | 2040 (MT/year) | 2050 (lb/year) |
|---|---|---|---|---|---|---|---|
| **Carbon Monoxide** | 0.000444789 | 9,000 | 18,000 | 35,999 | 4 | 8 | 16 |
| **Ozone** | 0.015625948 | 316,174 | 632,348 | 1,264,696 | 143 | 287 | 574 |
| **Nitrogen Dioxide** | 0.003400605 | 68,808 | 137,615 | 275,230 | 31 | 62 | 125 |
| **Sulfur Dioxide** | 0.000891683 | 18,042 | 36,084 | 72,169 | 8 | 16 | 33 |
| **PM2.5** | 0.000861864 | 17,439 | 34,878 | 69,756 | 8 | 16 | 32 |

| | **Total Co-Pollutants Reduction** | |
|---|---|---|
| 2030 | 195 | (MT Co-Pollutant) |
| 2040 | 390 | (MT Co-Pollutant) |
| 2050 | 779 | (MT Co-Pollutant) |

| Measure ANWL3 | Convert 10,000 acres of privately-owned manicured lawn through the establishment of a Resiliency Garden Program that enables homeowners to convert portions of their yard into climate-smart gardens. Offer rebates and technical guidance to residents who install and maintain qualifying gardens. Gardens supported may include: (1) Food Gardens, which will promote local food production to reduce emissions from food transportation, packaging, and storage; (2) Rain Gardens, which will manage stormwater on-site, reduce runoff and flooding, and limit energy-intensive water treatment; and (3) Pollinator Gardens; which will support biodiversity, sequester carbon in soil and perennial plants, and reduce lawn mowing emissions. | | |
|---|---|---|---|
| *Annual GHG emissions reduced in 2030* | *1,113* | *MTCO2e* | |
| *Annual GHG emissions reduced in 2031* | *2,226* | *MTCO2e* | |
| *Annual GHG emissions reduced in 2050* | *5,565* | *MTCO2e* | |
| Emissions reductions were estimated for avoided truck transportation of food which is instead produced locally. It was assumed the average trucking distance is 1,400 miles for long distance, based on the Food Carbon Calculator, and the local food is 48 miles. | | | |

**Carbon Sequestration**

| | | | |
|---|---|---|---|
| [value] | **Privately-Owned Manicured Lawn Area** | | |
| 2030 | 2,000 | (acres) | |
| 2040 | 4,000 | (acres) | |
| 2050 | 10,000 | (acres) | |
| [value] | **Transport Emissions** | | |
| | 0.09 | (kg CO2e/lbs) | *Source: Food Carbon Calculator, Inputs: Fruits/Berries, Apples, 1400 or 48 miles, 1.0. 0.0 (checked other foods for same distance too) https://foodemissions.com/Calculator* |
| | 0.02 | (kg CO2e/lbs) | |
| [input] | **Average Total lbs/Acre for Fruits and Veg.** | | |
| Veg | 7,357 | lbs/acre | *Source: USDA-National Agricultural Statistics Service, New England Vegetable Report (2019-2023) https://nevegetable.org/cultural-* |
| Fruit | 8,544 | lbs/acre | |
| [input] | **Allocation of Fruits and Vegetables** | | |
| | 50% | Veg | *Assumption* |
| | 50% | Fruit | |
| [calc] | **Total lbs/Acre for Fruits and Veg.** | | |
| 2030 | 7,357,000 | lbs Veg | |
| 2030 | 8,544,000 | lbs Fruit | |
| 2040 | 14,714,000 | lbs Veg | |
| 2040 | 17,088,000 | lbs Fruit | |

| | | |
|---|---|---|
| 2050 | 36,785,000 | lbs Veg |
| 2050 | 42,720,000 | lbs Fruit |

**Emissions Reductions From Food Transport**

| | | |
|---|---|---|
| 2030 | 1,113,070 | (kg CO2e/year) |
| 2040 | 2,226,140 | (kg CO2e/year) |
| 2050 | 5,565,350 | (kg CO2e/year) |

[FINAL] **Emissions Reductions From Food Transport**

| | | |
|---|---|---|
| 2030 | 1,113 | (MT CO2e/year) |
| 2040 | 2,226 | (MT CO2e/year) |
| 2050 | 5,565 | (MT CO2e/year) |

**Co-Pollutant Reduction**

Co-pollutant reductions were quantified by determining the number of long distance truck trips that would be avoided from local food production based on the co-pollutant emissions factors from Federal Highway Administration emissions calculator tools.

[calc] **Miles reduced**

1,352 (miles/trip)

[value] **Weight of shipping boxes**

40 (lbs/box) *Source: USDA Protecting Perishable Foods During Transport by Truck (bananas)*

[value] **Boxes per pallet**

48 (boxes/pallet *Source: Port Economics, Management and Policy The Transport of and Handling of Bananas*

[value] **Pallets per truck**

24 (pallets/truck *Source: NTD Standard Pallet Size*

**Trucks avoided**

| | | |
|---|---|---|
| 2030 | 345 | (trucks/year) |
| 2040 | 690 | (trucks/year) |
| 2050 | 1,725 | (trucks/year) |

**Totals miles avoided**

| | | |
|---|---|---|
| 2030 | 466,540 | (miles/year) |
| 2040 | 933,080 | (miles/year) |
| 2050 | 2,332,699 | (miles/year) |

[calc]

| Co-pollutant emissions | Factor (kg/trip) | 2030 Emissions (MT) | 2040 Emissions (MT) | 2050 Emissions (MT) |
|---|---|---|---|---|
| Carbon Monoxide (CO) | 2.638 | 0.91 | 1.82 | 4.55 |
| Particulate Matter ≤2.5 μ | 0.010 | 0.00 | 0.01 | 0.02 |
| Particulate Matter ≤10 μ | 0.056 | 0.02 | 0.04 | 0.10 |
| Nitrogen Oxides (NOx) | 0.067 | 0.02 | 0.05 | 0.12 |

| | | | | |
|---|---|---|---|---|
| Volatile Organic Compo | 0.065 | 0.02 | 0.05 | 0.11 |

*Source: FHWA CMAQ Emissions Calculator Toolkit*
*https://www.fhwa.dot.gov/environment/air_quality/cmaq/toolkit/*

| | | |
|---|---|---|
| [calc] | **Total Co-Pollutant Reductions** | |
| 2030 | 0.98 | (MT co-pollutants) |
| 2040 | 1.96 | (MT co-pollutants) |
| 2050 | 4.89 | (MT co-pollutants) |

| Measure ANWL2 | Convert 15,000 acres of municipally-owned pavement and/or manicured lawn through the development of a regional Municipal Resiliency Pocket initiative that transforms underutilized municipal lands into multifunctional green spaces. Reclaim vacant, degraded, or underutilized municipal land in the MSA into a network of small-scale ecological pockets to sequester carbon, reduce urban heat, absorb stormwater, and promote biodiversity. Types of resiliency pockets might include: (1) Mini-forests with dense, fast-growing native trees to support carbon capture and biodiversity; (2) Food forests with edible perennial landscapes accessible to the public to promote carbon-smart local food; (3) Parks with native grasses and flowers that require minimal maintenance and promote high ecological value; and (4) Rain gardens and bioswales planted in buffers to municipal lots and rights-of-way to reduce runoff and urban flooding. | | |
|---|---|---|---|
| | Annual GHG emissions reduced in 2030 | 176,763 | MTCO2e |
| | Annual GHG emissions reduced in 2040 | 353,527 | MTCO2e |
| | Annual GHG emissions reduced in 2050 | 530,290 | MTCO2e |
| | GHG emissions reductions were quantified using a carbon sequestration rate for Miyawaki forests of 33.08 mg C per hectare per year based on a 2025 study. It was assumed that by 2030 and 2050, 5,000 acres and 15,000 acres of Miyawaki forests could be established, respectively. | | |
| | GHG Reduction | | |

[value] **Land Area**

| | | |
|---|---|---|
| 2030 | 5,000 | (acres) |
| 2040 | 10,000 | (acres) |
| 2050 | 15,000 | (acres) |

[input] **Percent of Land Area Allocated to Miyawaki Forest**

70% (percent)

[calc] **Percent of Land Area Allocated to Other Efforts**

30% (percent)

[value] **Rate of Carbon Sequestration for a Miyawaki Forest**

33.08 (Mg C/ha-yr) *Max maturity rate by 5 years*

*Source: Roy et al., Assessing carbon sequestration in urban Miyawaki forests of south India: Implications for climate mitigation planning and land suitability https://www.sciencedirect.com/science/article/pii/S2666719325001517*

[value] **Conversions**

| | |
|---|---|
| 0.00025 | (sq m to Acres) |
| 0.0001 | (sq m to ha) |
| 3.666667 | (Carbon to CO2e) |
| 0.40 | (Acre to Hectare) |

[calc] **Carbon Sequestered by Miyawaki Forests by 2030, 2040, 2050**

| | | | |
|---|---|---|---|
| 2030 | 46,855 | (Mg C/year) | *1 Mg = 1 MT* |
| 2040 | 93,709 | (Mg C/year) | |
| 2050 | 140,564 | (Mg C/year) | |

[value] **Rate of Carbon Sequestration for Other Forest**

| | | |
|---|---|---|
| 2.23 | (MTC/ha/yr) | *Carbon sequestration factor* |

**Carbon Sequestered by 2030, 2040, 2050 from Other Forests**

| | | |
|---|---|---|
| 2030 | 4,963 | (MTCO2e) |
| 2040 | 9,927 | (MTCO2e) |
| 2050 | 14,890 | (MTCO2e) |

[calc] **Carbon Sequestered by 2030, 2040, 2050**

| | | |
|---|---|---|
| 2030 | 176,763 | (MTCO2e) |
| 2040 | 353,527 | (MTCO2e) |
| 2050 | 530,290 | (MTCO2e) |

**Co-Pollutant Reduction**

Given that limited data is available for Miyawaki forest co-pollutant removals, data from the OurTrees tool by iTree was used to back calculate a factor for several pollutants.

[calc] **Land Area**

| | | |
|---|---|---|
| **2030** | 20,233,904 | (sq m) |
| **2040** | 40,467,808 | (sq m) |
| **2050** | 60,701,712 | (sq m) |

| **Pollutant** | **Emissions factor (lb/year/sq m)** | 2030 (lb/year) | 2040 (lb/year) | 2050 (lb/year) | 2030 (MT/year) | 2040 (MT/year) | 2050 (lb/year) |
|---|---|---|---|---|---|---|---|
| **Carbon Monoxide** | 0.00044479 | 9,000 | 18,000 | 26,999 | 4.1 | 8.2 | 12.2 |
| **Ozone** | 0.01562595 | 316,174 | 632,348 | 948,522 | 143.4 | 286.8 | 430.2 |
| **Nitrogen Dioxide** | 0.0034006 | 68,808 | 137,615 | 206,423 | 31.2 | 62.4 | 93.6 |
| **Sulfur Dioxide** | 0.00089168 | 18,042 | 36,084 | 54,127 | 8.2 | 16.4 | 24.5 |
| **PM2.5** | 0.00086186 | 17,439 | 34,878 | 52,317 | 7.9 | 15.8 | 23.7 |

**Total Co-Pollutants Reduction**

| | | |
|---|---|---|
| 2030 | 195 | (MT Co-Pollutant) |

| | | |
|---|---|---|
| 2040 | 390 | (MT Co-Pollutant) |
| 2050 | 584 | (MT Co-Pollutant) |

| Measure | ***Reduce the usage of synthetic pesticides and fertilizers on 9,000 acres of municipal, commercial, and residential land by 2050.***<br>***Encourage farms in the MSA to adopt regenerative practices that reduce nitrogen fertilizer use and eliminate pesticide applications, and partner with MDAR, CTDOA, Mount Wachusett Community College, Central Mass Grown, and other similar organizations/programs to provide technical and financial assistance on regenerative farming practices.*** | | |
|---|---|---|---|
| | ***Annual GHG emissions reduced in 2030*** | ***3,557*** | ***MTCO2e*** |
| | ***Annual GHG emissions reduced in 2040*** | ***8,865*** | ***MTCO2e*** |
| | ***Annual GHG emissions reduced in 2050*** | ***12,891*** | ***MTCO2e*** |
| GHG reductions associated with fertilizer reduction on 9,000 acres were calculated using data from the 2022 GHG Inventory sources, including the National Land Cover Database and MA and CT statewide GHG inventories. | | | |

**Data Inputs: Cropland (Acres) and Statewide Agriculture Emissions**

[Value] **Total Cropland in Acres - MA**
57,312 (acres) *Source: 2022 GHG Inventory (2021 National Land Cover Data)*

[Value] **Total Cropland in Acres - CT**
47,566 (acres) *Source: 2022 GHG Inventory (2021 NLCD)*

[Value] **Total Cultivated Cropland (acres) Middlesex, MA**
186 (acres) *Source: 2022 GHG Inventory (2021 NLCD)*

[Value] **Total Cultivated Cropland (acres) New London, CT**
349 (acres) *Source: 2022 GHG Inventory (2021 NLCD)*

[Value] **Total Cultivated Cropland (acres) Tolland, CT**
23 (acres) *Source: 2022 GHG Inventory (2021 NLCD)*

[Value] **Total Cultivated Cropland (acres) Windham, CT**
8,611 (acres) *Source: 2022 GHG Inventory (2021 NLCD)*

[Value] **Total Cultivated Cropland (acres) Worcester, MA**
1,392 (acres) *Source: 2022 GHG Inventory (2021 NLCD)*

[Value] **MA Statewide Agriculture Emissions**

| | | |
|---|---|---|
| 0.01279769 | (MMTCO2e) | Liming |
| 0.00052255 | (MMTCO2e) | Urea Fertilizatio |
| 0.000257 | (MMTN2O) | Ag Soils |

*Source: MA DEP GHG Inventories https://www.mass.gov/lists/massdep-emissions-inventories*

[Value] **CT Statewide Agriculture Emissions**
0.000257 (MMTN2O) Ag Soils

*Source: CT DEEP GHG Inventories https://portal.ct.gov/DEEP/Climate-*

*Change/CT-Greenhouse-Gas-Inventory-Reports*

[Value] **IPCC AR5 100-Year Global Warming Potentials**
265 N2O

[Value] **Million Metric Tons Conversion**
1,000,000 (Metric Ton)

[Value] **MSA Cropland Percent of total Statewide Cropland** *Source: 2022 GHG Inventory (2021 NLCD)*

| County | MSA only Cropland | % of Statewide Cropland |
|---|---|---|
| New London, CT | 349 | 0.7% |
| Tolland, CT | 23 | 0.049% |
| Windham, CT | 8,611 | 18.1% |
| Middlesex, MA | 186 | 0.3% |
| Worcester, MA | 1,392 | 2.4% |

| Total Fertilizer Emissions by County (Within MSA) by Type | | | | |
|---|---|---|---|---|
| | Liming Emissions (MTCO2e) | Urea Emissions (MTCO2e) | Ag Soils (MTCO2e) | **Total Emissions (MTCO2e)** |
| New London | - | - | 501 | 501 |
| Tolland | - | - | 33 | 33 |
| Windham | - | - | 12,348 | 12,348 |
| Middlesex | 41.5 | 1.7 | 221 | 264 |
| Worcester | 310.9 | 12.7 | 1,657 | 1,980 |
| | | | ***Totals*** | 15,127 |

| Reduction Scenarios 2030, 2040, and 2050 | | | | |
|---|---|---|---|---|
| State | Total Cropland (acres) 2021 | **2030** | **2040** | **2050** |
| CT | 8,984 | **25%** | **50%** | **70%** |
| MA | 1,578 | **15%** | **25%** | **45%** |

| Total Cropland for Fertilizer Reduction | | | | | | |
|---|---|---|---|---|---|---|
| County | **2030 (acres)** | 2030 % of cropland | **2040 (acres)** | 2040 % of cropland | **2050 (acres)** | 2050 % of cropland |
| CT | 6,738 | 14% | 3,369 | 7% | 1,011 | 2% |

| | | | | | | |
|---|---|---|---|---|---|---|
| MA | 1,341 | 2% | 1,006 | 2% | 553 | 1% |
| | | | | Total Cropland For Fertilizer Reduction by 2050 (Acres) | | 8,998 |

| Total Fertilizer Emissions by County (Within MSA) by Type - 2030 | | | | |
|---|---|---|---|---|
| State | Liming Emissions (MTCO2e) | Urea Emissions (MTCO2e) | Ag Soils (MTCO2e) | **Total Emissions (MTCO2e)** |
| CT | - | - | 9,662 | 9,662 |
| MA | 300 | 12 | 1,596 | 1,908 |
| | | | ***Totals*** | 11,570.0 |

| Total Fertilizer Emissions by County (Within MSA) by Type - 2040 | | | | |
|---|---|---|---|---|
| State | Liming Emissions (MTCO2e) | Urea Emissions (MTCO2e) | Ag Soils (MTCO2e) | **Total Emissions (MTCO2e)** |
| CT | - | - | 4,831 | 4,831 |
| MA | 225 | 9 | 1,197 | 1,431 |
| | | | ***Totals*** | 6,262.0 |

| Total Fertilizer Emissions by County (Within MSA) by Type - 2045 | | | | |
|---|---|---|---|---|
| State | Liming Emissions (MTCO2e) | Urea Emissions (MTCO2e) | Ag Soils (MTCO2e) | **Total Emissions (MTCO2e)** |
| CT | - | - | 1,449 | 1,449 |
| MA | 124 | 5 | 659 | 787 |
| | | | ***Totals*** | 2,236.4 |

| Reduced Croplands Fertilized and Emission Reductions 2030, 2040, 2050 | | | | | | |
|---|---|---|---|---|---|---|
| State | **2030 Cropland (acres)** | **2030 Emissions (MTCO2e)** | **2040 Cropland (acres)** | **2040 Emissions (MTCO2e)** | **2050 Cropland (acres)** | **2050 Emissions (MTCO2e)** |
| CT | 6,738 | 9,662 | 3,369 | 4,831 | 1,011 | 1,449 |
| MA | 1,341 | 1,908 | 1,006 | 1,431 | 553 | 787 |
| | | | | **Total Cropland Reduced by 2050** | | 8,998 |
| | | | | **Total Emissions Reduced by 2050** | | 12,891 |

[FINAL] **Annual GHG emissions reduced in 2030**
3,557 (MTCO2e)

[FINAL] **Annual GHG emissions reduced in 2040**
8,865 (MTCO2e)

[FINAL] **Annual GHG emissions reduced in 2050**

12,891 (MTCO2e)

**Agriculture Practice Co-Pollutant Reductions**

Co-pollutant reductions were quantified by assuming a 22% and 47% reductions in cropland for 2030 and 2050, respectively. Percent reductions were applied to the EPA National Emissions Inventory data for ammonia associated with agricultural fertilizer applications.

| County | Total MT Ammonia | Percent of county in MSA | MSA Allocated MT Ammonia |
|---|---|---|---|
| CT-New London | 281 | 20% | 58 |
| CT-Tolland | 168 | 3% | 4 |
| CT-Windham | 187 | 100% | 187 |
| MA-Middlesex | 264 | 73% | 193 |
| MA-Worcester | 523 | 99% | 517 |

*Source: EPA National Emissions Inventory 2020 Data Retrieval Tool, filter for county and Agriculture Fertilizer https://awsedap.epa.gov/public/single/?appid=20230c40-026d-494e-903f-3f112761a208&sheet=5d3fdda7-14bc-4284-a9bb-cfd856b9348d&opt=ctxmenu,currsel*

[calc] **Cropland reduction**

2030 2,483

2050 8,998

[calc] **Percent reduction from 2021 croplands**

2030 24%

2050 85%

[calc] **Total Ammonia Allocated to MSA**

959 (MT Ammonia)

[FINAL] **Co-Pollutant Reduction from Reduced Fertilizer Usage**

2030 225 (MT Ammonia)

2050 817 (MT Ammonia)

| | |
|---|---|
| ***Measure*** | ***Mixed-Use Zoning + Transit-Oriented Development (TOD) in relevant areas like town and village centers, transportation corridors and other designated districts: Compact, walkable development reduces both VMT and building emissions. Smart growth zoning can reduce per capita emissions by 20–40% (EPA Smart Growth Reports). Rail-served communities like Worcester, Grafton, and Fitchburg are key targets for such reforms. The region can aim to work with 25% of municipalities in the MSA which have ready or moderate levels of infrastructural preparedness by 2035 and all remaining/relevant municipal or village centers (another estimated 30%) by 2050.***<br>***Emphasize Brownfield clean-up/redevelopment and limit access to open spaces and conservation land for any new development: This strategy focuses on encouraging compact growth through cluster development, transfer of development rights (TDR), and growth boundaries. The goal is to have 50% of towns in the MSA adopt these reforms by 2040 and reach an optimum state by 2050. Preserving forests, farmland, and open spaces is crucial in Worcester County, where nearly 75% of the land remains undeveloped. Protecting these areas helps maintain important natural carbon sinks, reduces emissions from new infrastructure expansion, and limits vehicle miles traveled by encouraging denser, more compact development patterns.*** |

***Annual GHG emissions reduced in 2030*** **16,607** ***MTCO2e***

***Annual GHG emissions reduced in 2050*** **32,168** ***MTCO2e***

GHG emissions reductions were quantified using the gasoline passenger vehicle miles traveled from the 2022 GHG inventory for the largest 25 communities by population as the 2030 implementation and also including the next largest 24 communities in the total VMT for 2050. An average fuel efficiency of 22.6 miles per gallon was used (from 2022 GHG Inventory) to calculate the gasoline savings.

