COMMONWEALTH OF MASSACHUSETTS

Global Warming Solutions Act
10-Year Progress Report

Massachusetts Global Warming Solutions

Executive Office of Energy and Environmental Affairs

ACKNOWLEDGEMENTS

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LETTER FROM THE SECRETARY

I am pleased to present the Executive Office of Energy and Environmental Affairs' (EEA) Ten-Year Progress Report on the implementation of the Global Warming Solutions Act of 2008 (GWSA). This report fulfills an important mandate of the GWSA, and highlights Massachusetts nation-leading progress towards reducing greenhouse gas emissions.

Ten years ago, Massachusetts signed into law the nation's most ambitious greenhouse gas reduction legislation. In 2016, at Governor Baker's direction, EEA expanded and integrated its greenhouse gas mitigation efforts with its work to increase the resiliency of our communities against the impacts of climate change. This Progress Report highlights the significant progress the Commonwealth has made toward reaching the dual goal of a resilient Commonwealth and a 25% reduction in greenhouse gas emissions below the 1990 baseline by 2020 – as well as where we still have more work to do. We are confident that each agency within EEA and partnering Secretariats, under the leadership of the Baker-Polito Administration, will continue to implement the policies of the 2015 Update of the Clean Energy and Climate Plan for 2010 (2015 CECP Update) and meet our 2020 emissions limit.

Reducing energy demand provides a critical foundation for our work to reduce emissions. The Mass Save® and municipal-led energy efficiency programs have reduced electricity demand, even as Massachusetts' population has steadily grown. More than just energy and emissions, these efficiency programs have also saved consumers billions of dollars on their utility bills. Specifically, the electricity generation sector has rapidly shifted away from carbon-intensive fuels, declining by 52% through a range of policies from energy efficiency deployment, growth of renewable resources, and retirement of carbon-intensive generators. These clean energy technology industries have led to more than 100,000 new jobs and have contributed more than $11 billion *per year* to the Massachusetts economy.

In the Transportation Sector, forward-looking motor vehicle standards have saved Massachusetts drivers at the pump and reduced our dependence on imported petroleum products. Moreover, these standards have dramatically reduced the emission of harmful pollutants from vehicle exhaust, with enormous public health benefits. However, there is more work to do to reduce transportation emissions which continue to grow as our population and economy have grown. To address this challenge, the Baker-Polito Administration has taken a number of steps over the last year to convene stakeholders through the Commonwealth, hold interstate dialogues, and study the best science and data in order to better understand and evaluate the most feasible strategies to reduce transportation sector emissions. Building on these efforts, Governor Baker created the Commission on the Future of Transportation to provide recommendations to support future efforts to deliver a cleaner, more resilient, and reliable transportation system for all residents. Their report, released in December 2018, will inform our analysis and development of a roadmap to meet the GWSA emissions limit in 2050.

In the last ten years, the Commonwealth has led the nation in reducing greenhouse gas emissions and fueled a new economy built on innovation and technology. Most of the policies contained within the 2015 CECP Update have led to emissions reductions. In some cases, the impacts of these policies have simply been masked by other changes as the economy has moved to embrace clean and efficient technologies. As we look to 2020 and beyond, Massachusetts has an opportunity to continue its leadership, working with regional states and partners through programs like the Regional Greenhouse Gas Initiative, the Transportation and Climate Initiative, and the U.S. Climate Alliance. Global warming is not isolated to Massachusetts; only by engaging and working with our partners in New England and across the world will we be able to reduce greenhouse gas emissions, preserve our natural resources, continue to grow our economy, and protect our residents and communities from the impacts of climate change.

Sincerely,

Matthew A. Beaton
Secretary of Energy and Environmental Affairs

ABBREVIATIONS

2015 CECP Update – 2015 update of the Massachusetts Clean Energy and Climate Plan for 2020
APS – Alternative Energy Portfolio Standard
Btu – British thermal unit
CECP – Massachusetts Clean Energy and Climate Plan for 2020, published in 2010.
CEP – Comprehensive Energy Plan
CES – Clean Energy Standard
CHP – Combined Heat and Power
CO_2 – carbon dioxide
CO_2e – carbon dioxide equivalents
DOER – Massachusetts Department of Energy Resources
DPU – Massachusetts Department of Public Utilities
EEA – Massachusetts Executive Office of Energy and Environmental Affairs
EEAC – Massachusetts Energy Efficiency Advisory Council
EIR – Environmental Impact Report
EISA – Energy Independence and Security Act
E.O. 569 – Executive Order 569
EPA – Environmental Protection Agency
EV – electric vehicle
EVSE – electric vehicle supply equipment
FHWA – Federal Highway Administration
GCA – Green Communities Act of 2018
GHG – greenhouse gas
GWSA – Global Warming Solutions Act of 2008
MAPC – Metropolitan Area Planning Council
MassCEC – Massachusetts Clean Energy Center
MassDEP – Massachusetts Department of Environmental Protection
MassDOT – Massachusetts Department of Transportation
MassEVIP – Massachusetts Electric Vehicle Incentive Program
$MMTCO_2e$ – million metric tons of carbon dioxide equivalents
MMBtu – million British thermal units
MOR-EV – Massachusetts Offers Rebates for Electric Vehicles
MW – megawatt
MWh – megawatt hour
NHTSA – National Highway Traffic and Safety Administration
PAs – Program Administrators of energy efficiency programs
RGGI – Regional Greenhouse Gas Initiative
RPS – Renewable Portfolio Standard
SMART – Solar Massachusetts Renewable Target
TWh – terawatt hour
VMT – vehicle miles traveled
ZEV – zero emission vehicle

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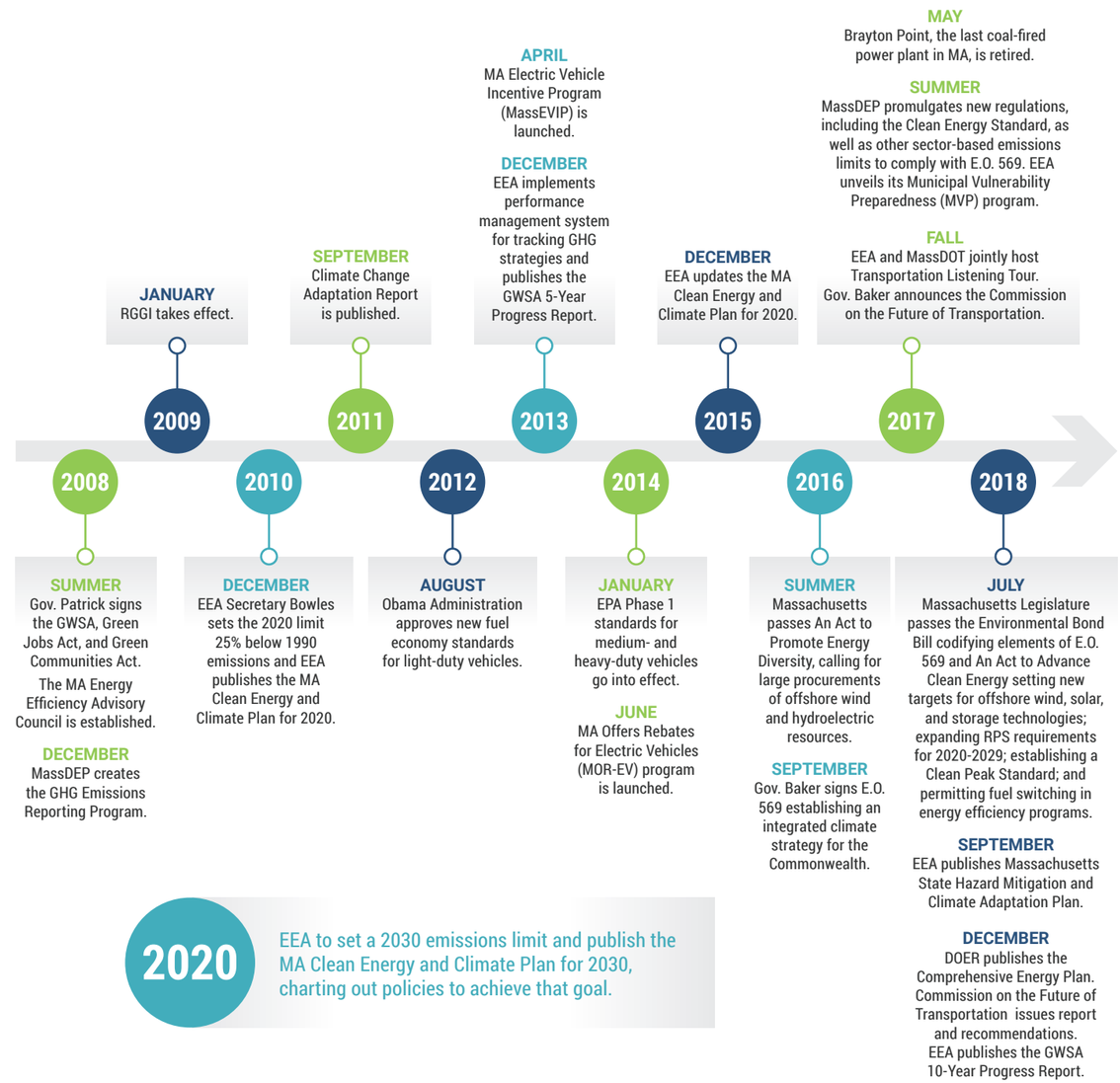
EXECUTIVE SUMMARY