**GHG Calculations**

[value] **VMT by gasoline passenger vehicles for 20 largest municipalities**
2,128,128,612 (vehicle miles traveled)

[value] **VMT by gasoline passenger vehicles for the 24 next largest municipalities**
1,994,094,521 (vehicle miles traveled)

[input] **VMT reduction**
2% (percent) Additional VMT reduction beyond the transportation measures for specific communities

[calc] **Miles to be reduced**
2030 42,562,572 (vehicle miles traveled)
2050 82,444,463 (vehicle miles traveled)

[value] **Average fuel efficiency for gasoline passenger vehicle registered in largest 20**
22.58 (miles/gal gasoline)

[calc] **Gasoline Fuel Savings**
2030 1,884,597 (gallons)
2050 3,650,498 (gallons)

[value] **Gasoline Emissions Factors**
0.0087800 (MTCO2/gal) *Source: EPA Emissions Factor Hub*
0.0000004 (MTCH4/gal) 28 GWP
0.0000001 (MTN2O/gal) 265 CO2

[calc] **Combined gasoline emissions factor**
0.0088118 (MTCO2e/gal gas)

[calc] **Emissions reduction from VMT reduction**
2030 16,607 (MTCO2e)
2050 32,168 (MTCO2e)

**Co-Pollutant Reduction**

*Methodology Description: The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Bicycle, Pedestrian, and Shred Micromobility was used to determine co-pollutant emissions reductions from replacing vehicle trips with walking and biking trips.*

[value] **Average trip distance**
2.0129 (miles/trip) *Default value*

[input] **Percent of VMT reduction attributed to walking/biking**
10% (%) *Assumptions*

[calc] **Number of trips attributed to walking or biking**
2030 2,114,490 (trips)
2050 4,095,805 (trips)

| 2030 | | | |
|---|---|---|---|
| **Pollutant** | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** |
| Carbon Monoxide (CO) | 0.00466 | 0.00170 | 3,597 |
| Particulate Matter ≤2.5 µm | 0.00002 | 0.00001 | 15 |
| Particulate Matter ≤10 µm | 0.00009 | 0.00003 | 69 |
| Nitrogen Oxides (NOx) | 0.00015 | 0.00005 | 116 |
| Volatile Organic | 0.00016 | 0.00006 | 123 |

| 2050 | | | |
|---|---|---|---|
| Pollutant | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** |
| Carbon Monoxide (CO) | 0.00289 | 0.00105 | 4,321 |
| Particulate Matter ≤2.5 µm | 0.00002 | 0.00001 | 24 |

| | | | |
|---|---|---|---|
| Particulate Matter ≤10 µm | 0.00009 | 0.00003 | 130 |
| Nitrogen Oxides (NOx) | 0.00006 | 0.00002 | 84 |
| Volatile Organic | 0.00012 | 0.00004 | 173 |

[calc] **2030 Total Co-Pollutant Reductions**

3,921 (MT Co-Pollutants)

[calc] **2050 Total Co-Pollutant Reductions**

4,732 (MT Co-Pollutants)

| Measure | Use retro-commissioning, deep retrofits, and replacement of heating/cooling systems to optimize the use of energy. Aim to upgrade local and state-owned facilities in the next 25 years, prioritizing high energy and high usage buildings (for example, emergency operation centers and school buildings). Also, incentivize and target optimization for all remaining buildings by 2050, prioritizing the larger facilities first, creating strong incentive mechanisms to promote this transition. The aim is to get most of the high energy usage facilities to net zero, using distributed energy costs, and adding microgrids/renewable energy generation as a part of the process. |
|---|---|

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***22,497*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2040*** | ***38,566*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***64,275*** | ***MTCO2e*** |

Reductions were calculated by assuming municipal natural gas and heating oil usage (data from Mass Energy Insight for 2022) would decrease by 35%, 60%, 100% by 2030, 2040, and 2050, in alignment with the Climate Leader Community Decarbonization Roadmap Guidance. Any increase in electricity usage would be from renewable sources.

**GHG Emissions Reduction**

[value] **Therms natural gas for municipalities**
11,532,599 (therms) *Source: Mass Energy Insight (MEI), gaps filled with average as needed*

[input] **Municipal fuel oil use**
140,025 (gallons) *Source: 2022 GHG Inventory*

[input] **Percent to reduce natural gas and fuel usage by 2030**
35% *Source: Climate Leader Community Decarbonization Roadmap Guidance*

[calc] **Therms of natural gas reduction**
4,036,410 (therms)

[value] **Conversion from gal to MMBTU fuel oil #2**
0.138 (gal/MMBTU) *Source: EPA emission factors hub*

[calc] **Fuel oil reduction 2030 in MMBTU**
6,763 (MMBTU)

[input] **Percent for natural gas reduction 2040**
60% (%) *Source: Climate Leader Community Decarbonization Roadmap Guidance*

[calc] **Natural gas reduction to reduce by 2040**
6,919,560 (therms)

[calc] **Fuel oil reduction 2040 in gallons**
84,015 (gallons)

[calc] **Fuel oil reduction 2040 in MMBTU**

11,594 (MMBTU) *Conversion*

[input] **Percent for natural gas reduction 2050**

100% (%) *Source: Climate Leader Community Decarbonization Roadmap Guidance*

[calc] **Natural gas reduction to reduce by 2050**

11,532,599 (therms)

[input] **Percent for fuel oil reduction 2050**

100% (%) *Source: Climate Leader Community Decarbonization Roadmap Guidance*

[calc] **Fuel oil reduction 2050 in gallons**

140,025 (gallons)

[calc] **Fuel oil reduction 2050 in MMBTU**

19,323 (MMBTU) *Conversion*

[value] **Natural gas emissions factors**

| | | | |
|---|---|---|---|
| 0.00530 | ($MTCO_2$/ther | | *Source: EPA Emissions Factor Hub* |
| 0.0000001 | ($MTCH_4$/ther | *28* | *GWP* |
| 0.00000001 | ($MTN_2O$/ther | *265* | *CO2* |

[value] **Combined emissions factor for natural gas**

0.0053047 (MTCO2/therm)

[calc] **Emission reduction for natural gas**

| | | |
|---|---|---|
| 2030 | 21,413 | (MTCO2e) |
| 2040 | 36,708 | (MTCO2e) |
| 2050 | 61,177 | (MTCO2e) |

[value] **Fuel oil #2 emissions factors**

| | | | |
|---|---|---|---|
| | | *ce: EPA Emissions Factor* | |
| 0.07396 | ($MTCO_2$/MMB | | |
| 0.000003 | ($MTCH_4$/MMB | *28* | *GWP* |
| 0.00000060 | ($MTN_2O$/MMB | *265* | *CO2* |

[value] **Combined emissions factor for fuel oil**

0.074203 (MTCO2e/MMBTU)

[calc] **Emissions reduction from fuel oil**

| | | |
|---|---|---|
| 2030 | 502 | (MTCO2e) |
| 2040 | 860 | (MTCO2e) |
| 2050 | 1,434 | (MTCO2e) |

[value] **Municipal propane usage** *Source: 2022 GHG Inventory*

26,355 (MMBTU)

[input] **Propane precent reduction**

| | | |
|---|---|---|
| 2030 | 35% | (%) |
| 2040 | 60% | (%) |
| 2050 | 100% | (%) |

| | | | |
|---|---|---|---|
| [calc] | **Propane precent reduction** | | |
| 2030 | 9,224 | (MMBTU) | |
| 2040 | 15,813 | (MMBTU) | |
| 2050 | 26,355 | (MMBTU) | |
| [value] | **Propane emissions factors** | | |
| | 0.06287 | ($MTCO_2$/MMI | *Source: EPA Emissions Factor Hub* |
| | 0.000003 | ($MTCH_4$/MMI | *28* *GWP* |
| | 0.0000006 | ($MTN_2O$/MMI | *265* *CO2* |
| [calc] | **Combined propane emissions factor MMBTU** | | |
| | 0.063113 | (MTCO2e) | |
| [calc] | **Propane emissions reduction** | | |
| 2030 | 582 | (MTCO2e) | |
| 2040 | 998 | (MTCO2e) | |
| 2050 | 1,663 | (MTCO2e) | |
| [FINAL] | **Total Emissions Reduction** | | |
| 2030 | 22,497 | (MTCO2e) | |
| 2040 | 38,566 | (MTCO2e) | |
| 2050 | 64,275 | (MTCO2e) | |

**Co-Pollutants**

Co-pollutant emissions reductions account for the reduction in natural gas and fuel oil due to electrification using emissions factors for NOx and SO2.

| | | | |
|---|---|---|---|
| [value] | **Emission Factors for Natural Gas Co-Pollutants** | | |
| NG (NO | 94 | (lbs/Mmcf) | *Source: NESCAUM Estimating the Emissions Benefits of Switching to Heat Pumps* |
| NG (SO | 0.6 | (lbs/Mmcf) | *for Residential Heating Table 2* |
| [value] | **Emission Factors for Fuel Oil Co-Pollutants** | | |
| FO (NO | 0.11 | (lbs/MMBtu) | |
| FO (SO | 0.042 | (lbs/gallon) | |

| | | | | |
|---|---|---|---|---|
| [calc] | **Fuel Usage Reduction** | | *Converted* | |
| 2030 NG | 4,036,410 | (therms) | 404 | (Mmcf) |
| 2030 FC | 6,763 | (MMBtu) | | |
| 2050 NG | 11,532,599 | (therms) | 1,153 | (Mmcf) |
| 2050 FC | 19,323 | (MMBtu) | | |
| [value] | **Conversions** | | | |
| | 0.0001 | Therms to Mmcf conversion | | |
| | 2,205 | Lbs/Metric Ton conversion | | |
| [value] | **Conversion and Co-pollutant calculations 2030** | | | |
| NG (NO | 17.2 | (MT Co-Pollutants) | | |
| NG (SO | 0.1 | (MT Co-Pollutants) | | |
| FO (NO | 0.3 | (MT Co-Pollutants) | | |

| | | |
|---|---|---|
| FO (SO | 0.9 | (MT Co-Pollutants) |

| [value] | **Conversion and Co-pollutant calculations 2050** | |
|---|---|---|
| NG ($NO_x$ | 49.2 | (MT Co-Pollutants) |
| NG (SO | 0.3 | (MT Co-Pollutants) |
| FO ($NO_x$ | 1.0 | (MT Co-Pollutants) |
| FO (SO | 2.7 | (MT Co-Pollutants) |

| **[FINAL]** | **Total Co-Pollutants** | |
|---|---|---|
| 2030 | 18.6 | (MT Co-Pollutants) |
| 2050 | 53.1 | (MT Co-Pollutants) |

| Measure | |
|---|---|
| | ***Encourage the reuse and upgrading of existing facilities to minimize demolition waste, reduce embodied carbon, and avoid unnecessary new construction. Promote deconstruction and the recycling of building materials to build a local circular construction economy. Some key actions include: Require all demolitions to submit adaptive reuse justifications and materials reuse plan by 2030; Pilot deconstruction/demolition consideration bylaws for non-historic buildings in 5 towns by 2035; Provide tax credits and incentives for adaptive reuse projects and build the necessary local infrastructure like regional permit centers and material recovery hubs (explore/adopt public-private partnerships to establish regional reuse markets and sustainable material recovery facilities). Some tangible success parameters could be: all major demolition projects would have to have an adaptive reuse/deconstruction strategy, reduce demolition waste by 40% by 2040; build the public and private ecosystem that facilitates adaptive reuse, circular construction and cradle to door - aiming for at least 3-4 regional hubs in the target area.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***588*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***2,939*** | ***MTCO2e*** |

Methodology Description: GHG reductions were quantified by allocating a portion of the C&D waste reduction to this measure based on the MassDEP Waste Characterization Study and 2022 GHG Inventory. It was assumed by 2030, 50% of waste could be diverted and 50% by 2050.

**GHG Calculations**

[value] **Total Estimated Landfilled/Incinerated Waste in MSA**
822,408 (Short To *Source: 2022 GHG Inventory*

[input] **Estimated Percentage of Waste Which is Construction/Building Materials Sent to Landfills/Incinerators**
9.15% (%) Source: MassDEP Summary of Waste

[calc] **Total Estimated Short Tons of Recyclables in Landfills/Incinerators**
75,250 (Short Tons)

[input] **Target Diversion Percent by 2030**
10% (%) *Assumption*

**Target Diversion Percent by 2050**
[input]
50% (%) *Assumption*

[calc] **Target Diversion by 2030**
7,525 (Short Tons)

[calc] **Target Diversion by 2050**
37,625 (Short Tons)

[values **Waste disposal by type**
Landfill 17% (%) *Source: 2022 GHG Inventory*

| | | | |
|---|---|---|---|
| Inciner | 83% | (%) | |
| [values | **Landfill CH4 Emissions Variables** | | |
| Lo | 0.08 | | *Source: 2022 GHG Inventory* |
| frec | 0.85 | | |
| Ox | 0.10 | | |
| [calc] | **Landfill Methane Emissions Reduced by 2030** | | |
| | 13.50 | (MTCH4) | |
| [calc] | **Landfill Methane Emissions Reduced by 2050** | | |
| | 67.51 | (MTCH4) | |
| [values | **Incineration CO2, CH4, and N2O Emissions Variables** | | |
| Eq 8.6 | 0.6% | | *Source: 2022 GHG Inventory, GPC Equation 8.6* |
| Carbon | 3.67 | | |
| convers | 0.000001 | | |
| CH4 | 0.20 | (g CH4/ton) | |
| N2O | 50 | (g N2O/ton) | |
| CH4 G | 28 | | *AR5* |
| N2O G | 265 | | *AR5* |
| [calc] | **Incineration CO2, CH4, N2O emissions 2030** | | |
| CO2 | 127 | (MTCO2e) | |
| CH4 | 0.0 | (MTCO2e) | |
| N2O | 83 | (MTCO2e) | |
| [calc] | **Incineration CO2, CH4, N2O emissions 2050** | | |
| CO2 | 634 | (MTCO2e) | |
| CH4 | 0.2 | (MTCO2e) | |
| N2O | 415 | (MTCO2e) | |
| [calc] | **2030 Total Emissions Reduced from Incineration** | | |
| | 210 | (MTCO2e) | |
| [calc] | **2030 Total Emissions Reduced from Landfill** | | |
| | 378 | (MTCO2e) | |
| [FINAL | **2030 Annual GHG Emissions Reduced** | | |
| | 588 | (MTCO2e) | |
| [calc] | **2050 Total Emissions Reduced from Incineration** | | |
| | 1,049 | (MTCO2e) | |
| [calc] | **2050 Total Emissions Reduced from Landfill** | | |
| | 1,890 | (MTCO2e) | |
| [FINAL | **2050 Annual GHG emissions reduced** | | |
| | 2,939 | (MTCO2e) | |

**Co-Pollutants**

The EPA LandGEM emission factors for HAPs and CAPs in relation to landfill emissions were used to quantify this measure. The emissions factor was applied to the total reduced waste from landfills.

**Landfill Co-Pollutants**

*Source: EPA Landfill Gas Emissions Model (LandGEM) Version 3.1 User Manual*

[value] **Conversion for Landfill gas (LFG) generated per ton of waste**

1.98E-08 ppmv × ft³ × MW = lb

7,063 ft³/ton

| Pollutant | ppmv | MW | *EF (lb/ton)* | *Waste (tons) 2030* | *Waste (tons) 2050* | *Emissions (Metric Tons) 2030* | *Emissions (Metric Tons) 2050* |
|---|---|---|---|---|---|---|---|
| **Benzene** | 39 | 78 | *0.4260* | *7,525* | *37,625* | *2* | *8* |
| **Toluene** | 170 | 92 | *2.1903* | *7,525* | *37,625* | *8* | *41* |
| **Vinyl chloride** | 7.3 | 63 | *0.0638* | *7,525* | *37,625* | *0* | *1* |
| **Carbon monoxide** | 110 | 28 | *0.4309* | *7,525* | *37,625* | *2* | *8* |
| **Methylene chloride** | 5.8 | 85 | *0.0689* | *7,525* | *37,625* | *0* | *1* |
| **Chloroform** | 0.3 | 119 | *0.0057* | *7,525* | *37,625* | *0* | *0* |
| **Carbon tetrachloride** | 0.0 | 154 | *0.0000* | *7,525* | *37,625* | *0* | *0* |
| **Ethylbenzene** | 4.6 | 106 | *0.0683* | *7,525* | *37,625* | *0* | *1* |
| **Trichloroethylene** | 2.8 | 131 | *0.0515* | *7,525* | *37,625* | *0* | *1* |
| **Perchloroethylene** | 2.1 | 166 | *0.0487* | *7,525* | *37,625* | *0* | *1* |
| | | | | | 2030 | ***13*** | ***(MT Co-Pollutants)*** |

| | | |
|---|---|---|
| 2050 | ***63*** | ***(MT Co-Pollutants)*** |

| | |
|---|---|
| ***Measure*** | ***Accelerate the adoption of sustainable materials and building practices by reforming procurement, educating stakeholders, and creating the necessary market demand. Prioritize carbon-smart, locally sourced, and circular materials in public and private construction. Key actions include:***<br>***Integrate green concrete, recycled aggregates, and low-carbon materials into 30 % of municipally or state-owned projects by 2035; 100% of municipally or state-owned projects by 2050.***<br>***Develop local pilot programs for porous pavement, recycled lumber, fly ash concrete, and passive cooling/green roofs. Work with state agencies to incentivize the use of tested materials like green concrete (e.g., via DOT and public construction specs).***<br>***Reduce embodied emissions of new construction by 40% by 2045.***<br>***Update local procurement policies in 30 towns to favor sustainable and/or recycled materials by 2035.***<br>***Educate engineers and architects about material performance, pricing, and code compatibility.*** |

***Annual avoided emissions in 2030*** ***2,322*** ***MTCO2e***

***Annual avoided emissions in 2030*** ***9,288*** ***MTCO2e***

Methodology description: Utilizing Care Tool, managed by Architecture 2030, a non-profit focusing on reducing emission in the build environment, values for wood, hybrid and concrete/steel were used. This tool provides the embodied carbon of each material type in kg/CO2e/sf of floor area. This was applied to an estimated square footage of a newly developed building to determine the difference in selecting a wood framed building over steel and concrete and calculated for 25 buildings in 2030 and 100 buildings in 2050, as one example of how material selection can reduce embodied carbon emissions.