1.1 SUMMARY OF GLOBAL WARMING SOLUTIONS ACT IMPLEMENTATION

The Global Warming Solutions Act (GWSA) was signed into law in 2008, making Massachusetts one of the few U.S. states with ambitious greenhouse gas (GHG) emissions reduction limits of 25% reduction below the 1990 baseline level by 2020 and at least 80% reduction by 2050. Since then, the Commonwealth has made great strides in implementing feasible and cost effective GHG emissions reduction strategies, coordinating state agencies, engaging stakeholders, evaluating progress towards the GWSA limits, and integrating GHG reduction strategies with climate change adaptation strategies. Through the combination of reducing and electrifying energy demand and decarbonizing energy sources, Massachusetts is on our way to meeting the emissions limits in the GWSA while continuing to support a vibrant economy, resilient communities, and a growing population.

Figure 1 shows that since the passage of the GWSA, Massachusetts has created a strong framework of state laws, regulations, and executive orders that guides the Commonwealth's actions to address climate change. The framework builds on the three overarching strategies through which the Commonwealth can effectively reduce GHG emissions: energy use reduction, electrification, and decarbonization. *The Massachusetts Clean Energy and Climate Plan for 2020 (CECP)* in 2010 and its update in 2015 (2015 CECP Update) featured a broad suite of policies that aim to reduce GHG emissions in the Commonwealth across all sectors through increased energy efficiency in buildings and vehicles, the electrification of vehicles and thermal conditioning in buildings, and the replacement of carbon intensive fuels with renewable energy sources.

FIGURE 1 | MAJOR MILESTONES SINCE PASSAGE OF THE GWSA.



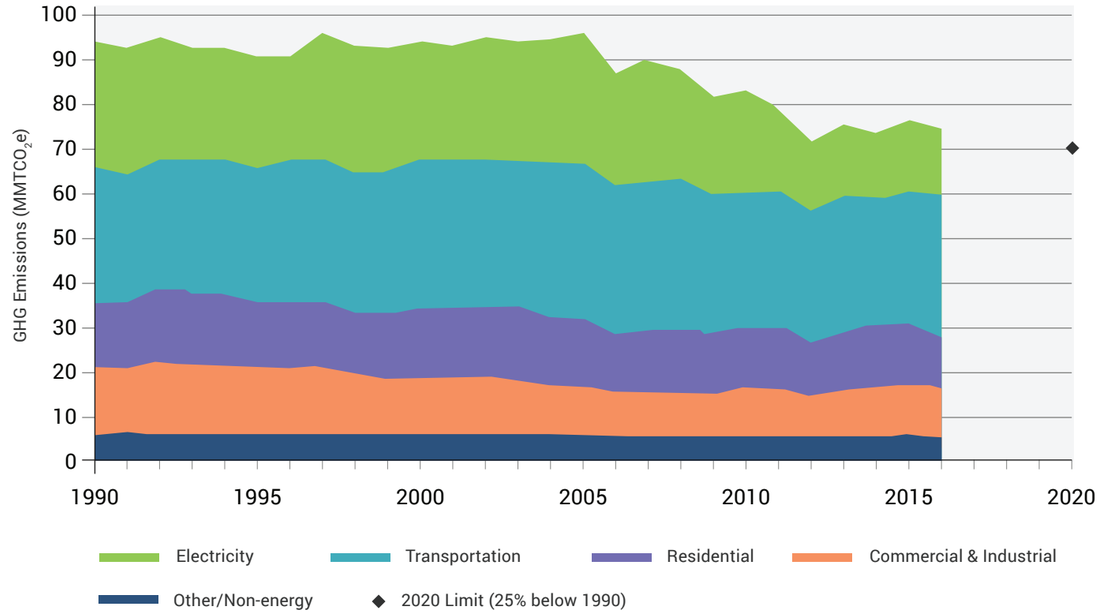
REDUCTION OF ENERGY USE ACROSS ALL SECTORS