**Embodied emissions from New Building Construction Data and Calculations**

| | | | |
|---|---|---|---|
| [value] | **Average square footage of new constructed building** | | |
| | 4,000 | (sq ft) | *Assumption* |

| | | | |
|---|---|---|---|
| [value] | **Comparison of Embodied Carbon for Timber, Concrete, and Steel Frames** | | |
| Wood | 23.2 | (kg CO2e/sf of floor area) | |
| Hybrid | 30.19 | (kg CO2e/sf of floor area) | *Source: CareTool.Org* |
| Steel/Concrete | 46.45 | (kg CO2e/sf of floor area) | |

| | | |
|---|---|---|
| [value] | **Conversion** | |
| | 1,000 | kg to Metric Tons |

| | | | |
|---|---|---|---|
| [value] | **Total MTCO2e of newly constructed building and embodied carbon by type** | | |
| Wood | 93 | MTCO2e | |
| Hybrid | 121 | MTCO2e | |
| Steel/Concrete | 186 | MTCO2e | |

| | | |
|---|---|---|
| [value] | **Total number of newly constructed building projects by 2030 and 2050** | |
| 2030 | 25 | *Assumption* |
| 2050 | 100 | |

| | | |
|---|---|---|
| [value] | **Estimated embodied carbon for steel/concrete** | |
| 2030 | 4,645 | MTCO2e |
| 2050 | 18,580 | MTCO2e |

| | | |
|---|---|---|
| [value] | **Estimated embodied carbon for wood** | |
| 2030 | 2,323 | MTCO2e |
| 2050 | 9,292 | MTCO2e |

| | | |
|---|---|---|
| [value] | **Difference in emissions from steel and Concrete for projected new construction projects** | |
| 2030 | 2,322 | MTCO2e |
| 2050 | 9,288 | MTCO2e |

| | | |
|---|---|---|
| **[FINAL]** | **Total Emissions Reductions from Embodied Carbon if sourced by Wood** | |
| 2030 | 2,322 | MTCO2e |
| 2050 | 9,288 | MTCO2e |

## Co-pollutant Reductions

In addition to material type, sourcing locations also have an impact on emissions. As an example, co-pollutant emissions reduction from reduced transportation distance of materials have been quantified.

| | | | |
|---|---|---|---|
| [value] | **Estimated miles traveled from ON, Canada to MA** | | |
| | 700 | (miles) | 700 |

| | | |
|---|---|---|
| [value] | **Estimated miles traveled for Local Timber as alternative construction material** | |
| | 100 | (miles) |

| | | | |
|---|---|---|---|
| [value] | **Difference in Miles traveled for sustainable materials** | | |
| | 600 | (miles) | FHA input |
| | 2 | Estimated number of trips for one building constructed | |

| 2030 Canada to MA State | | | | Locally Sourced 2030 | | |
|---|---|---|---|---|---|---|
| **Pollutant** | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** |
| Carbon Monoxide (CO) | 1.3941751 | 0.50887 | 1 | 0.200 | 0.07290 | 0.146 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Particulate Matter ≤2.5 µm (PM2 | 0.0051042 | 0.00186 | 0 | 0.001 | 0.00027 | 0.001 |
| Particulate Matter ≤10 µm (PM10 | 0.0296219 | 0.01081 | 0 | 0.004 | 0.00155 | 0.003 |
| Nitrogen Oxides (NOx) | 0.0354324 | 0.01293 | 0 | 0.005 | 0.00186 | 0.004 |
| Volatile Organic Compounds (VO | 0.0345439 | 0.01261 | 0 | 0.005 | 0.00182 | 0.004 |
| **2050 Canada to MA State** | | | | **Locally Sourced 2050** | | |
| **Pollutant** | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** | **Total (kg/day/trip) reduced** | **Total (MT/year/trip) reduced** | **Total (MT/year) reduced** |
| Carbon Monoxide (CO) | 0.8478674 | 0.30947 | 1 | 0.1215 | 0.04435 | 0.089 |
| Particulate Matter ≤2.5 µm (PM2.5 | 0.0045422 | 0.00166 | 0 | 0.0007 | 0.00024 | 0.000 |
| Particulate Matter ≤10 µm (PM10 | 0.0289867 | 0.01058 | 0 | 0.0041 | 0.00151 | 0.003 |
| Nitrogen Oxides (NOx) | 0.0079642 | 0.00291 | 0 | 0.0012 | 0.00043 | 0.001 |
| Volatile Organic Compounds (VO | 0.025611 | 0.00935 | 0 | 0.0037 | 0.00135 | 0.003 |

[Baseline] **Total Emissions Reductions from Embodied Carbon**

2030 1.09 MT

2050 0.67 MT

[calc]

**Total Emissions Reductions from Embodied Carbon Per Trip**

2030 0.94 MT

2050 0.57 MT

[FINAL] **Scenario**

2030 47 MT assuming 2 trip per building (25 buildings by 2030)

2050 114 MT assuming 2 trip per building (100 buildings by 2030)

[FINAL] **Annual GHG emissions reduced in 2030**
(MTCO2e)

[FINAL] **Annual GHG emissions reduced in 2040**
(MTCO2e

[FINAL] **Annual GHG emissions reduced in 2050**
(MTCO2e

**Links to data sources:**

Gardner Downtown Tree Inventory & Plan
https://www.gardner-ma.gov/DocumentCenter/View/7475/GardnerTreeReport_2020-1029?bidId=

Worcester Urban Forest Master Plan
https://www.worcesterma.gov/uploads/e7/53/e753cc773b32911dc1c56267b9c37400/worcester-urban-forest-master-plan-draft.pdf

Andover Tree Inventory
https://andoverma.treekeepersoftware.com/index.cfm?deviceWidth=1920-draft.pdf

Tree Equity Webinar - https://www.linkedin.com/posts/keep-indianapolis-beautiful_were-teaming-up-with-american-forests-for-activity-7166116649740304385-P9a1/

EPA GHG Equivalencies Calculator - Calculations and References
https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

EIA Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings
https://www3.epa.gov/climatechange/Downloads/method-calculating-carbon-sequestration-trees-urban-and-suburban-settings.pdf

| | |
|---|---|
| ***Measure*** | ***Build a supportive ecosystem for sustainable development by aligning building codes, incentives, and public awareness efforts with net-zero goals. Make sustainable design the default through flexible code adoption, energy modeling, community education, and a culture of collaboration. Work with the local municipalities in MA for 100% adoption of the stretch energy code by 2035, and 100% adoption of the specialized opt-in stretch code by 2050. Work with local municipalities in CT to advocate for the adoption of a stretch energy code that reflects the best practices and strategies for new buildings to meet high efficiency standards. Require energy/BEM modeling for large developments (>10,000 sq. ft.) with public disclosure by 2035; emphasize strategies like passive heating/cooling in all constructions; create flexible permitting incentives for passive and net-zero designs via point-based development bonuses. Reduce total building energy demand through behavioral and systems strategies by 15% by 2030 and 40% by 2050. Ensure 100% of lighting sales are high-efficiency by 2030; 100% of new residential appliances are electric by 2035; 100% for commercial appliances by 2045.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***512,032*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***1,354,800*** | ***MTCO2e*** |

Methodology Description: GHG reductions were quantified based on the reduction of residential and commercial fuel oil, natural gas, and propane usage assuming a 15% reduction in fuel usage in 2030 and a 40% reduction in fuel usage in 2050. The avoided emissions from the elimination of fossil fuels in new home construction is also included, assuming 19,628 homes are built by 2030 and 47,107 homes are built by 2050 based on projected population growth.

**Energy Reduction GHG Emissions Reduction**

| | | | |
|---|---|---|---|
| [value] | **Total Natural Gas for Residential and Commercial** | | |
| | 276,958,079 | (therms) | *Source: 2022 GHG Inventory* |
| | | | *Excludes municipal and industrial usage* |
| [input] | **Total Fuel Oil for Residential and Commercial** | | |
| | 16,076,830 | (MMBTU) | *Source: 2022 GHG Inventory* |
| | | | *Excludes municipal and industrial usage* |
| [input] | **Percent to Reduce Natural Gas** | | |
| 2030 | 15% | | |
| 2040 | 30% | | |
| 2050 | 40% | | |
| [input] | **Percent to Reduce Fuel Oil** | | |
| 2030 | 15% | | |
| 2040 | 30% | | |
| 2050 | 40% | | |
| [calc] | **Natural Gas Reduction** | | |
| 2030 | 41,543,712 | (therms) | |
| 2040 | 83,087,424 | (therms) | |
| 2050 | 110,783,232 | (therms) | |
| [calc] | **Fuel Oil Reduction** | | |
| 2030 | 2,411,525 | (MMBTU) | |
| 2040 | 4,823,049 | (MMBTU) | |
| 2050 | 6,430,732 | (MMBTU) | |
| | **Emissions Factor for Natural Gas** | | |
| [value] | 0.0053047 | (MTCO2/therm) | |

| | | | |
|---|---|---|---|
| [calc] | **Total Emission Reductions for Natural Gas** | | |
| 2030 | 220,378 | (MTCO2e) | |
| 2040 | 440,757 | (MTCO2e) | |
| 2050 | 587,675 | (MTCO2e) | |
| | **Emission Factor for Fuel Oil** | | |
| [value] | 0.074203 | (MTCO2e/MMBTU) | |
| [calc] | **Total Emission Reductions for Fuel Oil** | | |
| 2030 | 178,942 | (MTCO2e) | |
| 2040 | 357,885 | (MTCO2e) | |
| 2050 | 477,180 | (MTCO2e) | |
| | **Residential and Commercial Propane Usage** | | |
| [value] | 7,699,279 | (MMBTU) | |
| | | | *Source: 2022 CMRPC GHG Inventory* |
| | | | *Excludes municipal usage* |
| [input] | **Propane Percent Reduction** | | |
| 2030 | 15% | (%) | |
| 2040 | 30% | (%) | |
| 2050 | 40% | (%) | |
| [calc] | **Propane Precent Reduction** | | |
| 2030 | 1,154,892 | (MMBTU) | |
| 2040 | 2,309,784 | (MMBTU) | |
| 2050 | 3,079,712 | (MMBTU) | |
| | **Propane Emissions Factor** | | |
| [calc] | 0.063113 | (MTCO2e/MMBTU) | |
| [calc] | **Propane Emissions Reductions** | | |
| 2030 | 72,889 | (MTCO2e) | |
| 2040 | 145,777 | (MTCO2e) | |
| 2050 | 194,370 | (MTCO2e) | |
| [FINAL] | **Total Emissions Reduction** | | |
| 2030 | 472,209 | (MTCO2e) | |
| 2040 | 944,419 | (MTCO2e) | |
| 2050 | 1,259,225 | (MTCO2e) | |

**Building Code GHG Reduction**

| | | | |
|---|---|---|---|
| [value] | **Energy requirement of an average home in New England that meets the current MA stretch codes (HERS 42)** | | |
| Elec | 15 | [MMBtu/house] | Source: Example From MA Updated Residential Stretch Code Summary https://neep.org/sites/default/files/media- |
| NG | 35 | [MMBtu/house] | |
| Propane | 29 | [MMBtu/house] | |
| Fuel Oil | 44 | [MMBtu/house] | |
| Total | 124 | [MMBtu/house] | |
| [input] | **All Electric Home Electricity Usage** | | |
| | 50 | [MMBTU/house] | *Assumption* |
| [value] | **Additional number of households** | | |
| 2030 | 19,628 | (households) | *Source: CMRPC Population estimates growth scaled to entire MSA, 2.5 people per household from Census Data S1101 Worcester County Households and Families Dataset* |
| 2050 | 47,107 | (households) | |
| [calc] | **Percentage of Fuel Source Used for Homes in the MSA Baseline** | | |
| Electric | 21% | | |
| NG | 34% | | *Source: ACS Table B25117 Tenure By* |

| | | |
|---|---|---|
| Propane | 7% | *House Heating Fuel - Worcester County* |
| Oil | 39% | |

| | | | |
|---|---|---|---|
| [value] | | | *Source: 2022 GHG Inventory (EPA Emissions Factor Hub)* |
| | **Emission Factors** | | |
| NG | 0.0531148 | (MTCO2e/MMBtu) | |
| Propane | 0.0631238 | (MTCO2e/MMBtu) | |
| Oil | 0.0742138 | (MTCO2e/MMBtu) | |

| | | |
|---|---|---|
| [calc] | **Estimated Annual 2030 Emissions Savings from New Home Construction** | |
| NG | 12,491 | (MTCO2e) |
| Propane | 2,136 | (MTCO2e) |
| Oil | 25,196 | (MTCO2e) |

| | | |
|---|---|---|
| [calc] | **Estimated Annual 2050 Emissions Savings from New Home Construction** | |
| NG | 29,977 | (MTCO2e) |
| Propane | 5,127 | (MTCO2e) |
| Oil | 60,471 | (MTCO2e) |

| | | |
|---|---|---|
| | **Annual GHG emissions reduced in 2030** | |
| [FINAL] | 39,823 | (MTCO2e) |

| | | |
|---|---|---|
| | **Annual GHG emissions reduced in 2050** | |
| [FINAL] | 95,576 | (MTCO2e) |

**Total GHG Reductions**

| | | |
|---|---|---|
| [FINAL] | **Total GHG Reductions** | |
| 2030 | 512,032 | (MTCO2e) |
| 2050 | 1,354,800 | (MTCO2e) |

**Co-Pollutants**

Co-pollutant emissions reductions account for the reduction in natural gas and fuel oil due to electrification using emissions factors for NOx and SO2. The avoided co-pollutants from new construction homes without fossil fuels are also included.

| | | | |
|---|---|---|---|
| [value] | **Emission Factors for Natural Gas Co-Pollutants** | | |
| NG ($NO_x^2$) | 94 | (lbs/Mmcf) | *Source: NESCAUM Estimating the* |
| NG ($SO_2$) | 0.6 | (lbs/Mmcf) | *for Residential Heating Table 2* |

| | | |
|---|---|---|
| [value] | **Emission Factors for Fuel Oil Co-Pollutants** | |
| FO ($NO_x^2$) | 0.11 | (lbs/MMBtu) |
| FO ($SO_2$) | 0.042 | (lbs/gallon) |

| | | |
|---|---|---|
| [calc] | **Fuel Usage Reduction - Existing Energy Reduction** | |
| 2030 NG | 41,543,712 | (therms) |
| 2030 FO | 2,411,525 | (MMBtu) |
| 2050 NG | 110,783,232 | (therms) |
| 2050 FO | 6,430,732 | (MMBtu) |

| | | |
|---|---|---|
| [calc] | **Avoided Fuel Usage - New Construction** | |
| 2030 NG | 235,161 | (MMBtu) |
| 2030 FO | 339,510 | (MMBtu) |
| 2050 NG | 564,385 | (MMBtu) |
| 2050 FO | 814,823 | (MMBtu) |

| | | |
|---|---|---|
| | **Combined Fuel Reduction** | |
| 2030 NG | 43,895,317 | |
| 2030 FO | 2,751,034 | |
| 2050 NG | 116,427,084 | |
| 2050 FO | 7,245,555 | |

| | | |
|---|---|---|
| [value] | **Conversion and Co-pollutant calculations 2030** | |
| | 0.0001 | Therms to Mmcf conversion |
| | 4,389.53 | (Mmcf) |

| | | |
|---|---|---|
| | 2,205 | Lbs/Metric Ton conversion |
| NG ($NO_x^2$) | 187.1 | (MT Co-Pollutants) |
| NG (SO ) | 1.2 | (MT Co-Pollutants) |
| FO ($NO_x^2$) | 120.3 | (MT Co-Pollutants) |
| FO (SO ) | 45.9 | (MT Co-Pollutants) |

[value] **Conversion and Co-pollutant calculations 2050**

| | | |
|---|---|---|
| | 0.0001 | Therms to Mmcf conversion |
| | 11,643 | (Mmcf) |
| NG ($NO_x^2$) | 496.3 | (MT Co-Pollutants) |
| NG (SO ) | 3.2 | (MT Co-Pollutants) |
| FO ($NO_x^2$) | 320.8 | (MT Co-Pollutants) |
| FO (SO ) | 122.5 | (MT Co-Pollutants) |

**[FINAL] Total Co-Pollutants**

| | | |
|---|---|---|
| 2030 | 355 | (MT Co-Pollutants) |
| 2050 | 943 | (MT Co-Pollutants) |

| | |
|---|---|
| ***Measure I1.*** | ***Develop and implement a mandatory greenhouse gas emissions reporting and reduction framework for large industrial facilities in the Worcester-CT MSA to support net-zero emissions by 2050. In MA, expand the Large Building Energy Reporting (LBER) policy to mandate reporting energy usage data for buildings greater than 18,000 sq ft. by 2030 and buildings greater than 15,000 sq ft. by 2035. In CT, create and adopt a comparable LBER program to mandate the reporting of energy usage data for buildings greater than 20,000 sq ft. by 2030, buildings greater than 18,000 sq ft. by 2035, and buildings greater than 15,000 sq ft. by 2040. Pilot a voluntary program that requires the submission and implementation of decarbonization for large buildings (greater than 15,000 sq ft.) by 2040 and mandate this program by 2050.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***1,209*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2040*** | ***2,822*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***3,225*** | ***MTCO2e*** |

Given limited direct emissions reductions associated with reporting, it was assumed that 10% of the industrial fossil fuel use reduction quantified in the other industrial measure could be allocated to this measure as it is likely that reporting would lead to action.

| | | |
|---|---|---|
| | **GHG Reductions** | |
| [value] | **Measure I3. Total MTCO2e Emission Reductions from Industrial Decarbonization** | |
| 2030 | 12,095 | (MTCO2e) |
| 2040 | 28,221 | (MTCO2e) |
| 2050 | 32,252 | (MTCO2e) |
| | | |
| [input] | **Percent of industrial building emissions reduction to allocate to reporting** | |
| | 10% | (percent) |
| | | |
| [FINAL | **Emissions reductions from reporting leading to implementation** | |
| 2030 | 1,209 | (MTCO2e) |
| 2040 | 2,822 | (MTCO2e) |
| 2050 | 3,225 | (MTCO2e) |
| | Co-Pollutant Reductions | |
| [input] | **Measure I3. Total Co-Pollutants from Industrial Decarbonization** | |
| 2030 | 11 | (MT Co-Pollutants) |
| 2050 | 29 | (MT Co-Pollutants) |
| | | |
| [FINAL | **Co-pollutant reductions from reporting leading to implementation** | |
| 2030 | 1 | (MTCO2e) |
| 2050 | 3 | (MTCO2e) |

| | |
|---|---|
| ***Measure I3.*** | ***Accelerate the transition of industrial facilities to low-carbon energy systems, focusing on electrification, energy efficiency, and zero-emission mobility. Utilizing rebates for electric heat pump installations, smart controls, and occupancy-based heating/cooling/lighting, electrify 60% of large industrial facilities (greater than 15,000 sq ft.), and reduce energy usage by 35% by 2040. Require electric vehicle charging infrastructure in all new industrial facilities greater than 20,000 sq ft. starting in 2030, and 15,000 sq ft. starting in 2035. Electrify industrial fleets to the extent possible, and promote idle-reduction retrofits and low-carbon fuels where full electrification isn't yet feasible. Electrify or utilize alternative fuel in 50% industrial light-duty vehicles and 15% medium-duty vehicles by 2040, aiming for 100% electrification/alternative fuels of industrial light-duty vehicles and 30% medium-duty vehicles by 2050.*** |

| | | |
|---|---|---|
| ***Annual GHG emissions reduced in 2030*** | ***12,095*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2040*** | ***28,221*** | ***MTCO2e*** |
| ***Annual GHG emissions reduced in 2050*** | ***32,252*** | ***MTCO2e*** |

Methodology Description: Emissions reductions have been calculated based on a reduction in natural gas and fuel oil use at industrial facilities. It was assumed that a 15% reduction would occur by 2030 and a 40% reduction would occur by 2050.