- In 2018, the American Council for an Energy-Efficient Economy named Massachusetts the #1 state for energy efficiency in buildings for the 8th year in a row. The Massachusetts Energy Efficiency Advisory Council (EEAC) recently approved the latest three-year energy efficiency plan (2019-2021) that maintains nation-leading saving levels while transitioning to a more holistic approach to energy efficiency, demand management, and strategic electrification and ensuring continued growth of energy efficiency and economic benefits in the Commonwealth. Since 2010, the Mass Save® statewide efficiency programs have resulted, cumulatively, in over 6.8 million megawatt hours (MWh) of electricity savings, 93.4 million therms of natural gas savings, and 1.4 trillion British thermal units (Btu) in other heating fuel savings from existing residential and commercial buildings. For new construction, the Mass Save® statewide efficiency programs have resulted in over 1.4 million MWh of electricity savings and 23.9 million therms of natural gas savings since 2010.[1] Cumulatively, these savings combined have reduced emissions by more than 3.9 million metric tonnes of carbon dioxide equivalent ($MMTCO_2e$) and saved consumers more than a billion dollars on their energy bills.[2]
- In 2009, Massachusetts became the first state to adopt a local-option stretch energy code that extends beyond the base building energy code. The Stretch Code emphasizes energy performance instead of prescriptive requirements, and is an important strategy to reduce energy consumption in newly constructed homes and commercial buildings. As of November 2018, 250 municipalities had adopted the Stretch Code, which is mandatory for designation as a Green Community.
- Massachusetts law requires the Commonwealth to adopt and implement California's motor vehicle emissions standards as long as they are at least as protective as the federal standards. California has harmonized its standards with federal standards through 2025. Because of these standards, fuel efficiency in light-duty passenger vehicles sold in Massachusetts have increased 12% from 2009 to 2016, reducing GHG emissions from these vehicles by 2.6 $MMTCO_2e$ in 2016.
- The Greening the Gateway Cities program has planted over 19,000 trees in 14 Gateway Cities as of December 2018. The program is designed to reduce household heating and cooling energy use by increasing tree canopy cover in urban residential areas in the Commonwealth. It is estimated that every 1% increase in tree canopy above a minimum 10% canopy cover brings a 1.9% reduction in energy needs for cooling and up to a 1.1% reduction in energy for heating. The GHG reduction impact of these planted trees will increase significantly as they continue to grow in size.

ELECTRIFICATION OF TRANSPORTATION AND THERMAL CONDITIONING

- Massachusetts is a member of the Multi-state Zero Emission Vehicle (ZEV) Task Force and is committed to increasing the share of ZEVs in the Commonwealth. The Massachusetts Offers Rebates for Electric Vehicles (MOR-EV) program by the Department of Energy Resources (DOER) and the Clean Cities Coalition has issued or reserved over $23 million in consumer rebates for over 11,000 ZEV purchases or leases since 2014. In December 2018, the MOR-EV program was extended through June 30, 2019 with additional funding to sustain this popular program. The Massachusetts Electric Vehicle Incentive Program (MassEVIP) through the Department of Environmental Protection (MassDEP) has given $2.66 million to Massachusetts municipalities, state agencies, and public colleges and universities to acquire 267 electric vehicles and 92 publicly accessible charging stations, and $1.35 million to employers to acquire 543 electric charging stations at 265 separate locations. The 15,111 electric vehicles registered in the Commonwealth as of September 2018 have resulted in net reductions of 33,150 metric tons of CO_2e in 2018.
- The Commonwealth is set to receive approximately $75 million from the Volkswagen Settlement Trust to spend on vehicle-related environmental mitigation projects, of which up to 15% can be spent on electric charging infrastructure. MassDEP has finalized the Beneficiary Mitigation Plan for cycle one investments and will spend up to $23.5 million in Year One to support the purchase of electric transit buses by the Pioneer Valley and Martha's Vineyard Transit Authorities, to supplement the existing network of electric vehicle supply equipment (EVSE) with additional EVSE, and to implement new projects selected from a public solicitation process that could include the replacement of a diesel engine, vehicle, or equipment with an all-electric engine, vehicle, or equipment.
- The Massachusetts Clean Energy Center's Clean Heating and Cooling programs have committed $48 million through 2020 to support the installation of highly efficient or renewable heating and hot water technologies at homes and businesses across the Commonwealth that often replace or supplement systems burning fossil fuel. Further electrification of thermal conditioning in buildings is expected to significantly increase following the amendment of the Green Communities Act of 2008 (GCA) in August 2018 to authorize energy efficiency investments in fuel switching and demand management strategies—such as cost effective strategic electrification, storage, and active demand management—by energy utilities for the Mass Save® program.

FIGURE 2 | MASSACHUSETTS GHG EMISSIONS, 1990 – 2016



DECARBONIZATION OF THE ELECTRIC GRID AND REMAINING FUEL

- In January 2007, Massachusetts joined the Regional Greenhouse Gas Initiative (RGGI), a cooperative effort by Northeast and Mid-Atlantic States to reduce CO_2 emissions from large fossil-fueled power plants. CO_2 emissions from the power sector in the RGGI states since 2007 have decreased by approximately 40%, and due to recent regulatory amendments, will fall an additional 30% between 2021 and 2030 relative to the 2020 level.
- Retirements of coal and oil-fired power plants have contributed a reduction in GHG emissions of 5.0 $MMTCO_2e$ to date.[3] MassDEP promulgated regulation 310 CMR 7.74 *Reducing CO_2 Emissions from Electricity Generating Facilities* in 2017 to set an annual declining limit on CO_2 emissions from large electric generating facilities in the Commonwealth. The limit further ensures that the generation of electricity in Massachusetts continues to decarbonize as required by the GWSA.
- The electric grid in Massachusetts has become significantly cleaner due to the Renewable Portfolio Standard (RPS). The expansion of the RPS requirement from a 0.5% per year increase to a 1% annual increase starting in 2009 translates to a reduction in GHG emissions of 0.5 $MMTCO_2e$ in 2015. With the passage of the *Advance Clean Energy Act of 2018*, the RPS requirement increases again to 2% annually between 2020 and 2030, reaching 35% in 2030 and increasing to 55% in 2050. The Clean Energy Standard (CES), promulgated in 2017, will reach a standard of 80% in 2050.[4] These requirements will be met in the near- and medium-term with renewable energy certificates from qualified resources as well as the clean energy procurements authorized by the *Energy Diversity Act of 2016*. The projects selected by Massachusetts' Electric Distribution Companies via these procurements are expected to provide 9.45 TWh of hydroelectric generation and 800 MW of offshore wind generation in the mid-2020s.

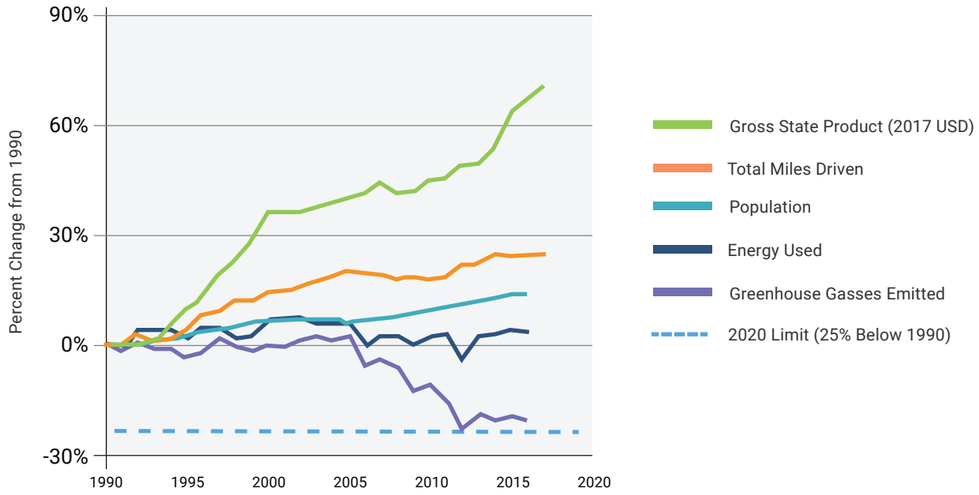
1.2 GHG EMISSIONS TRENDS AND SUCCESSES

The implementation of GHG emission reduction policies that were highlighted in the 2015 CECP Update, as well as additional policies and regulations implemented since then, are helping the Commonwealth effectively reduce GHG emissions and stay on track to meet the

[1] Reductions are estimated using an approach that isolates the impact of each policy on emissions each year. Because other factors affect emissions, they may not be correlated with trends over time. See Appendix A for summary of calculation methodology.
[2] Dollar estimate assumes 10-15 cents per KWh and $1 per therm.
[3] The closure of Pilgrim nuclear power plant in 2019 is estimated to result in an increase in emissions of 2.3 $MMTCO_2e$ from still operating power plants.
[4] RPS Class 1 credits are eligible for CES.

GWSA emissions limit in 2020. The latest statewide GHG inventory by MassDEP shows that GHG emissions in 2016 were 21.4% below the 1990 baseline level (Figure 2). The decrease in GHG emissions comes despite a 13% growth in population and 24% growth in vehicle miles traveled (VMT) (Figure 3). Significant GHG emissions reduction from the electric sector since 2005 has been a major contributor to the drop in gross GHG emissions, and vehicle standards have lowered the carbon intensity of each VMT while energy efficiency measures in buildings helped control energy demand despite increased economic growth and variable weather conditions.

FIGURE 3 | TRENDS OF GROWTH IN GSP, VMT, AND POPULATION WHILE GHG EMISSIONS ARE DECREASING AND ENERGY USE HAS BEEN STABLE