**Industrial Reductions in Natural Gas and Fuel Oil Calculations**

[input] **Reduction in fuel usage by 2030**
15% (%) *Assumption*

[input] **Reduction in fuel usage by 2040**
35% (%) *Assumption*

[input] **Reduction in fuel usage by 2050**
40% (%) *Assumption*

[value] **Total annual fuel oil usage for industrial**
139,626 (MMBtu) *Source: CMRPC GHG inventory 2022*

[calc] **Fuel oil reduced by 2030**
20,944 (MMBtu)

[calc] **Fuel oil reduced by 2040**
48,869 (MMBtu)

[calc] **Fuel oil reduced by 2050**
55,850 (MMBtu)

[value] **Emission Factor - Fuel Oil**
0.0742 (MTCO2e/MMBTU)

[calc] **Emissions from fuel oil reduced by 2030**
1,554 (MTCO2e)

[calc] **Emissions from fuel oil reduced by 2040**
3,626 (MTCO2e)

[calc] **Emissions from fuel oil reduced by 2050**
4,144 (MTCO2e)

[input] **Percentage of Industrial Fuel Oil of Total Fuel Oil (C/I and Municipal)**
7.32% (%) *Source: CMRPC GHG Inventory 2022*

[value] **2022 Total Natural Gas from C&I and Total Natural Gas T&D Losses from C&I**
198,848,513 (Consumption therms)
4,971,213 (T&D Losses therms)

[calc] **Estimated Therms of Natural Gas for Industrial**
14,555,711 (Consumption therms)
363,893 (T&D Losses therms)

*Assumes same ratio of industrial to other uses as fuel oil. Natural gas source data does not differentiate commercial, industrial, and municipal.*

[calc] **Natural Gas reduced by 2030**
2,183,357 (Consumption therms)
54,584 (T&D Losses therms)

[calc] **Natural Gas reduced by 2040**
5,094,499 (Consumption therms)
127,362 (T&D Losses therms)

[calc] **Natural Gas reduced by 2050**
5,822,284 (Consumption therms)
145,557 (T&D Losses therms)

[value] **Emission Factor - Natural Gas**
0.0053 (MTCO2e/Therm)

[calc] **Emissions from Natural Gas reduced by 2030**
11,594 (Consumption MTCO2e)
290 (T&D Losses MTCO2e)

[calc] **Emissions from Natural Gas reduced by 2040**
27,054 (Consumption MTCO2e)
676 (T&D Losses MTCO2e)

| | | | |
|---|---|---|---|
| [calc] | **Emissions from Natural Gas reduced by 2050** | | |
| | 30,919 | (Consumption MTCO2e) | |
| | 773 | (T&D Losses MTCO2e) | |
| [calc] | **Annual GHG emissions reduced in 2030** | | |
| | 13,438 | (MTCO2e) | |
| [calc] | **Annual GHG emissions reduced in 2040** | | |
| | 31,356 | (MTCO2e) | |
| [calc] | **Annual GHG emissions reduced in 2050** | | |
| | 35,836 | (MTCO2e) | |
| [input] | **Allocation to reporting measure** | | |
| | 10% | (percent) | |
| [FINAL] | **Annual GHG emissions reductionsafter subtracting other measure** | | |
| 2030 | 12,095 | (MTCO2e) | |
| 2040 | 28,221 | (MTCO2e) | |
| 2050 | 32,252 | (MTCO2e) | |

| **Co-Pollutants** |
|---|
| Co-pollutant emissions reductions account for the reduction in natural gas and fuel oil due to electrification using emissions factors for NOx and SO2. |

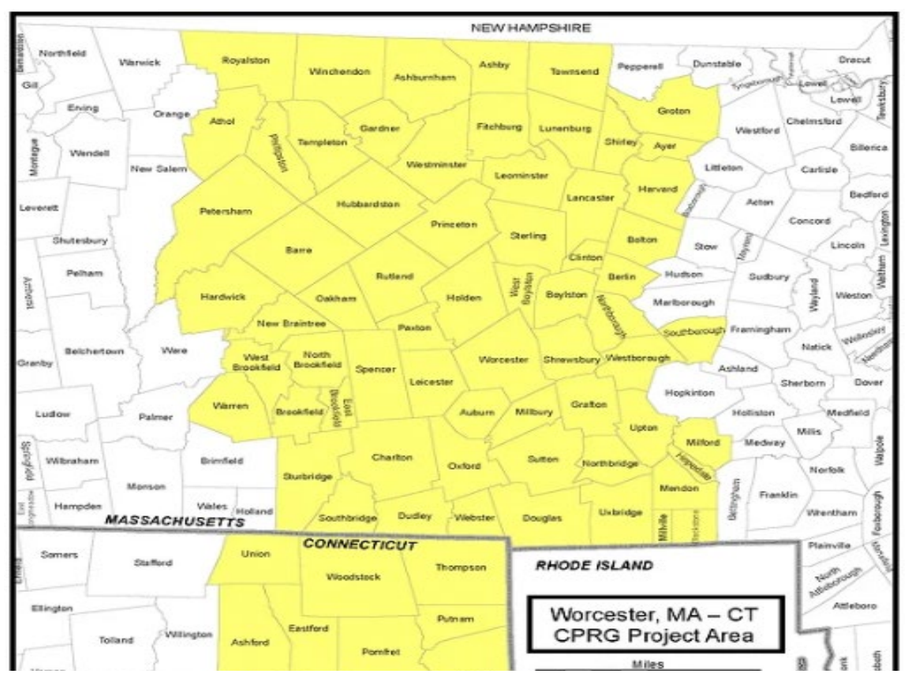
| | | | |
|---|---|---|---|
| [value] | **Emission Factors for Natural Gas Co-Pollutants** | | |
| NG ($NO_x^2$) | 94 | (lbs/Mmcf) | *Source: NESCAUM Estimating the Emissions* |
| NG (SO ) | 0.6 | (lbs/Mmcf) | *Benefits of Switching to Heat Pumps* |
| [value] | **Emission Factors for Fuel Oil Co-Pollutants** | | |
| FO ($NO_x^2$) | 0.11 | (lbs/MMBtu) | |
| FO (SO ) | 0.042 | (lbs/gallon) | |
| [calc] | **Fuel Usage Reduction** | | *Converted* |
| 2030 NG | 2,183,357 | (therms) | 218.34 (Mmcf) |
| 2030 FO | 20,944 | (MMBtu) | |
| 2050 NG | 5,822,284 | (therms) | 582 (Mmcf) |
| 2050 FO | 55,850 | (MMBtu) | |
| [value] | **Conversions** | | |
| | 0.0001 | Therms to Mmcf conversion | |
| | 2,205 | Lbs/Metric Ton conversion | |
| [calc] | **Co-pollutant calculations 2030** | | |
| NG ($NO_x^2$) | 9.3 | (MT Co-Pollutants) | |
| NG (SO ) | 0.1 | (MT Co-Pollutants) | |
| FO ($NO_x^2$) | 1.0 | (MT Co-Pollutants) | |
| FO (SO ) | 0.4 | (MT Co-Pollutants) | |

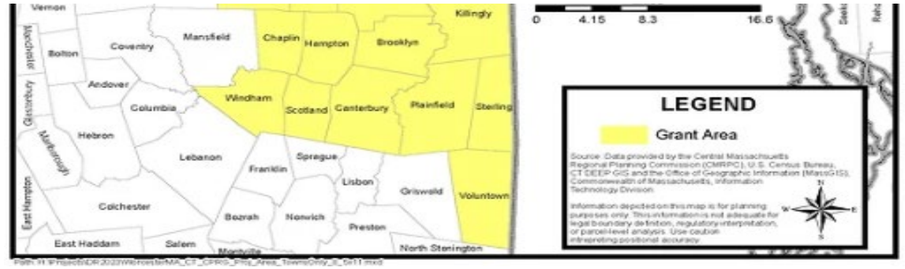
| | | |
|---|---|---|
| [value] | **Conversion and co-pollutant calculations 2050** | |
| NG ($NO_x^2$) | 24.8 | (MT Co-Pollutants) |
| NG ($SO$ ) | 0.2 | (MT Co-Pollutants) |
| FO ($NO_x^2$) | 2.8 | (MT Co-Pollutants) |
| FO ($SO$ ) | 1.1 | (MT Co-Pollutants) |
| | | |
| [calc] | **Total co-Pollutants** | |
| 2030 | 10.8 | (MT Co-Pollutants) |
| 2050 | 28.8 | (MT Co-Pollutants) |
| | | |
| [input] | **Allocation to reporting measure** | |
| | 10% | (percent) |
| | | |
| [FINAL] | **Total co-pollutants after subtracting other measure** | |
| 2030 | 10 | (MT Co-Pollutants) |
| 2050 | 26 | (MT Co-Pollutants) |

# Greater Worcester Business-As-Usual Emissions Scenario

The Business-As-Usual (BAU) scenario and estimated historic emissions through 1990 are calculated within this spreadsheet as part of the Climate Pollution Reduction Grant (CPRG) program funded by the Environmental Protection Agency (EPA). These estimates use the regional GHG emissions inventory for 2022 which includes 80 communities across Massachusetts and Connecticut that were included in the Metropolitan Statistical Area (MSA), as mapped below.

The methodology for the BAU is aligned with the approach used by the MA Office of Climate Innovation and Resilience for the statewide CCAP. Statewide estimated emissions by sector for 2030, 2040, and 2050 were sourced from the draft memo titled, *Massachusetts Decarbonization Greenhouse Gas Methodology Memo Task 4 and Task 16 Deliverable* (05/05/2025) developed by AECOM (Table 3). These values were scaled to the Greater Boston region using the Energy Policy Simulator (EPS) Adjusted 2021 GHG Inventory, included in Table 1 of the memo.




Vernon
Killingly
Mansfield
Chaplin
Hampton
Brooklyn
Coventry
Bolton
Andover
Windham
Scotland
Canterbury
Plainfield
Sterling
Columbia
Hebron
Lebanon
Franklin
Sprague
Lisbon
Griswold
Voluntown
Colchester
Bozrah
Norwich
Preston
East Haddam
Salem
North Stonington
Lebanon
Canterbury
Marlborough
East Hampton
0
4.15
8.3
16.6
LEGEND
Grant Area
Source: Data provided by the Central Massachusetts Regional Planning Commission (CMRPC), U.S. Census Bureau, CT DEEP GIS and the Office of Geographic Information (MassGIS), Commonwealth of Massachusetts, Information Technology Division.
Information depicted on this map is for planning purposes only. This information is not adequate for legal boundary definition, regulatory interpretation, or parcel-level analysis. Use caution interpreting positional accuracy.
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S

**MA DEP GHG Inventory Data**
(see hidden sheet called "Data Extraction Data")

| Year | Total | Residential Stationary | C&I Stationary | Electric Power | Electric T&D | Natural Gas System (Leaks) | Transportation | Solid Waste | Wastewater | Agriculture & Land Use |
|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 60.3 | 8.110 | 13.860 | 20.360 | 0.372 | 1.660 | 30.000 | 0.000 | 0.000 | 0.000 |
| 1981 | 60.0 | 10.610 | 13.770 | 20.160 | 0.372 | 1.660 | 29.600 | 0.000 | 0.000 | 0.000 |
| 1982 | 60.2 | 9.637 | 13.560 | 21.200 | 0.372 | 1.620 | 27.800 | 0.000 | 0.000 | 0.000 |
| 1983 | 58.7 | 10.180 | 12.970 | 20.400 | 0.372 | 1.580 | 26.600 | 0.000 | 0.000 | 0.000 |
| 1984 | 60.8 | 10.720 | 13.420 | 22.900 | 0.372 | 1.580 | 27.000 | 0.000 | 0.000 | 0.000 |
| 1985 | 60.4 | 13.090 | 12.860 | 21.600 | 0.337 | 1.580 | 26.700 | 0.000 | 0.000 | 0.000 |
| 1986 | 57.3 | 14.760 | 12.600 | 23.070 | 0.408 | 1.580 | 26.900 | 0.000 | 0.000 | 0.000 |
| 1987 | 58.4 | 14.180 | 12.600 | 23.400 | 0.408 | 1.580 | 27.200 | 0.000 | 0.000 | 0.000 |
| 1988 | 58.8 | 13.000 | 12.900 | 24.300 | 0.408 | 1.580 | 26.300 | 0.000 | 0.000 | 0.000 |
| 1989 | 60.8 | 14.180 | 13.470 | 25.670 | 0.408 | 1.470 | 26.700 | 0.000 | 0.000 | 0.000 |
| 1990 | 60.2 | 14.180 | 13.470 | 25.670 | 0.408 | 1.470 | 26.100 | 0.000 | 0.000 | 0.000 |
| 1991 | 59.2 | 12.180 | 13.470 | 24.770 | 0.408 | 1.360 | 27.400 | 0.000 | 0.000 | 0.000 |
| 1992 | 60.2 | 16.180 | 12.220 | 25.200 | 0.408 | 1.360 | 27.200 | 0.000 | 0.000 | 0.000 |
| 1993 | 58.8 | 16.180 | 12.220 | 25.200 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 1994 | 60.2 | 16.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 1995 | 60.2 | 16.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 1996 | 60.2 | 16.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 1997 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 1998 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 1999 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2000 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2001 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2002 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2003 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2004 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2005 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2006 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2007 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2008 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2009 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2010 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2011 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2012 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2013 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2014 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2015 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2016 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2017 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2018 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2019 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2020 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2021 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2022 | 60.4 | 15.180 | 12.220 | 26.100 | 0.408 | 1.360 | 25.400 | 0.000 | 0.000 | 0.000 |
| 2023 | | | | | | | | | | |
| 2024 | | | | | | | | | | |
| 2025 | | | | | | | | | | |
| 2026 | | | | | | | | | | |
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| 2045 | | | | | | | | | | |
| 2046 | | | | | | | | | | |
| 2047 | | | | | | | | | | |
| 2048 | | | | | | | | | | |
| 2049 | | | | | | | | | | |
| 2050 | | | | | | | | | | |

**MA DEP Inventory Sectors/Sources Organized**
(combined multiple sources into a single source for Electric and Waste)

| Gross Total | Residential Stationary | C&I Stationary | Electric Power | Natural Gas Distribution | Transportation | Waste | Agriculture |
|---|---|---|---|---|---|---|---|
| 60.3 | 8.110 | 13.860 | 20.760 | 1.660 | 30.100 | 0.000 | 0.000 |
| 60.0 | 10.610 | 13.770 | 20.160 | 1.660 | 29.600 | 0.000 | 0.000 |
| 60.2 | 9.637 | 13.560 | 21.200 | 1.620 | 27.800 | 0.000 | 0.000 |
| 58.7 | 10.180 | 12.970 | 20.400 | 1.580 | 26.600 | 0.000 | 0.000 |
| 60.8 | 10.720 | 13.420 | 22.900 | 1.580 | 27.000 | 0.000 | 0.000 |
| 60.4 | 13.090 | 12.860 | 21.936 | 1.580 | 26.700 | 0.000 | 0.000 |
| 57.3 | 14.760 | 12.600 | 23.478 | 1.580 | 26.900 | 0.000 | 0.000 |
| 58.4 | 14.180 | 12.600 | 23.808 | 1.580 | 27.200 | 0.000 | 0.000 |
| 58.8 | 13.000 | 12.900 | 24.708 | 1.470 | 26.300 | 0.000 | 0.000 |
| 60.8 | 14.180 | 13.470 | 26.070 | 1.470 | 26.700 | 0.000 | 0.000 |
| 60.2 | 14.180 | 13.470 | 26.070 | 1.360 | 26.100 | 0.000 | 0.000 |
| 59.2 | 12.180 | 13.470 | 25.178 | 1.360 | 27.400 | 0.000 | 0.000 |
| 60.2 | 16.180 | 12.220 | 25.608 | 1.360 | 27.200 | 0.000 | 0.000 |
| 58.8 | 16.180 | 12.220 | 25.608 | 1.360 | 25.400 | 0.000 | 0.000 |
| 60.2 | 16.180 | 12.220 | 26.508 | 1.360 | 25.400 | 0.000 | 0.000 |
| 60.2 | 16.180 | 12.220 | 26.508 | 1.360 | 25.400 | 0.000 | 0.000 |
| 60.2 | 16.180 | 12.220 | 26.508 | 1.360 | 25.400 | 0.000 | 0.000 |
| 60.4 | 15

# Measure Quantification as of 12/01/25

**Transportation:**

**Measure: T1 Bicycle and Pedestrian Improvements**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 133,323 MTCO2e | 266,646 MTCO2e |
| Co-Pollutants | 15,967 MT Co-Pollutants | 19,937 MT Co-Pollutants |

Data from the Greater Worcester Regional GHG Inventory for 2022 was used to calculate a reduction in vehicle miles traveled (VMT) of passenger gasoline vehicles that could be associated with the elements described in the measure. It was assumed that VMT would be reduced by 5% by 2030 and 10% by 2050.

The Federal Highway Administration CMAQ Emissions Calculator Bicycle, Pedestrian, and Micromobility Emissions Tool was used to quantify co pollutants in relation to a reduction in VMT. A 2 to 1 ratio was input into the calculator and the year was set to 2030 to obtain the total kg/day/trip co-pollutants reduction. The co-pollutants reduction output is applied to the number of trips allocated to walking and biking as part of the vehicle trips reduced. The same was done for 2050 but the year is set to 2040 in place of 2050 because that is the furthest year the tool is able to evaluate.

**Cost:**

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $27,699,794 | $115,766,369 |

Cost estimates for this measure include the development of shared use paths and bike share programs. The Shared Use Path Design Guide Cost Estimator available from MA EEA was used to determine an example cost for a shared use path. A value of approximately $2.5 million per mile of path was used, with assumptions that 10 miles and 20 miles of path would be developed by 2030 and 2050, respectively. The costs for bike share programs were derived from recent examples within Massachusetts, including the Minuteman, ValleyBike, and Newburyport bike share programs. The three-year program costs range from $187,450 to $2.3 million, representing a variety of programs including those for a single community and up to as many as ten communities, and programs with

regular bikes and e-bikes. It was assumed that by 2030 three small scale and one large scale bike share programs would be established and by 2050, 12 small scale and 4 large scale programs would be established (in addition to the programs started by 2030).

**Measure: T2 Expand and Improve Public Transit**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 3,155 MTCO2e | 15,829 MTCO2e |
| Co-Pollutants | 3 MT Co-Pollutants | 8 MT Co-Pollutants |

Senior van services are provided both by municipalities and by Regional Transit Authorities (RTAs), therefore, data for electrifying vehicles used in the operations of both were included in the measure quantification. The fuel usage, mileage, and fuel efficiency data for RTA vehicles for demand response was obtained from the Federal Transit Administration 2022 Fuel and Energy Datasets and from previous coordination with RTAs directly (data collected during PCAP). Emissions reductions were calculated assuming a 20% reduction in fuel usage by 2030 and 100% electrification by 2050 for both municipal vehicles and RTA vehicles. To avoid double counting of vans in municipal fleets, the emissions reduction was subtracted from Measures T4 and T5.

The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Electric Vehicles and EV Charging Infrastructure tool was used to quantify the co-pollutants of heavy and light dusty senior vans. The co-pollutants reduction is based on the EV miles traveled by municipal vehicles that were previously gasoline and diesel powered vehicles. The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Non-EV Bus Replacement was used to quantify RTA co-pollutant reductions by applying mileage to be driven by electric buses.

**Cost:**

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $25,785,927 | $274,850,880 |

The cost for electrification of transit buses was calculated using the number of buses in the fleet for three RTAs based on the 2022 Annual Agency Profiles from the Federal Transit Administration. The 2020 study, Financial Analysis of Battery Electric Transit Buses, by the National Renewable Energy Laboratory, provided a cost of $887,308 per battery electric bus and cost of $50,000 for each charger. These values were converted to 2025 dollars

using the US Bureau of Labor Statistics CPI Inflation Calculator. Similarly, cost for electrification of demand response and senior van vehicles were calculated using costs from the EPA CCAP Cost of Measures Resource values of $55,000 per vehicle and $7,500 (2015 dollars) per charger. Costs for all three vehicle types were summed to provide an overall measure cost.

**Measure: T3 Alternative Fuel Charging Infrastructure**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 521,092 MTCO2e | 959,370 MTCO2e |
| Co-Pollutants | 7,956 MT Co-Pollutants | 8,283 MT Co-Pollutants |

GHG reductions associated with electric vehicle charging were quantified by using the Electric Vehicle Infrastructure Coordinating Council Initial Assessment to the General Couty report which identifies the charging demand required to meet the MA 2030 statewide EV adoption goal. This report includes the number of charging ports by type which were scaled down to the MA portion of the MSA by population.

The co-pollutants reduction is based on the number of EV's supported by charging infrastructure and calculated using the Federal Highway Administration CMAQ Emissions Calculator Toolkit for Electric Vehicles and EV Charging Infrastructure.

**Cost:**

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $103,086,000 | $154,629,000 |

The EPA CCAP Cost Estimating Resource identified the cost of a level two charger as $7,500 (2015 dollars). This was converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator and multiplied by the number of charging ports. The number of ports was determined in the GHG reduction calculations for 2030 and 2050 based on statewide projected charging port needs, scaled to the MSA by population.

**Measure: T4 Adoption of Zero-Emission Light-Duty Vehicles**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 3,971 MTCO2e | 22,466 MTCO2e |
| Co-Pollutants | 33 MT Co-Pollutants | 113 MT Co-Pollutants |

The 2022 Greater Worcester Regional GHG Inventory data was used to identify the gasoline usage by municipal vehicles and calculate an emissions reduction associated with electrifying 20% of the fleet vehicles by 2030 and 100% by 2050. The MA DOER Climate Leader Community Program identified 20% by 2030 as a fleet electrification target for MA municipalities, this was also applied to CT fleet vehicles. The increase in electricity associated with the use of EVs was accounted for in 2030, but in 2050 an electricity emissions factor of zero was used as it was assumed that electricity to charge vehicles will be from renewable sources.

The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Electric Vehicles and EV Charging Infrastructure tool was used to quantify the co-pollutants. The co-pollutants reduction is based on EV miles traveled by municipal vehicles that were previously gasoline powered vehicles.