The downward trend of statewide GHG emissions indicates that our climate change mitigation policies are working. Of the 20.2 $MMTCO_2e$ reduced in 2016 from the 1990 baseline level, approximately 11.6 $MMTCO_2e$ are attributed directly to the implementation of GHG mitigation policies from 2010 to 2016 (Figure 4)[5]. These reductions (represented by the solid colored bars) will grow larger over time as implementation of these policies continues. The remainder of the GHG emissions reductions observed in the GHG inventory (represented by the hashed colored bars) are not directly attributable to policies in the 2015 CECP Update, whether due to lack of available data, policies implemented before passage of the GWSA, or other factors, such as weather conditions, relative fuel prices, and changes in consumer preferences. The negative reductions in the transportation and non-energy emissions sectors indicate that emissions reduction from policies implemented before the GWSA or from non-policy impacts counteract the GHG reductions from GHG mitigation policies implemented after the GWSA. On the other hand, policies implemented before the GWSA and non-policy impacts in the building and energy sectors have assisted the overall GHG reductions seen in these two sectors. In 2020, post-GWSA policy implementation is projected to reduce approximately 19 $MMTCO_2e$ or 20% below the 1990 level while the impact of pre-GWSA policies and other factors are projected to reduce an additional 5 $MMTCO_2e$ or 6% below the 1990 level (Table 1). Combined, the overall expected GHG emissions reduction will put the Commonwealth on track to meet the 2020 emissions limit of the GWSA.

[5] Analyses behind the estimates of GHG savings from policy implementation are summarized in Appendix A.

FIGURE 4 | PLANNED, ACHIEVED, AND PROJECTED GHG EMISSIONS REDUCTIONS (NEGATIVE REDUCTIONS ARE EMISSIONS, WHICH COUNTERACT THE POSITIVE REDUCTIONS)

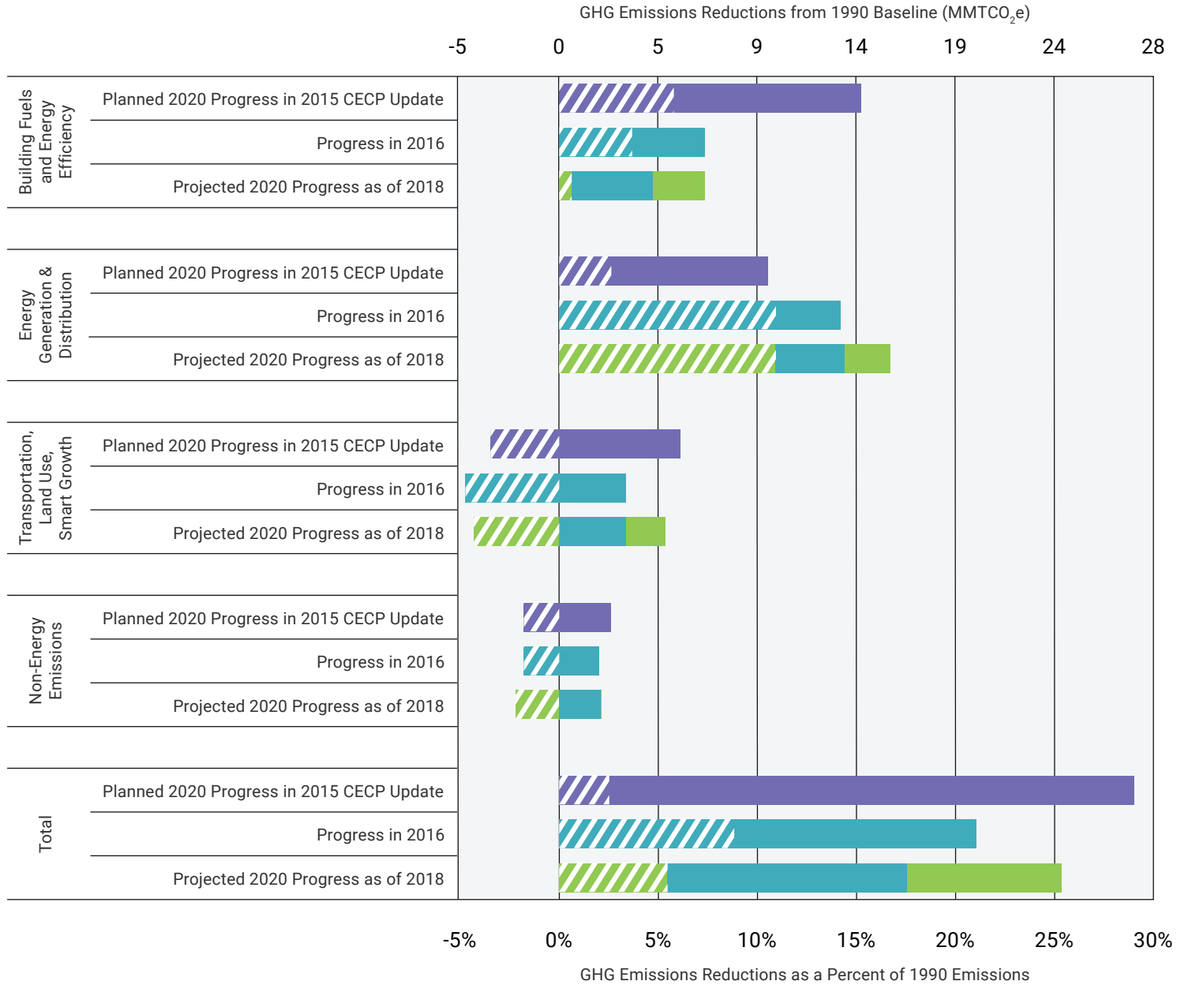


TABLE 1 | SUMMARY OF ESTIMATED GHG REDUCTIONS FROM POLICY IMPLEMENTATION*

	PLANNED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2015)		2016 PROGRESS		PROJECTED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2018)	
	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL
Building Fuels and Energy Efficiency	9.0	9.5%	4.0	4.2%	6.8	7.2%
All Cost-Effective Energy Efficiency	5.4	5.8%	3.2	3.4%	5.1	5.4%
Advanced Building Energy Codes	1.5	1.6%	0.7	0.7%	0.8	0.9%
Building Energy Rating and Labeling	–	–	Cross-cutting policy; savings reflected elsewhere.			
Expanding Energy Efficiency Programs to Commercial and Industrial Heating Oil	<<0.1	<<0.1%	Reductions to be included in All Cost-Effective Energy Efficiency.			
Appliance and Product Standards	1.0	1.1%	0.1	0.1%	0.8	0.8%
Renewable Thermal Technologies	1.0	1.1%	<<0.1	<<0.1%	0.1	0.1%
Tree Retention and Planting to Reduce Heating and Cooling Loads	<<0.1	<<0.1%	<<0.1	<<0.1%	<<0.1	<<0.1%
Transportation, Land Use, and Smart Growth	5.7	6.1%	3.2	3.4%	5.0	5.3%
Federal and California Vehicle Efficiency and GHG Standards (CAFE/Pavley)	3.7	3.9%	2.6	2.7%	3.7	4.0%
Federal Emissions and Fuel Efficiency Standards for Medium and Heavy Duty Vehicles	0.4	0.4%	<<0.1	<<0.1%	0.5	0.5%
Federal Renewable Fuel Standard (RFS) and Regional Clean Fuel Standard (CFS)	0.1	0.1%	<<0.1	<<0.1%	0.1	0.1%
Clean/Electric Vehicle Incentives	0.1	0.1%	Reductions included in CAFE/Pavley standards.			
State Transportation Initiatives and Regulations (includes policy formerly called GreenDOT)	1.0	1.1%	Transportation reductions included in CAFE/Pavley standards; Buildings reductions included in All Cost Effective Energy Efficiency.			
Smart Growth	0.4	0.4%	0.6**	0.6%**	0.7**	0.8%**
Electricity Generation and Distribution	7.8	8.2%	2.4	2.5%	4.7	5.0%
Coal-Fired Power Plant Retirements	2.7	2.9%	1.7	1.7%	2.7	2.9%
Regional Greenhouse Gas Initiative (RGGI)	–	–	Cross-cutting policy; reductions counted elsewhere.			
Renewable Portfolio Standard (RPS)	1.1	1.1%	0.7	0.8%	1.0	1.1%
Clean Energy Standard (CES)	–	–	0.0	0.0%	1.0	1.0%
Clean Energy Procurements	4.0	4.2%	Some reductions to be counted in RPS and CES after 2020.			
Electric Grid Modernization	–	–	Cross-cutting policy; reduction counted elsewhere.			
Non-Energy Emissions	2.5	2.6%	2.1	2.2%	2.2	2.3%
Reducing GHG Emissions from Plastics Combustion	0.3	0.3%	0.1	0.1%	0.1	0.1%
Reducing SF6 Emissions from Gas-Insulated Switchgear	0.4	0.4%	0.4	0.4%	0.4	0.4%
Reducing Emissions from the Natural Gas Distribution Network	1.7	1.8%	1.7	1.8%	1.7	1.8%
Stationary Equipment Refrigerant Management	0.1	0.1%	Policy not yet pursued.			
Total Reductions Attributable to Policies post-GWSA	25.0	26.4%	11.6	12.3%	18.7	19.8%
Other Changes Not Attributable to Policies post-GWSA	2.5	2.6%	8.6	9.1%	5.3	5.6%
Total Emissions Reductions	27.5	29.0%	20.2	21.4%	24.0	25.4%

* See Appendix A for summary of methodology
** Rough estimate using proxy data.

Massachusetts' experience implementing the GWSA shows that environmental programs can support economic development. Since the passage of the GWSA, Gross State Product (GSP) has increased by more than $91 billion (21%), from $436 billion in 2008 to $527 billion in 2017 after adjusting for inflation (Figure 3).[6] The clean energy industry employs more than 110,000 people in Massachusetts (Figure 5), and contributes $13.2 billion to the Commonwealth's economy, or about 2.5% of the annual GSP.[7] As the clean energy industry continues to grow, so will the overall economy of Massachusetts.