**Cost:**

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $54,477,429 | $217,909,718 |

The cost for transitioning light duty municipal fleet vehicles to electric was determined by assuming the cost per vehicle was $55,000 (2025 dollars) based on the EPA CCAP Cost of Measures Resource. The number of chargers needed was determined by assuming each port can support two vehicles and each charger has two ports. The cost per charger was assumed to be $7,500 (2015 dollars), also sourced from the EPA, and converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. The cost for vehicle purchasing and chargers were summed to determine the total cost.

**Measure: T5 Adoption of Zero-Emission Medium- and Heavy-Duty Vehicles**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 2,196 MTCO2e | 11,477 MTCO2e |
| Co-Pollutants | 8 MT Co-Pollutants | 22 MT Co-Pollutants |

The 2022 Greater Worcester Regional GHG Inventory data was used to identify the diesel usage by municipal vehicles and calculate an emissions reduction associated with electrification of 20% of the fleet vehicles by 2030 and 75% by 2050. The MA DOER Climate Leader Community Program identified 20% by 2030 as a fleet electrification target for MA

municipalities, this was also applied to CT fleet vehicles. The increase in electricity associated with the use of EVs was accounted for in 2030, but in 2050 an electricity emissions factor of zero was used as it was assumed that electricity to charge vehicles will be from renewable sources.

The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Electric Vehicles and EV Charging Infrastructure tool is used to quantify the co-pollutants. The co-pollutants reduction is based on the EV miles traveled by municipal vehicles that were previously diesel-powered vehicles.

**Cost:**

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $99,051,914 | $272,392,763 |

The cost for transitioning light duty municipal fleet vehicles to electric was determined by assuming the cost per vehicle was $150,000. The number of chargers needed was determined by assuming each port can support two vehicles and each charger has two ports. The cost per charger was assumed to be $7,500 (2015 dollars), sourced from the EPA CCAP Cost of Measures Resource. This value was converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. The cost for vehicle purchasing and chargers were summed to determine the total cost.

**Agriculture and Natural and Working Lands:**

**Measure: ANWL1 Urban Tree**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 3,186 MTCO2e | 23,897 MTCO2e |
| Co-Pollutants | 32 MT Co-Pollutants | 243 MT Co-Pollutants |

Increased carbon sequestration was calculated using National Land Cover 2021 Data for total forest land in square miles for Fitchburg, Gardner, Leominster, Southbridge, Webster, and Worcester in MA, as well as Windham, CT. It was assumed that a 2% increase in forest land area could be achieved by 2030 and a 15% increase in 2050. The carbon sequestration rate of 2.23 MT C per hectare per year from the EPA Local Greenhouse Gas Inventory Tool was used to determine the possible carbon sequestration.

Co-pollutant emissions reductions were quantified using the OurTree tool by iTree for six

municipalities in the Greater Worcester region. It was assumed that co-pollutant reductions would increase by the same percent as the increase in land area, 2% and 15% for 2030 and 2050, respectively.

**Measure: ANWL 2 Protected Forestland**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 16,545 MTCO2e | 66,180 MTCO2e |
| Co-Pollutants | 2 MT Co-Pollutants | 12 MT Co-Pollutants |

The continued carbon sequestration from protecting 300 acres of forestland was calculated using a rate of 2.23 MT C per hectare per year from the EPA Local Greenhouse Gas Inventory Tool.

Co-pollutants were quantified by back calculating a factor for several pollutants from data outputs from the OurTrees tool by iTree.

**Measure: ANWL 3 Resiliency Garden Program**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 1,113 MTCO2e | 5,565 MTCO2e |
| Co-Pollutants | 0.2 MT Co-Pollutants | 0.5 MT Co-Pollutants |

Emissions reductions were estimated for avoided truck transportation of food which is instead produced locally. It was assumed the average trucking distance is 1,400 miles for long distance, based on the Food Carbon Calculator, and the local food is 48 miles.

Co-pollutant reductions associated with the reduced transportation were calculated using the Federal Highway Administration emissions calculator tools.

**Measure: ANWL 4 Municipal Spaces**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 176,763 MTCO2e | 530,290 MTCO2e |
| Co-Pollutants | 195 MT Co-Pollutants | 584 MT Co-Pollutants |

GHG emissions reductions were quantified using a carbon sequestration rate for Miyawaki forests of 33.08 mg C per hectare per year based on a 2025 study and 2.23 MTC per hectare per year from the EPA Local Greenhouse Gas Inventory Tool for other land areas. It was assumed that by 2030 and 2050, 5,000 acres and 15,000 acres of land could be converted, respectively. It was assumed that 70% of the land would be allocated to Miyawaki Forests and 30% to other methods.

Given that limited data is available for Miyawaki forest co-pollutant removals, data from the OurTrees tool by iTree was used to back calculate a factor for several pollutants.

**Measure: ANWL 5 Synthetic Fertilizer**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 3,557 MTCO2e | 12,891 MTCO2e |
| Co-Pollutants | 225 MT Co-Pollutants | 817 MT Co-Pollutants |

GHG reductions associated with fertilizer reduction on 9,000 acres were calculated using data from the 2022 GHG Inventory sources including the National Land Cover Database and MA and CT statewide GHG inventories.

Co-pollutant reductions were quantified by assuming 24% and 85% reductions in cropland for 2030 and 2050, respectively. Percent reductions were applied to the EPA National Emissions Inventory data for ammonia associated with agricultural fertilizer applications.

**Buildings:**

**Measure: CRB1. VMT Reduction**

| **Emissions Reductions** | **2030** | **2050** |
|---|---|---|
| GHG | 16,607 MTCO2e | 32,168 MTCO2e |
| Co-Pollutants | 3,921 MT Co-Pollutants | 4,732 MT Co-Pollutants |

GHG emissions reductions were quantified using the gasoline passenger vehicle miles traveled from the 2022 GHG inventory for the largest 25 communities by population as the 2030 implementation and also including the next largest 24 communities in the total VMT for 2050. An average fuel efficiency of 22.6 miles per gallon was used (from 2022 GHG Inventory) to calculate the gasoline savings.

The Federal Highway Administration CMAQ Emissions Calculator Toolkit for Bicycle, Pedestrian, and Shred Micromobility was used to determine co-pollutant emissions reductions from replacing a portion of the VMT reduction trips with walking and biking trips.

**Measure CRB2. Weatherize and Electrify**

| **Emissions Reductions** | **2030** | **2050** |
|---|---|---|

| | | |
|---|---|---|
| GHG | 22,497 MTCO2e | 64,275 MTCO2e |
| Co-Pollutants | 19 MT Co-Pollutants | 53 MT Co-Pollutants |

GHG reductions were calculated by assuming municipal natural gas and heating oil usage (data from Mass Energy Insight for 2022) would decrease by 35%, 60%, 100% by 2030, 2040, and 2050, in alignment with the Climate Leader Community Decarbonization Roadmap Guidance. Any increase in electricity usage would be from renewable sources.

Co-pollutant emissions reductions account for the reduction in natural gas and fuel oil due to electrification using emissions factors for NOx and SO2.

**Measure CRB3. Circular Construction**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 588 MTCO2e | 2,939 MTCO2e |
| Co-Pollutants | 13 MT Co-Pollutants | 63 MT Co-Pollutants |

GHG reductions were quantified by allocating a portion of the C&D waste reduction to this measure based on the MassDEP Waste Characterization Study and 2022 GHG Inventory. It was assumed by 2030, 10% of waste could be diverted and 50% by 2050.

The EPA LandGEM emission factors for HAPs and CAPs in relation to landfill emissions were used to quantify this measure. The emissions factor was applied to the total reduced waste from landfills.

**Measure CRB4. Sustainable Materials**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 2,322 MTCO2e | 9,288 MTCO2e |
| Co-Pollutants | 47 MT Co-Pollutants | 114 MT Co-Pollutants |

Emissions avoided from future building material selection were calculated using the Care Tool which is managed by Architecture 2030, a non-profit focusing on reducing emission in the build environment. This tool provides the embodied carbon of different material types in kg/CO2e/sf of floor area. This was applied to an estimated square footage of a newly developed building to determine the difference in selecting a wood framed building over steel and concrete and calculated for 25 buildings in 2030 and 100 buildings in 2050, as one example of how material selection can reduce embodied carbon emissions.

In addition to material type, sourcing locations also have an impact on emissions. As an example, co-pollutant emissions reduction from reduced transportation distance of materials have been quantified. The calculation assumes a savings of 600 miles per trip and two trips of materials per building.

**Measure CRB5. Building Codes**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 512,032 MTCO2e | 1,354,800 MTCO2e |
| Co-Pollutants | 355 MT Co-Pollutants | 943 MT Co-Pollutants |

GHG reductions were quantified based on the reduction of residential and commercial fuel oil, natural gas, and propane usage assuming a 15% reduction in fuel usage in 2030 and a 40% reduction in fuel usage in 2050. The avoided emissions from the elimination of fossil fuels in new home construction is also included, assuming 19,628 homes are built by 2030 and 47,107 homes are built by 2050 based on projected population growth.

Co-pollutant emissions reductions account for the reduction in natural gas and fuel oil due to electrification using emissions factors for NOx and SO2. The avoided co-pollutants from new construction homes without fossil fuels are also included.

**Waste**:

**Measure: WMM1 Organics Waste Diversion**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 286 MTCO2e | 5,440 MTCO2e |
| Co-Pollutants | 19 MT Co-Pollutants | 358 MT Co-Pollutants |

The estimated quantity of organic waste generated in the MSA and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. A percentage of this organic waste was assumed to be diverted in 2030 and 2050 to composting and anaerobic digestion. The emissions associated with composting are subtracted from the total emissions reduction and anaerobic digestion was assumed to have a methane capture rate of 100% and therefore no emissions associated with the process.

The EPA LandGEM emission factors for HAPs and CAPs in relation to landfill emissions was used to quantify this measure. The emissions factor was applied to the total diverted waste from landfills.

**Measure: WMM2 Anerobic Digestion**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 13,537 MTCO2e | 96,704 MTCO2e |
| Co-Pollutants | 8 MT Co-Pollutants | 58 MT Co-Pollutants |

A 1.8% average annual percent increase in net electricity was used to calculate the projected electricity in 2030 and 2050 based on ISO New England data. The share of electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. It was assumed that anaerobic digestion would be the source of 1% and 5% of the MSA's electricity in 2030 and 2050, respectively. Additional electricity reductions are quantified in the respective sector.

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from anaerobic digestion.

**Measure: WMM3 Composition Extended Producer**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 553 MTCO2e | 10,498 MTCO2e |
| Co-Pollutants | 12 MT Co-Pollutants | 225 MT Co-Pollutants |

The estimated quantity of recyclable plastics and papers generated in the MSA and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. A percentage of this was assumed to be diverted in 2030 and 2050.

The EPA LandGEM emission factors for HAPs and CAPs in relation to landfill emissions were used to quantify this measure. The emissions factor was applied to the total diverted waste from landfills.

**Measure: WMM4. Comprehensive Unit Price**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 8,102 MTCO2e | 14,182 MTCO2e |
| Co-Pollutants | 101 MT Co-Pollutants | 304 MT Co-Pollutants |

The population in the MSA which is not already served by a Pay-As-You-Throw/SMART program was estimated and an assumed 0.9 short tons per person per year was used to calculate the estimated baseline waste, aligned with the approach used in the 2022 GHG Inventory. A percent reduction of waste was assumed for 2030 and 2050 for increased participation in PAYT/SMART programs.

The EPA LandGEM emission factors for HAPs and CAPs in relation to landfill emissions were used to quantify this measure. The emissions factor was applied to the total reduced waste from landfills.

**Measure: WMM5 Regional Resource Recovery**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 294 MTCO2e | 5,291 MTCO2e |
| Co-Pollutants | 6 MT Co-Pollutants | 114 MT Co-Pollutants |

The estimated quantity of construction and demolition, electronics, and bulky material waste generated in the MSA and disposed of as municipal solid waste was determined using a MassDEP waste characterization study. A percentage of this was assumed to be diverted in 2030 and 2050.

The EPA LandGEM emission factors for HAPs and CAPs in relation to landfill emissions were used to quantify this measure. The emissions factor was applied to the total diverted waste from landfills.

**INDUSTRY**

**Measure: I1 Large Building Energy Reporting**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 1,209 MTCO2e | 3,225 MTCO2e |
| Co-Pollutants | 1 MT Co-Pollutants | 3 MT Co-Pollutants |

Given limited direct emissions reductions associated with reporting, it was assumed that 10% of the industrial fossil fuel use reduction quantified in the other industrial measure could be allocated to this measure as it is likely that reporting would lead to action.

**Measure: I2 Industrial Waste**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 469 MTCO2e | 2,812 MTCO2e |
| Co-Pollutants | 10 MT Co-Pollutants | 60 MT Co-Pollutants |

Limited data was available to indicate the sources of industrial waste generated in the MSA, therefore, a quantity of waste and a percent reduction were assumed to be associated with industrial activities. The emissions associated with this reduction were calculated, assuming the same ratio of waste landfilled and incinerated in the MSA as used in the 2022 GHG Inventory.

The EPA LandGEM emission factors for HAPs and CAPs in relation to landfill emissions were used to quantify this measure. The emissions factor was applied to the total reduced waste from landfills.

**Measure: I3 Industrial Decarbonization**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 12,095 MTCO2e | 32,252 MTCO2e |
| Co-Pollutants | 10 MT Co-Pollutants | 26 MT Co-Pollutants |

Emissions reductions have been calculated based on a reduction in natural gas and fuel oil use at industrial facilities. It was assumed that a 15% reduction would occur by 2030 and a 40% reduction would occur by 2050. 10% of what was calculated in this measure was allocated to reporting measure, assuming that reporting can lead to the electrification of industrial facilities.

Co-pollutant emissions reductions account for the reduction in natural gas and fuel oil due to electrification using emissions factors for NOx and SO2. 10% of the co-pollutant reductions were also allocated to the other measure.

**ELECTRIC POWER**

**EGU1. Solar Power Generation**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 197,081 MTCO2e | 459,343 MTCO2e |
| Co-Pollutants | 122 MT Co-Pollutants | 290 MT Co-Pollutants |

A 1.8% average annual percent increase in net electricity was used to calculate the projected electricity in 2030 and 2050 based on ISO New England data. The share of electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. In 2030 and 2050, solar was assumed to account for 15% and 25% of the supply, respectively.

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from solar.

**EGU2. Wind Power Generation**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 52,555 MTCO2e | 330,727 MTCO2e |
| Co-Pollutants | 32 MT Co-Pollutants | 209 MT Co-Pollutants |

A 1.8% average annual percent increase in net electricity was used to calculate the projected electricity in 2030 and 2050 based on ISO New England data. The share of electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. In 2030 and 2050, wind was assumed to account for 4% and 18% of the supply, respectively.

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from wind.

**EGU3. Nuclear Power Generation**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 105,110 MTCO2e | 459,343 MTCO2e |
| Co-Pollutants | 65 MT Co-Pollutants | 290 MT Co-Pollutants |

A 1.8% average annual percent increase in net electricity was used to calculate the projected electricity in 2030 and 2050 based on ISO New England data. The share of electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. In 2030 and 2050, nuclear was assumed to account for 8% and 25% of the supply, respectively.

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from nuclear.

**EGU4. Battery Energy Storage Systems**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 13,139 MTCO2e | 91,869 MTCO2e |
| Co-Pollutants | 8 MT Co-Pollutants | 58 MT Co-Pollutants |

A 1.8% average annual percent increase in net electricity was used to calculate the projected electricity in 2030 and 2050 based on ISO New England data. The share of electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. In 2030 and 2050, battery storage was assumed to account for 1% and 5% of the supply, respectively.

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from battery storage.

**EGU5. Hydro-Power Solutions**

| Emissions Reductions | 2030 | 2050 |
|---|---|---|
| GHG | 65,694 MTCO2e | 404,222 MTCO2e |
| Co-Pollutants | 41 MT Co-Pollutants | 255 MT Co-Pollutants |

A 1.8% average annual percent increase in net electricity was used to calculate the projected electricity in 2030 and 2050 based on ISO New England data. The share of

electricity generated by renewable sources based on information from the EIA State Energy Data System for Massachusetts informed the assumptions on the share of electricity from renewable energy for each year. In 2030 and 2050, hydro was assumed to account for 5% and 22% of the supply, respectively.

Co-pollutant emissions factors were sourced from EPA's AVERT tool and applied to the electricity from hydro.

# Implementation Funding Available

## Federal

**Active Transportation Infrastructure Investment Program (ATIIP):** This is a competitive grant program to construct projects to provide safe and connected active transportation facilities in active transportation networks or active transportation spines - https://www.transportation.gov/rural/grant-toolkit/active-transportation-infrastructure-investment-program-atiip

**Alternative Fuel Infrastructure Tax Credit (IRS):** This is a tax credit for qualified locations on or after January 1, 2023, through December 1, 2032. Tax exempt entities, including state and local governments, are eligible to receive this credit in the same amount as businesses - https://afdc.energy.gov/laws/10513

**CFI Discretionary Grant Program:** Created by the Infrastructure and Investment and Jobs Act (IIJA), this programs provides funding in two categories: (1) Community Charging and Alternative Fueling Grants, and (2) Charging and Alternative Fuel Corridor Grants. The IIJA provides $2.5 billion over five years for this program - https://www.fhwa.dot.gov/environment/cfi/

**CMAQ Grant Program:** This program provides flexible funding to State and local governments for transportation projects and programs to help meet requirements of the Clean Air Act. Projects may include the installation of EV charging and the purchase of electric vehicles, among others - https://www.fhwa.dot.gov/environment/air_quality/cmaq/

**EDA Disaster Supplemental Grant Program:** This program provides grant funding for economic recovery projects in areas which have experienced major disaster declarations - FY2025 Disaster Supplemental Grant Program | U.S. Economic Development Administration

**Energy Storage Demonstration and Pilot Grant Program:** This grant program aims to fund three energy storage demonstration projects in the country - Energy Storage Demonstration and Pilot Grant Program | Department of Energy

**Grants for Buses and Bus Facilities Programs (FTA):** This program makes funding available to replace, rehabilitate and purchase buses and related equipment to construct bus-related facilities, including technological changes or innovations to modify low or no emission vehicles or facilities - https://www.transit.dot.gov/bus-program

**Hydroelectric Production Incentive Program:** This program provides incentive payments to qualifying hydroelectric power generation facilities - Section 242: Hydroelectric Production Incentive Program | Department of Energy

**Maintaining and Enhancing Hydroelectricity Incentives:** This program provides incentive funding for capital projects for hydroelectric power facilities - Section 247: Maintaining and Enhancing Hydroelectricity Incentives | Department of Energy

**MMWEC Pooled Loan Program:** This program provides Massachusetts Municipal Wholesale Electric Company members with loans for utility projects, including energy storage and renewable energy projects - Pooled Loan Program – MMWEC

**Small Wind Turbines (Residential) Tax Credit:** This program, which currently expires on January 1, 2026, provides tax credits for residential small wind turbines - Small Wind Turbines (Residential) Tax Credit | ENERGY STAR

**US Department of Energy Wind Energy Technologies Office Funding Opportunities:** These funding opportunities are for research and development of technologies for reducing the cost of and improving the reliability of wind energy - Wind Energy Funding Opportunities | Department of Energy

**US Department of Energy Office of Energy Efficiency and Renewable Energy Funding Opportunities:** These funding opportunities are for research and development efforts that seek to reduce energy costs, prevent financial risks, and maintain and improve the nation's energy system - EERE Funding Opportunities | Department of Energy

**EPA's Technical Assistance to Brownfields (TAB) Communities Program:** Administered by EPA Region 1 in partnership with the University of Connecticut; supports siting on brownfields.

**EPA RE-Powering America's Land Initiative:** Supports renewable energy development on contaminated land.

**Inflation Reduction Act (IRA) Clean Electricity Investment Tax Credit and Clean Electricity Production Tax Credit:** These credits reward projects that meet labor standards and offer additional bonuses for using domestic materials, locating in energy or low-income communities, or delivering economic benefits. Summary of Inflation Reduction Act provisions related to renewable energy | US EPA

**DOE Office of Nuclear Energy's Advanced Reactor Demonstration Program (ARDP):** Supports development and operation of SMRs through cost shared federal awards. Advanced Reactor Demonstration Projects | Department of Energy

**US Department of Energy Generation III+ Small Modular Reactor Program:** Aims to speed up the development process of SMRs in the ARDP program. Supports both first mover teams that build initial plants and fast followers that address the gaps in licensing and design to broaden the adoption of SMRs. Generation III+ Small Modular Reactor Program | Department of Energy

**U.S. Department of Energy Loan Programs Office – Title XVII Clean Energy Financing:** This grant allows the financing of clean energy deployment and clean energy infrastructure redevelopment. Title 17 Energy Financing | Department of Energy

**DOE Grid Deployment Office – Transmission Facilitation Program:** $2.5 billion program to help build out new interregional transmission lines across the country. Supports the development of large-scale new transmission lines and updating existing lines as well. Transmission Facilitation Program | Department of Energy

**Federal Energy Regulatory Commission (FERC) – Incentives for Transmission Projects**: FERC can offer incentive rates and expedited approvals for transmission projects that improve grid reliability and reduce congestion. Transmission Incentives | Federal Energy Regulatory Commission

## State

**Advancing Commonwealth Energy Storage:** This program, which is part of the Massachusetts Energy Storage Initiative, provides funding for energy storage demonstration projects - Advancing Commonwealth Energy Storage (ACES) | MassCEC

**Commonwealth Hydropower:** This program provides grant funding for feasibility studies as well as upgrade and new construction projects for renewable portfolio standard-qualified hydropower facilities in Massachusetts - Commonwealth Hydropower | MassCEC

**Community Transit Grant Program (CTGP):** This program provides funding to help meet the transportation and mobility needs of older adults and people with disabilities. The program offers a fully-accessible EV as an option for applicants interested in fleet electrification - https://www.mass.gov/info-details/electrifying-community-transit-fleets

**Connecticut Energy Storage Solutions Program:** This program, administered by the Connecticut Green Bank and energy distribution companies in the state, provides incentives to homeowners and business owners to install and use energy storage - Energy Storage Solutions Program

**Connecticut EV Charging Program:** This program provides incentives for residential and commercial light-duty EV charging equipment to optimize charging behavior. It supports the state's EV deployment goals, aiming to integrate EVs and related technologies into the electric grid efficiently, maximizing electric system benefits - https://portal.ct.gov/pura/electric/office-of-technical-and-regulatory-analysis/clean-energy-programs/electric-vehicle-charging-program

**Connecticut Hydrogen and Electric Automobile Purchase Rebate (CHEAPR):** This program offers incentives for Connecticut residents who purchase or lease an eligible battery electric, plug-in hybrid, or fuel cell electric vehicle - https://portal.ct.gov/deep/air/mobile-sources/cheapr/cheapr---home

**Eversource Workplace Charging:** This program offers rebates to businsses to help install chargers in places like public parking lots, commercial office buildings and shopping centers. Applicants must also apply for available state and federal funding (i.e., MassEVIP) - https://www.eversource.com/content/business/save-money-energy/clean-energy-options/electric-vehicles/business-ev-charging-rebates

**Massachusetts Green Communities:** The Green Community Designation and Grant Program provides plethora financial and technical support to municipalities to cut municipal energy use and meet criteria established in the Green Communities Act, including the purchase of electric vehicles and the installation of EV charging stations - https://www.mass.gov/guides/becoming-a-designated-green-community

**Massachusetts Statewide Electric Bicycle Incentive Program:** This initiative aims to empower low- and moderate-income residents by making e-bikes more affordable by offering income-based vouchers of up to $1,200. The vouchers can be used towards the purchase of e-bikes, ensuring that more residents can access clean, efficient, and cost-effective transportation options - https://www.massbike.org/introducing_the_massachusetts_statewide_electric_bicycle_incentive_program

**MassCEC Accelerating Clean Transporation for All (ACT4ALL):** This program offers grants for projects addressing alternative clean transportation options, including e-bikes, EV consumer

education, ride-for-hire electricfication and incentives, and more - https://www.masscec.com/program/accelerating-clean-transportation-all-act4all

**MassCEC Fleet Advisor Program:** This program provides technical experitise by providing a technical consultant to businesses and non-profits to help analyze their fleet and come up with an electrification plan that is tailored to their business. It provides free electrification planning, an electrification report, an in-person site assessment, total cost of ownership analysis, a vehicle to market inventory analysis, charging analysis, and next step recommendations - https://www.masscec.com/program/mass-fleet-advisor

**MassCEC Medium- and Heavy-Duty (MHD) Mobile Charging Solutions:** This program provides both technical and financial support for up to four fleets interested in piloting mobile charging solutions. In addition, the program will also provide financial support for fleets interested in procuring MHD EVs. It will focus on fleets located and operating within EJ communities, Gateway Cities, and areas overburdened by air pollution - https://www.masscec.com/masscec-focus/clean-transportation/electric-vehicle-charging-infrastructure/medium-heavy-duty-mobile-charging

**MassCEC Offshore Wind Works Grants and Community of Practice:** These grants provide funding for offshore wind workforce development efforts in Massachusetts - Offshore Wind Works Grants and Community of Practice | MassCEC

**MassCEC School Bus Program:** This program aims to advance school bus fleet electrification by providing planning, technical support, and gap funding to public school districts. The program support electric school bus deployment by leveraging other funding sources, like the EPAs Clean School Bus Program - https://www.masscec.com/school-bus-program-overview

**MassCEC Vehicle to Everything (V2X) Demonstration Projects:** This program seeks residential, commercial, and school district applicants who own or are in the process of purchasing an EV capable of bi-directional charging to participate. It will provide a free bi-directional charger, including equipment and installation, in which the data will be collected and analyzed - https://www.masscec.com/masscec-focus/clean-transportation/electric-vehicle-charging-infrastructure/vehicle-to-everything-demonstration

**MassEVIP DCFC Incentive:** This program helps property owners with publicly accessible parking and educational campuses acquire EV fast charging incentives - https://www.mass.gov/how-to/apply-for-massevip-direct-current-fast-charging-incentives

**MassEVIP Fleets Incentives:** This program helps eligible public entities acquire electric vehicles for their fleets - https://www.mass.gov/how-to/apply-for-massevip-fleets-incentives

**MassEVIP Multi-Unit Dwelling and Campus Charging Incentive:** This program helps owners of multi-unit dwellings and educational campuses acquire EV charging stations - https://www.mass.gov/how-to/apply-for-massevip-multi-unit-dwelling-educational-campus-charging-incentives

**MassEVIP Public Charging Incentive:** This program helps property owners and managers with publicly accessible parking acquire EV charging stations - https://www.mass.gov/how-to/apply-for-massevip-public-access-charging-incentives

**MassEVIP Workplace and Fleets Charging Incentive:** This program helps employers and fleet operators acquire EV charging stations - https://www.mass.gov/how-to/apply-for-massevip-workplace-fleet-charging-incentives

**Municipal Vulnerability Preparedness Action Grant:** This grant program provides funding for projects that advance priority climate adaptation and resilience strategies in Massachusetts communities - MVP Action Grant | Mass.gov

**National Grid Fleet Programs:** This program works to support its customers to electrify their light-duty and medium- and heavy-duty vehicle fleets in a cost-effective, efficient, and sustainable manner - https://www.nationalgridus.com/MA-Business/Commercial-and-Fleet-EV-Programs/Fleet-Programs

**National Grid Multi-Unit Dwelling Programs:** This program helps property owners and developers to install EV charging stations at properties with 5 or more units by providing up to 100% funding of electrical infrastructure costs and additional rebates - https://www.nationalgridus.com/MA-Business/Commercial-and-Fleet-EV-Programs/Multi-Unit-Dwelling-Programs

**National Grid Public/Workplace Programs:** This program funds up to 100% of electrical infrastructure costs associated with installing EV charging stations and provides rebates on equipment costs and networking fees for approved qualifying publicly accessible stations - https://www.nationalgridus.com/MA-Business/Commercial-and-Fleet-EV-Programs/Public/Public-Workplace-Programs

**Peak Demand Management Grant Program:** This grant program provides funding for pilot projects that aim to reduce energy usage in Massachusetts during times of peak demand - Peak Demand Management Grant Program | Mass.gov

**SMART Energy Storage Adder Incentives:** These incentives, which are part of the broader Massachusetts SMART program, are provided for installing energy storage systems alongside solar projects - Solar Massachusetts Renewable Target Incentive Program | Eversource

**Solar Massachusetts Renewable Target (SMART) 3.0:** Provides performance-based incentives for solar energy projects.

**Massachusetts Clean Energy Center (MassCEC) InnovateMass Grant:** Grant that helps to fund renewable energy projects in the middle stage of development. InnovateMass | MassCEC

## Other

**Barr Foundation Clean Energy Grants:** These grants provide funding for renewable energy, energy efficiency, grid modernization, and clean energy knowledge sharing and workforce development across the Northeast USA - Clean Energy - Barr Foundation

**Connecticut Energy Storage Solutions Program:** This program, administered by the Connecticut Green Bank and energy distribution companies in the state, provides incentives to homeowners and business owners to install and use energy storage - Energy Storage Solutions Program

# Cost Estimation Methods

## Waste and Materials Management Sector

### WMM1

According to interviews with the Rhode Island School Recycling Project, the cost to pilot this program in one school district comes to approximately 50,000 dollars. With 86 school districts within Worcester County and 18 School districts in Windham County for a total of 104 districts. These programs can run during normal staff times and as part of the student's education the students take a large role in the physical separation of lunchroom waste.

Once established, the cost of organic waste diversion is broadly speaking cost neutral. There is some small upfront capital costs in the procurement of separate bins and equipment for handling food waste, however removing that waste from the mixed waste stream creates an overall reduction in waste generated, as the act of separating and cleaning food containers and recovering edible food from the waste stream reduces the bulkiness and weight of waste, reducing costs from tipping fees. Additionally, this organic waste can become a valuable feedstock for other processes, as will be detailed in another strategy

***Calculations***

**Cost 1**: $50000.00 x 104 school districts = $5,200,000

**Total Estimated Cost =** $5,200,000

### WMM2

Measuring costs for these retrofits and upgrades is difficult to quantify. It is a commonly cited issue with anaerobic digestion that the capital costs for these upgrades is high and can be cost prohibitive. The cost is variable per facility and also for what systems will be utilized, whether or not land needs to be acquired the extent of the retrofits, as well as what grants are available. An example of costs from a 2014 report analyzing a standalone digester in Millbury Massachusetts found the cost to develop the site was estimated to range from $35M for a site that could take in 10% of the organic waste from within a 30 mile radius of the facility to $85M for 50% of the organic waste from within 30 miles of the facility.[i] This site was not attached to the current WWTP and was located on the town's old WWTP and subsequently incurred additional costs by having to purchase water from the water company and truck in organic waste, among other expenses[ii]. The break-even tipping fee of this facility described in the feasibility study ranged between $140 (for the 10% of regional waste option) to $60 (for the 50% of regional waste options), which at the time of writing in 2013 the market tipping fees for organic waste was in the range of of $30 to $40 per wet ton for pre-

processed waste, making the project economically unfeasible at the time.[iii] However, a full decade later tipping fees have doubled in the Northeast, averaging $83.44 for MSW for landfilling waste, and has increased on average of 5.08% year over year[iv]. This cost is only ever expected to rise, as New England (ME, VT, NH, MA, RI, CT) landfill capacity is projected to decrease 82% by 2050[v]. Subsequently throughout the lifespan of this plan the economic feasibility of AD will increase dramatically as the landfills reach their capacity.

[i] Inc, CDM Smith. "Town of Millbury, Massachusetts Organics to Energy Feasibility Study." Completed Organics-to-Energy Studies, September 2013. https://www.masscec.com/sites/default/files/documents/Millbury%20Feasibility%20Study%2C%202013.pdf. (page: 3-25)
[ii] Inc, CDM Smith. "Town of Millbury, Massachusetts Organics to Energy Feasibility Study." Completed Organics-to-Energy Studies, September 2013. https://www.masscec.com/sites/default/files/documents/Millbury%20Feasibility%20Study%2C%202013.pdf. (page: 3-25)
[iii] Inc, CDM Smith. "Town of Millbury, Massachusetts Organics to Energy Feasibility Study." Completed Organics-to-Energy Studies, September 2013. https://www.masscec.com/sites/default/files/documents/Millbury%20Feasibility%20Study%2C%202013.pdf. (page: 3-25)
[iv] Knowlton, Alyssa, Suzie Boxman, and Brian Staley. "Analysis of MSW Landfill Tipping Fees – 2023: EREF." Environmental Research & Education Foundation, June 11, 2024. https://erefdn.org/product/analysis-of-msw-landfill-tipping-fees-2023/. page 10
[v] Inc, WasteZero. "Deep Unit Based Pricing Working Group - Ct.Gov." Unit-Based Pricing (UBP) Working Group, October 15, 2020. https://portal.ct.gov/-/media/DEEP/waste_management_and_disposal/CCSMM/UBP-Working-Group/WZ_Presentation.pdf.

### *Calculations*

**Cost 1**: 20 Anerobic Digestion Facilities at $35M per

**Cost 2**: 20 Anerobic Digestion Facilities at $85M per

**Total Estimated Cost = $700,000,000 - $1,700,000,000**

## WMM3

The costs of implementing these regulations from a legislative perspective is already captured within the general operating budget of the respective state legislations, as that cost can be measured in the hours of staffers and legislators drafting the agenda. Definitionally, EPR legislation is intended to generate revenue to be utilized for the collection and recycling, reuse, recovery, or

disposal of hard to process waste, and so will increase the funding available to municipalities within the MSA to handle waste. According to a report by the Product Stewardship Institute, Connecticut's four EPR programs diverted more than 26 million pounds of material from waste, yielded a cumulative cost savings of more than $2.6 million per year to Connecticut municipalities and industries involved provided recycling services worth another $6.7 million, netting the state a total of 9.3 million dollars in avoided expenses[i].

[i] Cassel, Scott. "Connecticut Extended Producer Responsibility Program Evaluation: Summary and Recommendations." Boston, MA: 29 Stanhope Street, October 21, 2016.

## WMM4

Costs for this measure vary depending on the type of PAYT program being rolled out. For Cart-based programs (where the town provides a cart sized to the resident's waste needs) each cart must be purchased and provided by the town to the residents. Using the example of Windsor Locks Connecticut's PAYT program we can derive some cost estimates for rollout.

*Table 3 Cost Estimates per Cart[i]*

| Cart Size (gal.) | Purchase Cost | Distribution cost |
|---|---|---|
| 24 | $32.00 | $5.00 |
| 32 | $50.00 | $5.00 |
| 64 | $60.00 | $5.00 |
| 94 | $70.00 | $5.00 |

For bag-based PAYT programs the up front are minimal, as the residents purchase the bags from distributors and waste haulers only accept approved bags, allowing for a substantial reduction in up front costs for the municipality.

*Table 4 Cost Estimates per Bag[ii]*

| Bag Size (gal.) | Bag and Bag Distribution Cost | Operational Costs for disposal | Total cost per Bag |
|---|---|---|---|
| 13 | $0.21 | $0.59 | $0.80 |
| 33 | $0.31 | $1.19 | $1.50 |

For both programs there is upgrades to the trucks that is required to ensure compliance. For Windsor Locks this cost was around $5000.00, but will vary based on the number of trucks and software being purchased[iii]. Overall, in Windsor Locks CT the town saw a reduction in expenses for both programs they tried, and a much greater reduction in expenses with the bag program:

*Table 5: Windsor Locks SMART Program Costs and Revenues[iv]*

| | Current Waste Program | PAYT/UBP Bag | PAYT/UBP Cart |
|---|---|---|---|
| **Revenues** | | | |
| Net Bag Revenue | $0 | $261,579 | $0 |
| Net Cart Revenues | $0 | $0 | $434,139 |
| Tax Revenue | $937,250 | $528,267 | $490,125 |
| **Total Revenues** | **$937,250** | **$789,846** | **$924,264** |
| **Expenses** | | | |
| Curbside Disposal | $335,008 | $187,604 | $278,057 |
| Recycling Disposal | $0 | $0 | $0 |
| Cart Management (Billing, Change Outs, Marketing) | 0 | 0 | $43,965 |
| Other Solid Waste Costs | $602,242 | $602,242 | $602,242 |
| **Total Expenses** | **$937,250** | **$789,846** | **$924,264** |

[i]Inc, WasteZero. "Deep Unit Based Pricing Working Group - Ct.Gov." Unit-Based Pricing (UBP) Working Group, October 15, 2020. https://portal.ct.gov/-/media/DEEP/waste_management_and_disposal/CCSMM/UBP-Working-Group/WZ_Presentation.pdf. (pg 28)
[ii] Inc, WasteZero. "Deep Unit Based Pricing Working Group - Ct.Gov." Unit-Based Pricing (UBP) Working Group, October 15, 2020. https://portal.ct.gov/-/media/DEEP/waste_management_and_disposal/CCSMM/UBP-Working-Group/WZ_Presentation.pdf. (pg 27)
[iii] Inc, WasteZero. "Deep Unit Based Pricing Working Group - Ct.Gov." Unit-Based Pricing (UBP) Working Group, October 15, 2020. https://portal.ct.gov/-/media/DEEP/waste_management_and_disposal/CCSMM/UBP-Working-Group/WZ_Presentation.pdf. (pg 24-30)
[iv] Inc, WasteZero. "Deep Unit Based Pricing Working Group - Ct.Gov." Unit-Based Pricing (UBP) Working Group, October 15, 2020. https://portal.ct.gov/-/media/DEEP/waste_management_and_disposal/CCSMM/UBP-Working-Group/WZ_Presentation.pdf. (pg 30)

## *Calculations*

**Cost 1**: Number of Households in the MSA x Number of 94 Gallon Carts
Households: 336,660 Worcester county + 45724 in Windham County

382,384 x $75

**Cost 2**: (Cost of Distributing Bags in Windsor Locks ($187,604)/ Number of Households in Windsor Locks) x Number of Households in MSA
($187,604/5357)* 382,384

**Cost 3**: Equation

**Total Estimated Cost = $13,391,220 - $28,678,800**

## WMM5

Due to the scalable nature of this strategy the costs are difficult to quantify. Initial capital costs for siting and purchasing existing facilities or retrofitting facilities to perform a waste processing function vary greatly depending on the size and function of the facility. However once established a Regional Waste Management Entity can be a net revenue generator: According to a financial audit of the Rhode Island Resource Recovery Corporation in 2024 the quasi-public entity ran a $22.4 million surplus after revenues and expenses were calculated.[i]

[i] Witham, Smith and Brown. "RHODE ISLAND RESOURCE RECOVERY CORPORATION (a Component Unit of the State of Rhode Island) FINANCIAL STATEMENTS JUNE 30, 2024 AND 2023." Financials, October 17, 2024. https://rirrc.org/.

# Electricity Generation and Use Sector

## EGU1

A total of 2.77 TWh of solar electricity (out of an anticipated need of 11.07 TWh of total clean energy generation) will be needed to be generated to lead to the emissions reductions of 308,677 MT of CO2e in 2050 that this measure aims for.

According to the United States Energy Information Administration's 2025 "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025" report, the levelized cost of electricity for solar photovoltaic systems is estimated as $31.86 per megawatt hour for infrastructure beginning service in 2030.[1]

The total estimated costs to implement this measure / The total capital costs (including construction, equipment, materials, and any required site preparation), operation and maintenance costs, administrative and personnel costs, and permitting/legal costs for installing solar energy systems capable of generating 2.77 TWh of energy are therefore estimated to be $88,202,490.18.

### *Calculations*

This plan has the goal of 25% of the electricity used in the Greater Worcester MSA in 2050 being generated by solar energy.

25% of 11,073,758.968 MWh of estimated total power from non-emitting sources in 2050 = 2,768,439.742 MWh

2,768,439.742 MWh * $31.86 per MWh for solar energy infrastructure = $88,202,490.18

**Total Estimated Cost =** $88,202,490.18

## EGU2

A total of 0.39 TWh of onshore wind electricity and 1.61 TWh of offshore wind electricity (out of an anticipated need of 11.07 TWh of total clean energy generation) will be needed to be generated to lead to the emissions reductions of 330,727 MT of CO2e in 2050 that this measure aims for.

According the United States Energy Information Administration's 2025 "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025" report, the levelized cost of electricity of onshore wind turbines is estimated as $18.90 per MWh and the levelized cost of electricity for offshore wind turbines is estimated as $88.16 per MWh for infrastructure beginning service in 2030.[2]

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[1] "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025," United States Energy Information Administration.

[2] "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025," United States Energy Information Administration.

Therefore, the total estimated capital costs (including construction, equipment, materials, and the purchase of land), operation and maintenance costs, administrative and personnel costs, and permitting/legal costs for onshore wind turbines included in this measure are estimated to be $7,325,291.56. The total estimated capital costs (including construction, equipment, materials, and lease of waters), operation and maintenance costs, administrative and personnel costs, and permitting/legal costs for offshore wind turbines included in this measure are estimated to be $141,558,075.64. Adding these two totals, the total estimated costs to implement this measure are $148,883,367.20.

### *Calculations*

This plan has the goal of 18% of the electricity used in the Greater Worcester MSA in 2050 being generated by wind energy, of which 3.5% is generated by onshore wind and 14.5% is generated by offshore wind.

3.5% of 11,073,758.968 MWh of estimated total power from non-emitting sources in 2050 = 387,581.56388 MWh

387,581.56388 MWh * $18.90 per MWh for onshore wind energy infrastructure = $7,325,291.56

14.5% of 11,073,758.968 MWh of estimated total power from non-emitting sources in 2050 = 1,605,695.05036 MWh

1,605,695.05036 MWh * $88.16 per MWh for offshore wind energy infrastructure = $141,558,075.64

$7,325,291.56 (total estimated cost for onshore wind energy infrastructure) + $141,558,075.64 (total estimated cost for offshore wind energy infrastructure) = $148,883,367.20

**Total Estimated Cost =** $148,883,367.20

## EGU3

A total of 2.77 TWh of nuclear electricity (out of an anticipated need of 11.07 TWh of total clean energy generation) will be needed to be generated to lead to the emissions reductions of 459,343 MT of CO2e in 2050 that this measure aims for.

According to the United States Energy Information Administration's 2025 "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025" report, the levelized cost of advanced nuclear is estimated as $81.46 per megawatt hour for infrastructure beginning service in 2030.[3]

The total estimated costs to implement this measure / The total capital costs (including construction, equipment, materials, and the purchase of land), operation and maintenance costs, administrative and personnel costs, and permitting/legal costs for generating 2.77 TWh of nuclear power are estimated to be $225,517,101.38.

### *Calculations*

This plan has the goal of 25% of the electricity used in the Greater Worcester MSA in 2050 being generated by nuclear energy.

25% of 11,073,758.968 MWh of estimated total power from non-emitting sources in 2050 = 2,768,439.742 MWh

2,768,439.742 MWh * $81.46 per MWh for nuclear energy infrastructure = $225,517,101.38

**Total Estimated Cost =** $225,517,101.38

## EGU4

A total of 0.55 TWh of energy (out of an anticipated need of 11.07 TWh of total clean energy) will be needed to be stored to lead to the emissions reductions of 91,869 MT of CO2e in 2050 in the MSA that this measure aims for.

According the United States Energy Information Administration's 2025 "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025" report, the average of the levelized cost of storage for combustion turbine and battery storage technologies is $129.14 per MWh for infrastructure beginning service in 2030.[4]

The total estimated costs to implement this measure / the total estimated capital costs (including construction, equipment, materials, and the purchase of land), operation and maintenance costs, administrative and personnel costs, and permitting/legal costs for these energy storage facilities are therefore estimated to be $71,503,261.66.

### *Calculations*

This plan has the goal of 5% of the electricity used in the Greater Worcester MSA in 2050 passing through energy storage after it is generated by non-emitting sources.

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[3] "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025," United States Energy Information Administration.

[4] "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025," United States Energy Information Administration.

5% of 11,073,758.968 MWh of estimated total power from non-emitting sources in 2050 = 553,687.9484 MWh

553,687.9484 MWh * $129.14 per MWh for energy storage infrastructure = $71,503,261.66

**Total Estimated Cost =** $71,503,261.66

## EGU5

A total of 2.44 TWh of hydroelectric power (out of an anticipated need of 11.07 TWh of total clean energy generation) will be needed to be generated to lead to the emissions reductions of 404,222 MT of CO2e in 2050 in the MSA that this measure aims for.

According the United States Energy Information Administration's 2025 "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025" report, the average of the levelized cost of electricity for hydroelectric power is $54.40 per MWh for infrastructure beginning service in 2030.[5]

The total estimated costs to implement this measure / The total estimated capital costs (including construction, equipment, materials, and the purchase of land), operation and maintenance costs, administrative and personnel costs, and permitting/legal costs for these hydroelectric power facilities are estimated to be $132,530,747.33.

### *Calculations*

This plan has the goal of 22% of the electricity used in the Greater Worcester MSA in 2050 being generated by hydroelectric energy.

22% of 11,073,758.968 MWh of estimated total power from non-emitting sources in 2050 = 2,436,226.97296 MWh

2,436,226.97296 MWh * $54.40 per MWh for hydroelectric energy infrastructure = $132,530,747.33

**Total Estimated Cost =** $132,530,747.33

[5] "Levelized Costs of New Generation Resources in the Annual Energy Outlook 2025," United States Energy Information Administration.

# Transportation Sector

## T1

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $27,699,794 | $115,766,369 |

Cost estimates for this measure include the development of shared use paths and bike share programs. The Shared Use Path Design Guide Cost Estimator available from MA EEA was used to determine an example cost for a shared use path. A value of approximately $2.5 million per mile of path was used, with assumptions that 10 miles and 20 miles of path would be developed by 2030 and 2050, respectively. The costs for bike share programs were derived from recent examples within Massachusetts, including the Minuteman, ValleyBike, and Newburyport bike share programs. The three-year program costs range from $187,450 to $2.3 million, representing a variety of programs including those for a single community and up to as many as ten communities, and programs with regular bikes and e-bikes. It was assumed that by 2030 three small scale and one large scale bike share programs would be established and by 2050, 12 small scale and 4 large scale programs would be established (in addition to the programs started by 2030).

## T2

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $25,785,927 | $274,850,880 |

The cost for electrification of transit buses was calculated using the number of buses in the fleet for three RTAs based on the 2022 Annual Agency Profiles from the Federal Transit Administration. The 2020 study, Financial Analysis of Battery Electric Transit Buses, by the National Renewable Energy Laboratory, provided a cost of $887,308 per battery electric bus and cost of $50,000 for each charger. These values were converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. Similarly, cost for electrification of demand response and senior van vehicles were calculated using costs from the EPA CCAP Cost of Measures Resource values of $55,000 per vehicle and $7,500 (2015 dollars) per charger. Costs for all three vehicle types were summed to provide an overall measure cost.

## T3

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $103,086,000 | $154,629,000 |

The EPA CCAP Cost Estimating Resource identified the cost of a level two charger as $7,500 (2015 dollars). This was converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator and multiplied by the number of charging ports. The number of ports was determined in the GHG reduction calculations for 2030 and 2050 based on statewide projected charging port needs, scaled to the MSA by population.

## T4

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $54,477,429 | $217,909,718 |

The cost for transitioning light duty municipal fleet vehicles to electric was determined by assuming the cost per vehicle was $55,000 (2025 dollars) based on the EPA CCAP Cost of Measures Resource. The number of chargers needed was determined by assuming each port can support two vehicles and each charger has two ports. The cost per charger was assumed to be $7,500 (2015 dollars), also sourced from the EPA, and converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. The cost for vehicle purchasing and chargers were summed to determine the total cost.

## T5

| | 2030 | 2050 |
|---|---|---|
| Cost Estimate | $99,051,914 | $272,392,763 |

The cost for transitioning light duty municipal fleet vehicles to electric was determined by assuming the cost per vehicle was $150,000. The number of chargers needed was determined by assuming each port can support two vehicles and each charger has two ports. The cost per charger was assumed to be $7,500 (2015 dollars), sourced from the EPA CCAP Cost of Measures Resource. This value was converted to 2025 dollars using the US Bureau of Labor Statistics CPI Inflation Calculator. The cost for vehicle purchasing and chargers were summed to determine the total cost.

# Agricultural, Natural, Working Lands Sector

## ANWL1

The estimate converts the canopy target into trees-per-acre using American Forests' Tree Equity Score assumption for a medium urban tree (~55.74 m² canopy), then multiplies by per-tree planting and three-year establishment costs. Native shrubs for hard or undersized sites are added and includes a modest program/overhead allowance for planning, permitting, outreach, inventory, and QA/QC.

The baseline draws on DCR's Greening the Gateway Cities Program (GGCP) partner budgets, which imply ≈$1,060 per tree for planting and one season of care. Adding two establishment years at ~$200 per tree per year yields a low-end program cost of ≈$1,460 per tree. For the high end in dense urban conditions, recent New York City benchmarks indicate ≈$3,300 per tree inclusive of establishment. Shrubs are budgeted at $100–$250 installed to green smaller sites and boost biodiversity. Final costs vary with site preparation, soil volumes, utility conflicts, summer watering intensity, and community engagement scope.

### *Calculations*

**Per-tree cost (3-year total)**:
Low = $1,060 (planting + 1 season; GGCP) + 2 × $200 = $1,460.
High = $3,300

**Per-acre cost:**

Low (before overhead) = (11 × $1,460) + (2.75 × $100) = $16,167.50 → with 15% overhead = $18,592.63 ≈ $18,600/acre.
High (before overhead) = (11 × $3,300) + (2.75 × $250) = $36,712.50 → with 15% overhead = $42,219.38 ≈ $42,100/acre.

**Cost 1**: (≈1,000 acres): 1,000 × $18,600= $18.6M

**Cost 2**: (≈1,000 acres): 1,000 ×$42,100 = $42.1M.

**Total Estimated Cost = $19 – $43 Million**

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## ANWL2

Easement/CR value is modeled as a share of fee value, commonly 30–60% of fee depending on development pressure and restriction stringency. To ground fee value, USDA NASS 2025 farm real-estate values are used as a conservative rural-land proxy blended 75% MA / 25% CT to reflect geography (=$14,775/acre). Applying the 30–60% share yields an easement price of ≈$4,433–$8,865 per acre. Acquisition budgets also require due-diligence/closing costs, qualified appraisal, baseline documentation, Phase I environmental, and title work, plus a stewardship endowment for perpetual monitoring. Using WeConservePA trust surveys, a representative per-easement transaction bundle averages ≈$7,691 (appraisal $2,167–$4,333 midpoint ≈$3,250; baseline ≈$2,436; Phase I ≈$1,781; title ≈$224). For stewardship, Mass Audubon's CR stewardship manual illustrates an endowment of ≈$14,300 per CR to generate $715/yr at a 5% spend rate. Because tract count is unknown, both figures are converted to per-acre values under a tract size scenario (200 acres/easement)

### *Calculations*

**Assumptions:**

Blended fee proxy = 0.75×$14,900 + 0.25×$14,400 = $14,775/acre
Easement value fraction = 30–60% of fee.
Per-easement transactions (avg) = appraisal $3,250 + baseline $2,436 + Phase I $1,781 + title $224 = $7,691.
Stewardship endowment per CR = $14,300
Tract-size scenarios: 200 acres/easement

**Easement price per acre:**

Low = 0.30 × $14,775 = $4,432.50 ≈ $4,433;
High = 0.60 × $14,775 = $8,865.00 ≈ $8,865.

**Convert per-easement adders to per-acre:**

Transactions/acre = $7,691 ÷ 200 acres → $38.46
Stewardship/acre = $14,300 ÷ 200 acres → $71.50

**All-in per acre:**

Low = $4,432.50 + $38.46 + $71.50 = $4,542.46 ≈ $4,542;

High = $8,865.00 + $38.46 + $71.50 = $8,974.96 ≈ $8,975.

**Program totals (20,000 acres):**

$4,542 × 20,000 ≈ $90.8M

$8,975 × 20,000 ≈ $179.5M;

**Total Estimated Cost =$90 – $180 Million**


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## ANWL3

Unit costs by garden type: Rain gardens (bioretention) commonly fall around $3–$5/ft² for DIY builds and $10–$15/ft² when professionally installed; Pollinator/conservation landscaping (native beds/meadow-style "lawn to garden" conversions) are typically $4–$10/ft² for small residential areas using plugs/mulch—consistent with conservation-landscaping rebates paying $5–$6/ft² and with native installs often priced $5–$20/ft² in practice. For larger areas seeded as meadow, seed

alone can be $0.06–$0.08/ft² (~$2,600–$3,500/ac) but requires multi-year prep/management; EPA documents also show seeded prairie installs at $2,000–$4,000/ac as a lower-cost pathway. Food gardens (raised/contained beds) vary most with construction: 4×8 DIY beds price around $155–$220 per bed (~$5–$7/ft² materials incl. fill), while professionally built wood beds are commonly $25–$50/ft². Scenario design: DIY-leaning "Low" and a pro-install "High" scenario. "Low" assumes 50% pollinator at $4/ft²; 30% rain at $5/ft²; 20% food at $6/ft². "High" assumes 40% pollinator at $10/ft²; 35% rain at $15/ft²; 25% food at $25/ft².

### ***Calculations***

**Area Conversion**:
Target conversion area = 15,000 ac = 15,000 × 43,560 = 653,400,000 ft².
Target conversion area = 10,000 ac = 10,000 x 43,560 = 435,600,000 ft².

**DIY Scenario:**

**Mix & Unit Costs**
Pollinator/conservation beds: 50% of area = 326,700,000 ft² @ $4/ft²
Rain gardens: 30% = 196,020,000 ft² @ $5/ft²
Food gardens: 20% = 130,680,000 ft² @ $6/ft²

**Installed Cost**
Pollinator: 326,700,000 × $4 = $1,306,800,000
Rain: 196,020,000 × $5 = $980,100,000
Food: 130,680,000 × $6 = $784,080,000
Total installed = $3,070,980,000.

**Professional Scenario**:

**Mix & Unit Costs**
Pollinator/conservation beds: 40% = 261,360,000 ft² @ $10/ft²
Rain gardens: 35% = 228,690,000 ft² @ $15/ft²
Food gardens: 25% = 163,350,000 ft² @ $25/ft²

**Installed Cost**
Pollinator: 261,360,000 × $10 = $2,613,600,000
Rain: 228,690,000 × $15 = $3,430,350,000
Food: 163,350,000 × $25 = $4,083,750,000
Total installed = $10,127,700,000.

**Total Estimated Cost = $3 Billion - $11 Billion**

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## ANWL4

For bioswales/rain gardens, planning-level ranges include \$15–\$60/ft² for commercial-scale bioretention and \$5.5–\$24/ft² for bioswales that explicitly include design/engineering/permitting and installation. For curb bump-outs/ROW bioswales, recent guides show \$4–\$30/ft² typical ranges. For native meadows/park plantings, EPA's Greenacres documents \$2,000–\$4,000 per acre for seeded prairie (~\$0.05–\$0.09/ft² seed-only), and UNH Extension notes native seed costs around \$60–\$80 per 1,000 ft² (~\$0.06–\$0.08/ft²) before site prep. Contractor examples report "mini meadows" at ~\$8/ft², but large-area meadows can be under \$1/ft². Therefore meadow/park plantings are modeled at \$1.00/ft² (installed, low scenario) to stay conservative.

Where underutilized municipal land is paved, budgets must include depaving before greening. Public fact sheets and cost guides show \$2.5–\$3.5/ft² (contractor) to remove asphalt/concrete plus hauling, homeowner/contractor guides cite ~\$1–\$7/ft² as typical removal ranges. For Miyawaki-style mini-forests, recent NYC pilots report costs averaging ~\${200} per 10 ft² (~\$20/ft²), with a 2,700-ft² forest around \$54,000. For food forests (perennial edible landscapes), sample vendor budgets put installation at \$40k–\$100k+ per acre (~\$0.92–\$2.30/ft²) depending on features (irrigation, fencing, structures).

Because costs hinge on site mix (pavement vs. lawn) and design choices (engineered bioswales vs. seeded meadows), two scenarios are presented for the 15,000 acres (653,400,000 ft²) target: Low-cost and High-cost. Low-cost includes lawn-heavy (DIY-leaning) seeded meadows/park natives and a smaller share of depave + plant and bioswales. The Low scenario unit costs include: meadows $1.00/ft², food forests $1.50/ft², bioswales $7.00/ft², depave/plant $8.50/ft². High-cost includes pavement/engineered-heavy with mini-forests and engineered bioswales, plus larger depave + engineered bioretention areas. The High scenario unit costs mini-forest $20/ft², bioswales $15/ft², depave/engineered $18/ft², food forests $2.00/ft².

### *Calculations*

**Area Conversion**: 15,000 acres × 43,560 ft²/acre = 653,400,000 ft²

**Low-Cost Scenario**:

**Mix & Unit Costs**

Meadows/park natives: 55% × 653,400,000 = 359,370,000 ft² @ $1.00/ft² → $359,370,000.

Food forests: 15% × 653,400,000 = 147,015,000 ft² @ $1.50/ft² → $147,015,000.

Bioswales/rain gardens: 20% × 653,400,000 = 196,020,000 ft² @ $7.00/ft² → $914,760,000.

Depave + plant (basic): 10% × 653,400,000 = 65,340,000 ft² @ $8.50/ft² (= ~$3 depave + ~$5–6 planting/soil) → $555,390,000.

Total Low-Cost Scenario = $359.37M + $147.02M + $914.76M + $555.39M = $1,976,535,000 (≈ $1.98B, ≈ $131,769 per acre).

**High-Cost Scenario**:

**Mix & Unit Costs**

Mini-forests (Miyawaki-style): 25% × 653,400,000 = 163,350,000 ft² @ $20/ft² → $3,267,000,000.

Bioswales/rain gardens (engineered): 35% × 653,400,000 = 228,690,000 ft² @ $15/ft² → $3,430,350,000.

Depave + engineered bioretention: 30% × 653,400,000 = 196,020,000 ft² @ $18/ft² (= ~$3 depave + ~$15 GSI) → $3,528,360,000.

Food forests (amenitized): 10% × 653,400,000 = 65,340,000 ft² @ $2.00/ft² → $130,680,000.

Total High-Cost Scenario = $3.267B + $3.430B + $3.528B + $0.131B = $10,356,390,000 (≈ $10.36B, ≈ $690,426 per acre).

**Total Estimated Cost = $2 - $11 Billion**

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## ANWL5

The transition from synthetic inputs to IPM/soil-health practices typically includes (a) soil testing, (b) aeration/overseeding with low-input turf/legumes, (c) organic soil amendments (e.g., compost topdressing), and (d) IPM training/monitoring & communications. UMass's soil lab lists a routine SOM test at ~$27 per sample. Professional aeration + overseeding commonly falls around $700–$1,400 per acre.

While the 9,000 acres cover non-agricultural landscapes, this measure also encourages farms to adopt regenerative practices that reduce nitrogen fertilizer use and eliminate pesticide applications. To budget for this, a $50/ac costs is added for communications and basic signage, and $5-$15/ac is added for regenerative farming training. These references inform assumptions about feasible uptake and the scale of training/technical assistance needed.

### *Calculations*

**Unit Inputs:**

Target treated area = 9,000 acres.
Soil testing: ~$27/sample (assume 1 sample per acre for planning).
Aeration + overseeding: $700–$1,400 per acre (installed).

**Per-Acre Costs:**

Soil test ($27) + aeration/overseed ($700–$1,400/ac) + training ($5–$15/ac) + basic signage/communications (~$50/ac)

Per-acre total (rounded): $800–$1,500

**Installed Costs**:

$800/ac × 9,000 ac = $7.20M
$1,500/ac × 9,000 ac = $13.50M

**Total Estimated Cost = $8 - $14 Million**

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# Commercial and Residential Buildings Sector

## CRB1

*Municipal Planning & Zoning Reform Assistance: $15 million*

This estimate reflects support for 40 to 50 municipalities (primarily urban and semi-rural towns) to adopt climate-aligned zoning reforms, including Transit-Oriented Development (TOD) overlays, growth boundaries, form-based codes, and Transfer of Development Rights (TDR) mechanisms. Each town is projected to require approximately $300,000 over a 5 to 10-year period to cover legal and technical assistance, RPA facilitation, stakeholder outreach, and public meetings. This investment will enable local governments to establish a regulatory framework for compact, walkable development that reduces vehicle emissions and preserves open spaces.

Per-town support: ~$300,000
Number of towns: 40–50
Total range: 50 towns × $300,000 = $15 million

*Brownfield Redevelopment Planning, Inventories & Pilots – $20–$26 million*

This measure would enable a coordinated regional strategy for brownfield reuse that supports infill development, reduces pollution, and protects green fields. Funding would be allocated across three components:

- Pilot Projects – $12–$16 million: Would support 3–5 high-impact redevelopment pilots ($3–$5 million each), covering environmental assessments, public engagement, early design, and permitting to unlock redevelopment readiness.

- Municipal Inventories and Reuse Planning – $4–$6 million: Would fund brownfield inventories and reuse plans in 30–40 municipalities (~$150,000 each), supporting site mapping, reuse analysis, and grant preparation to build local capacity.

- Regional Coordination and Technical Assistance – $4 million: Would provide funding to RPAs and partners for centralized data systems, inter-municipal learning, and permitting support to streamline reuse across the region.

*Public Engagement, Education, and Capacity Building: $5–$7 million*

This funding would support outreach, peer learning, and capacity building across 80 municipalities, tailored to varying town sizes and resource levels. RPAs would coordinate training sessions, regional toolkits, translation services, and virtual engagement platforms. Funding would be concentrated in the 2026–2040 period to accelerate early adoption, with tapering support through 2050 for ongoing education and technical reinforcement.

- Years 2026–2040 (Peak Engagement Phase): $300,000–$400,000/year across the region (includes RPA-led campaigns, toolkits, translated materials, in-person/virtual events).
- Years 2040–2050 (Taper Phase): $100,000–$150,000/year for maintenance, digital tools, periodic retraining.
    - Assumption: Average cost per town: $60,000–$90,000 over 15–20 years (scaled based on municipal size and need; smaller rural towns require more direct support)

        80 towns × $60,000–$90,000 = $4.8–$7.2 million total.

        (This estimate is grounded in comparable planning efforts across Massachusetts and similar regions. For instance, Municipal Vulnerability Preparedness (MVP) planning grants typically range from $15,000 to $100,000 per municipality for short-term engagement and resilience planning. Regional Planning Agencies (RPAs) often manage multi-town coordination with annual budgets ranging from $100,000 to $300,000. Additionally, technical assistance benchmarks from housing, climate, and public health initiatives typically allocate between $3,000 and $7,000 per town per year, depending on local needs and capacity. These precedents help inform the projected long-term investment required to support sustained and equitable engagement across 80 towns through 2050).

Inter-municipal Coordination + TDR Framework Development: $6–$8 million
Development and piloting of shared permitting tools, regional TDR frameworks, model bylaws, and staff support. Includes one or more inter-municipal overlays or clearinghouses ($2M–$3M per effort).

Monitoring, Mapping & Evaluation Tools: $3–$5 million
Includes GIS mapping, VMT tracking, zoning and development pattern databases, and regional dashboards. Assumes $150,000–$200,000 per year for RPAs and MassGIS-aligned updates through 2045.

## CRB2

The incremental implementation of this measure is estimated to cost $5.4–7.9 billion through 2050. The largest share comes from public building retrofits ($1.2–1.8 billion) for approximately 2,500–3,000 municipal facilities, and private-sector retrofits ($3.5–7.3 billion) targeting 25,000–35,000 buildings. Additional costs include regional planning support ($40–60 million) for RPAs and COGs to

provide technical assistance and joint procurement, workforce development ($75–100 million) to train 2,000–4,000 retrofit and electrification workers, public engagement and education ($30–50 million) to ensure equitable participation and capacity building, and monitoring, reporting, and verification ($15–20 million) for emissions tracking and adaptive management. A contingency and inflation reserve of $500–700 million (10–12 percent) is included to account for long-term cost escalation, bringing the rounded total to $5.4–7.9 billion.

## CRB3

Developing circular construction capacity in Greater Worcester will require investments of $125–$170 million. Reuse infrastructure development ($75–$100 million) will establish 2–3 regional hubs with sorting, storage, logistics, and operations, reflecting costs seen in Portland, OR, Ithaca, NY, and Stockholm's Wood City. Workforce development and training ($25–$35 million) will prepare 3,000–5,000 workers for deconstruction, salvage, and reuse logistics, aligning with Portland's program and national training benchmarks. Regional planning, tracking systems, and data tools ($15–$20 million) will fund ordinance drafting, coordination, GHG tracking, and digital platforms, drawing from EPA CPRG allocations and Nordic models. Community engagement and capacity building ($10–$15 million) will support outreach, equity-focused engagement, and workshops, following examples from Portland, San Antonio, and EPA Environmental Justice programs.

## CRB4

Based on benchmarks from the Massachusetts Green Communities Program, Connecticut's Energy Efficiency Fund, and RGGI, implementing green construction measures is estimated to cost $16–$36 million. This includes $1 million for research and policy development, $500,000–$600,000 to update procurement policies, and $10 million for 2–3 pilot projects showcasing sustainable materials and methods. Securing legislative authority will require $500,000, while $20 million will fund training for 2,500–3,000 professionals. An additional $4 million is allocated for developing integrated monitoring systems to track GHG reductions, energy efficiency, and material adoption.

## CRB5

The total estimated cost for energy code adoption, modeling, and incentive systems is projected at $255–$270 million. Energy code adoption and implementation is estimated at $18–22 million, covering municipal training, technical assistance, and administrative support over 25 years. Energy modeling and public disclosure for large developments (>10,000 sq. ft.) will require $13–15 million, including regional setup and ongoing monitoring. Green building incentives and flexible permitting systems represent the largest share at $220–$230 million, reflecting added staff time across 79 municipalities and potential incentives such as tax rebates or bonus floor area. Community outreach

and education, including workshops, campaigns, and public meetings to promote sustainability, is expected to cost $4–6 million over the 25-year period.

# Electricity Generation and Use Supplemental Information

## EGU1: Solar Power Generation

### Geographic Scope

High-priority sites for solar development include large commercial and industrial rooftops, which offer expansive, unobstructed surfaces that would be well-suited for solar arrays. As of 2023, 40 GW of Massachusetts statewide solar potential comes from rooftop solar.[i] Municipal, school, and residential solar also present opportunities as these facilities are distributed throughout nearly every community and serve as highly visible examples of renewable energy action. Parking lot canopies, particularly in large surface lots, are also desirable locations as they provide shading and protection from heat, rain, and snow on the ground. Brownfields, capped landfills, and decommissioned industrial sites also provide promising locations for solar siting after environmental review.

### Metrics for Tracking Progress

Data on the number of solar projects at the at the planning, design, and permitting phase that plan to generate energy used in the Region, calculated by type (rooftop, canopy, brightfield, and other ground-mounted) is not currently collected but can be developed through regional collaboration and integrated into an online website and dashboard for the Region.

Data on the number of solar installations completed in the Region, calculated by type (rooftop, canopy, brownfield, landfill, etc.) and as a regional total is currently collected by the Massachusetts Clean Energy Center (MassCEC), is publicly accessible, and can be integrated into an online website and dashboard for the Region.

Data on the total installed solar generation capacity (MW) in the Region is currently collected by MassCEC, is publicly accessible, and can be integrated into an online website and dashboard for the R.gion

Data on the annual solar energy generation (MWh or TWh) and percentage of the Region's electricity use sourced from solar energy can be estimated using MassCEC generation data and EIA regional consumption data; it is publicly accessible and can be integrated into an online website and dashboard for the Region.

Percentage of the Region's solar-generated electricity that is stored at any one time at energy storage facilities data is not currently collected but can be developed through regional collaboration and integrated into an online website and dashboard for the Region.

A dataset with the number of Municipal Light Plant solar energy projects installed in the Region can be developed through surveying and integrated into an online website and dashboard for the Region.

The number of solar installations located in or serving vulnerable communities in the Region is not currently collected but can be developed through surveying and integrated into an online website and dashboard for the Region.

## EGU2: Wind Power Generation

### Geographic Scope

Wind turbine facilities currently located in the Greater Worcester Region include the Templeton Wind Turbine in Templeton, the Mount Wachusett Wind Farm Project and the Department of Correction NCII Gardner Project in Gardner, the Princeton Municipal Light and Water Plant Project in Princeton, the Holy Name Catholic High School Wind Turbine in Worcester, and the Nature's Classroom Wind Turbine in Charlton.[ii]

### Metrics for Tracking Progress

Data on the number of onshore and offshore wind projects at the planning, design, and permitting phase that plan to generate energy used in the Region is currently collected by the Offshore Wind Power Hub and the New Bedford Light website for offshore wind[iii] and is not currently collected but can be collected through regional collaboration between Municipal Light Plants, private wind energy companies, DOER, DEEP, and regional planning organizations for onshore wind.

Data on the number of onshore and offshore wind turbines installed in and near the Region and the number of Municipal Light Plant wind energy projects installed in the Region is currently collected as part of the United States Wind Turbine Database[iv] and is publicly accessible. Data on which of these turbines specifically generate energy used in the Region is not currently collected but can be collected through regional collaboration between Municipal Light Plants, private wind energy companies, energy distribution companies, ISO New England, DOER, DPU, DEEP, and regional planning organizations.

Data on the number of onshore wind energy projects located in vulnerable communities can be collected through cross-referencing Massachusetts' and Connecticut's vulnerable communities dashboards[v] with the United States Wind Turbine Database.[vi]

Data on the percentage of the Region's electricity use which is sourced from onshore and offshore wind power, the percentage of the Region's offshore and onshore wind-generated electricity that is stored at any one time at energy storage facilities, the number of onshore wind energy projects co-located with energy storage in the Region, the number of wind energy industry jobs in the Region, and the number of these jobs in vulnerable communities in the Region is not currently collected but can be collected through regional collaboration between Municipal Light Plants, private wind energy companies, energy distribution companies, ISO New England, DOER, DPU, DEEP, and regional planning organizations.

The above data on wind energy can all be integrated into a publicly accessible online website and dashboard for the Region through regional collaboration.

## EGU3: Nuclear Power Generation

### Geographic Scope

Suitable locations for an in-region SMR would be identified through a regional siting and environmental impact study. Pending feasibility assessment and regulatory approval, an SMR would ideally be located in an area with access to existing transmission infrastructure and industrial zoning, as well as minimal environmental or population risk.

Imported nuclear energy would originate from existing or planned nuclear plants in the Northeast US, namely the Millstone Nuclear Powerstation (Unit 3) in Waterford, CT, which is responsible for 40% of Connecticut's energy generation, and Seabrook Station in Seabrook, NH, of which the Massachusetts Municipal Wholesale Electric Company (MMWEC) owns 11.59%, and two Massachusetts municipal utilities, namely the Taunton Municipal Light Plant and the Hudson Light & Power Department own a sum of 0.18%.[vii]

### Metrics for Tracking Progress

#### Development of an in-Region SMR

Proof of completion of SMR feasibility and siting study will be available after the study is initiated by CMRPC, in collaboration with state agencies and consultants.

Any permits issued for SMR siting and construction (local, state, federal) is tracked by permitting agencies, such as NRC (federal), MassDEP, and local planning and zoning boards.

Construction and operational milestones reached (such as groundbreaking, testing, commissioning) will be documented once the project begins, and the SMR project developer will share the data with host municipalities and the NRC to be shared publicly.

Emergency preparedness and response plans developed and adopted data is partially collected by municipalities who maintain hazard mitigation plans, although they may not contain plans for nuclear energy emergencies.

Public outreach and community engagement and education sessions related to SMR development should be shared to the public by CMRPC, the host municipality, and the project developer.

#### Imported Nuclear Energy

ISO New England partially collects data on the percent of electricity in the Region supplied by imported nuclear energy, and this data can be aggregated on a regional level.

Data on the Number and capacity (MW) of signed PPAs or contracts for imported nuclear power is collected internally by utilities, but it is not always publicly available. RPAs can work with Municipal Light Plants and utilities to get this data.

RPAs may need to conduct periodic surveys or request data on the number of communities or utilities in the Region participating in nuclear energy procurement.

RPAs can create a centralized reporting template for municipalities, community groups, and local government, but no formal agreements are needed for public education and engagement efforts related to imported nuclear energy.

## EGU4: Energy Storage Systems

### Geographic Scope

Currently-operating battery storage facilities in the Greater Worcester Region include the Groton Battery Energy Storage Systems 1 and 2 in Groton, MA, which each have 2 MW of energy storage capacity, the Ashburnham Energy Storage Project in Ashburnham, MA, which has 3 MW of energy storage capacity, the Brockelman Road Solar 2 Project in Lancaster, MA, which has 2 MW of energy storage capacity, the Chocksett Road Energy Storage Project in Sterling, MA, which has 2 MW of energy storage capacity, the Holden Battery Energy Storage System 1, which has 5 MW of energy storage capacity, and the Paxton Battery Energy Storage System 1, which has 3 MW of energy storage capacity.[viii]

The two currently operating large-scale pumped hydro energy storage facilities in western Massachusetts are the Northfield Mountain Pumped Hydro Storage Station in Erving and Northfield and the Bear Swamp Hydroelectric Station in Rowe and Florida. These facilities are only operating at 25-30% of their energy storage capacity due to them not being incentivized by the State,[ix] so there is an opportunity for the Greater Worcester Region to tap into their energy storage capacity if they can resume operating at full capacity.

### Metrics for Tracking Progress

Data on the number of energy storage projects installed that store energy in the Region is currently collected as part of the United States Renewable Electricity Infrastructure and Resources Dashboard[x] and is publicly accessible.

Data on the number of energy storage projects located in vulnerable communities in the Region can be collected through cross-referencing Massachusetts' and Connecticut's vulnerable communities dashboards [xi] with the United States Renewable Electricity Infrastructure and Resources Dashboard.[xii]

Data on the number of energy storage projects at the planning, design, and permitting phase that plan to store energy in the Region, the percentage of the Region's electricity use / number of TWh of electricity which is stored prior to use, the number of energy storage industry jobs in the Region, the number of these jobs in vulnerable communities in the Region, and the percentage of energy stored in the Region originally generated by renewable sources is not currently collected but can be collected through regional collaboration between Municipal Light Plants, private energy storage companies, energy distribution companies, ISO New England, DOER, DPU, DEEP, and regional planning organizations.

Data on the number of transmission line projects for distributing power from pumped hydro energy storage facilities in western Massachusetts to the Region at the planning, design, and permitting phase and the number of these transmission lines distributing power from these facilities to the Region does not yet exist due to there being no such plans for transmission lines at the present but can be collected once transmission line projects progress through regional collaboration between FirstLight, Emera Energy, and Brookfield Power, energy distribution companies, ISO New England, DOER, DPU, DEEP, and regional planning organizations.

Data on the percentage of the Region's electricity use / number of TWh of electricity which is sourced from pumped hydro energy storage facilities in western Massachusetts does not yet exist due to there being no such sourcing at the present but can be collected once this sourcing occurs through regional collaboration between FirstLight, Emera Energy, and Brookfield Power, energy distribution companies, ISO New England, DOER, DPU, DEEP, and regional planning organizations.

Data on the number of jobs in the Region supporting the transmission and use of power from pumped hydro energy storage facilities in western Massachusetts and the number of these jobs in vulnerable communities does not yet exist due to there being no jobs for this transmission and use at the present but can be collected once these jobs are hired for through regional collaboration between FirstLight, Emera Energy, and Brookfield Power, energy distribution companies, ISO New England, DOER, DPU, DEEP, and regional planning organizations.

The above data on energy storage systems can all be integrated into a publicly accessible online website and dashboard for the Region through regional collaboration.

## EGU5: Hydro-Power Solutions

### Geographic Scope

Current in-line hydropower facilities with over 1 MW of electricity production capacity in the Greater Worcester Region include the Cosgrove Intake and Power Station in Clinton, MA, which has a 3.2 MW power generation capacity but is currently operating at only half capacity, and the Oakdale Power Station in West Boylston, MA, which has a 3.5 MW power generation capacity. Current powered dams with over 1 MW of electricity production capacity in the Region include the Quinebaug Lower Project in Brooklyn, CT, which has a 2.5 MW power generation capacity and the Scotland Dam in Windham, CT, which has a 2.0 MW power generation capacity.[xiii] Non-powered dams in the Region with over 1 MW of electricity generation capacity include the Birch Hill Dam in Athol, MA, which has 1.9 MW of power generation capacity, the Westville Dam in Southbridge, MA, which has 1.6 MW of power generation capacity, and the West Thompson Dam in Putnam, CT, which has 2.8 MW of power generation capacity.[xiv] The Massachusetts Water Resources Authority (MWRA) has multiple in-line hydropower sites with significant power production potential along its system at which hydropower infrastructure is currently not cost-effective to install but which could one day provide power to the Region.

Electricity generated by hydropower facilities in Quebec could pass through the northern New England grid to reach the Region through several routes, potentially including along the TDI-owned transmission line in Vermont as well as along the New England Clean Energy Connect transmission line in Maine and New Hampshire.[xv]

### Metrics for Tracking Progress

Data on the number of hydropower and micro-hydropower projects installed that generate energy in the Region is currently collected as part of the United States Renewable Electricity Infrastructure and Resources Dashboard[xvi] and is publicly accessible. Data on the number and percentage of these projects which have received low impact hydropower certification can be collected through referencing the Low Impact Hydropower Institute's List of Certified Facilities.[xvii]

Data on the number of in-Region hydropower and micro-hydropower projects located in vulnerable communities can be collected through cross-referencing Massachusetts' and Connecticut's vulnerable communities dashboards[xviii] with the United States Renewable Electricity Infrastructure and Resources Dashboard.[xix]

Data on the number of hydropower and micro-hydropower projects at the planning, design, and permitting phase that plan to generate energy in the Region, the percentage of the Region's electricity use / number of TWh of electricity which is sourced from in-Region hydropower and micro-hydropower, the number of non-powered dam conversion to hydroelectric dam projects completed in the Region, the number of hydroelectric industry jobs in the Region, and the number of these jobs in vulnerable communities in the Region is not currently collected but can be collected through regional collaboration between dam owners, private hydropower companies, energy distribution companies, ISO New England, Municipal Light Plants, DOER, DEEP, and regional planning organizations.

Data on the number of transmission line projects for distributing hydropower from Quebec and northern New England to the Region at the planning, design, and permitting phase, the number of these transmission line projects installed, the percentage of the Region's electricity use / number of TWh of electricity which is sourced from Quebec and out-of-Region domestic hydropower, the number of jobs in the Region supporting the transmission and use of hydropower sourced from Quebec and domestically outside of the Region, and the number of these jobs in vulnerable communities is not currently collected but can be collected through regional collaboration between Hydro-Quebec, energy distribution companies, ISO New England, Municipal Light Plants, DOER, DPU, DEEP, the Quebec Energy Board, and regional planning organizations.

The above data on hydropower can all be integrated into a publicly accessible online website and dashboard for the Region through regional collaboration.

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[i] "Massachusetts Technical Potential for Solar," Synapse Energy Economics, Inc. and Massachusetts DOER.

[ii] "U.S. Wind Turbine Database," United States Department of the Interior, United States Geological Survey.

[iii] Anastasia E. Lennon, "Our offshore wind tracker: What's new with wind projects off Massachusetts and beyond?"; "Offshore Wind Power Hub," Offshore Wind Power Hub.

[iv] "U.S. Wind Turbine Database," United States Department of the Interior, United States Geological Survey.

[v] CT DEEP, "Learn More About Environmental Justice Communities;" Massachusetts Office of Environmental Justice & Equity, "Environmental Justice Populations in Massachusetts."

[vi] "U.S. Wind Turbine Database," United States Department of the Interior, United States Geological Survey.

[vii] "Our Energy Assets," Massachusetts Municipal Wholesale Electric Company.

[viii] "Renewable Energy Infrastructure and Resources Dashboard," United States Energy Information Administration.

[ix] Maria Fonseca-Guzman et al., "The State of Grid Energy Storage in Massachusetts," University of Massachusetts Lowell and the Associated Industries of Massachusetts Foundation.

[x] "Renewable Energy Infrastructure and Resources Dashboard," United States Energy Information Administration.

[xi] CT DEEP, "Learn More About Environmental Justice Communities;" Massachusetts Office of Environmental Justice & Equity, "Environmental Justice Populations in Massachusetts."

[xii] "Renewable Energy Infrastructure and Resources Dashboard," United States Energy Information Administration.

[xiii] "Renewable Energy Infrastructure and Resources Dashboard," United States Energy Information Administration.

[xiv] Boualem Hadjerioua et al., "An Assessment of Energy Potential at Non-Powered Dams in the United States," Oak Ridge National Laboratory.

[xv] Eve Vogel, "Introduction to the Special Issue: Québec Hydropower for a Green Massachusetts? Connections, Contradictions, and Contests of Renewable Electricity."

[xvi] "Renewable Energy Infrastructure and Resources Dashboard," United States Energy Information Administration.

[xvii] "Certified Facilities," Low Impact Hydropower Institute, October 31, 2025, https://lowimpacthydro.org/certified-facilities/.

[xviii] CT DEEP, "Learn More About Environmental Justice Communities;" Massachusetts Office of Environmental Justice & Equity, "Environmental Justice Populations in Massachusetts."

[xix] "Renewable Energy Infrastructure and Resources Dashboard," United States Energy Information Administration.