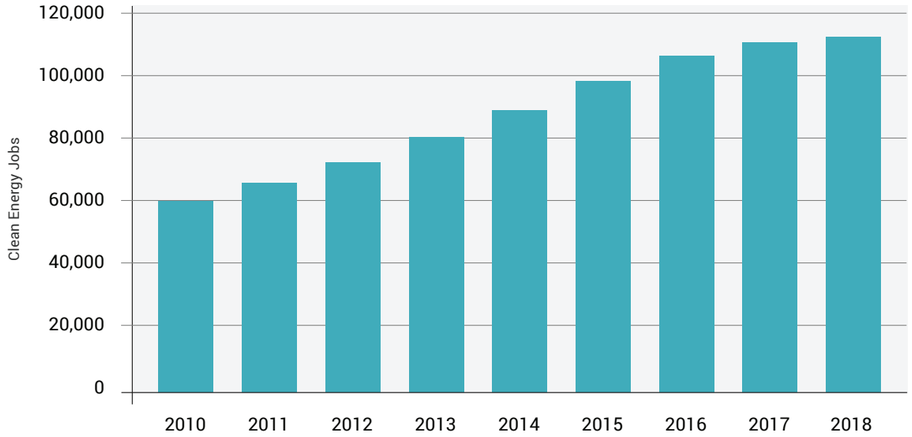
Clean energy innovation has played, and will continue to play, a powerful role in accelerating our progress toward the Commonwealth's GHG reduction goals. Clean energy innovation has reduced the cost of clean energy technologies, thereby facilitating more rapid adoption, and improved the performance of clean energy technologies. Meanwhile, clean energy business and financing model innovation has helped promote broader adoption of climate solutions, helping to impact difficult to reach customer segments.

In addition to stimulating economic growth, investing in renewable energy and energy efficiency keeps more of Massachusetts residents' dollars in their wallets. Mass Save® energy efficiency measures saved, cumulatively, 6.8 million MWh hours of electricity and 93 million therms of natural gas in 2017. Net economic benefits from ratepayer and state investment in the Mass Save® programs, since their expansion beginning in 2010 through 2020, are projected to exceed $18 billion through a combination of direct bill savings, avoided supply and infrastructure costs as well as non-energy benefits such as reduced costs for operation and maintenance, longer equipment replacement cycles, increased comfort and productivity improvements, and reductions in costs associated with reduced customer arrearages, service terminations, and reconnections.

Climate change mitigation policies also have the benefits of improving public health from co-reduction of other pollutants such as sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter (PM_{10} and $PM_{2.5}$). Sulfur and nitrogen oxides in the atmosphere can cause acid rain, act as respiratory irritants, and combine with other compounds to produce ozone and particulate matter, both of which can also cause or exacerbate respiratory conditions. Policies covering SO_x, NO_x, and mercury (Hg) (including pre-existing state clean air regulations) are estimated to result in $340 million to $18 billion in health benefits for Massachusetts, including 300-500 fewer premature deaths and 860 fewer hospitalizations.[8] Since

[6] All values are in constant 2017 dollars; nominal value of GSP in 2008 was $385 billion.
[7] MassCEC's 2018 Clean Energy Industry Report
[8] https://archive.epa.gov/clearskies/web/html/ma.html

FIGURE 5 | CLEAN ENERGY JOB GROWTH IN MASSACHUSETTS



2008, implementation of motor vehicle standards has led to a 50% decline in NO_x emissions and a 78% reduction in $PM_{2.5}$ emissions. The retirement of coal-fired power plants in Massachusetts since 2008 has contributed to a 95% decline in sulfur dioxide emissions.[9]

Additionally, some GHG mitigation policies provide significant co-benefits in terms of ecosystem services, or the many and varied benefits provided by the natural environment. For example, the Greening the Gateway Cities urban tree planting program alleviates the urban heat island effect and lowers the cooling needs of adjacent buildings, which reduces the energy bills of residents. Urban forestry also reduces storm-water runoff and absorbs air pollutants.

1.3 CONTINUED COLLABORATION, COORDINATION, AND COMMITMENT

The Commonwealth remains committed to meeting the requirements of the GWSA. In the first five years of GWSA implementation, EEA focused on building substantial institutional capacity, both within EEA and across state agencies, to enable smoother and more rapid implementation of climate and clean energy programs. This included close collaboration of EEA state agencies and coordination with other Secretariats that continues to date, as well as valuable external stakeholder engagement (such as the GWSA Implementation Advisory Committee) and important regional coordination both within and outside the Commonwealth.

Capacity building also included development of systems to track, evaluate, and report on climate change and clean energy programs, and the staff and software investments in GHG measurement, reporting, and policy implementation progress evaluation. In the first five years of GWSA implementation, EEA state agencies developed the Massachusetts GHG Registry and Inventory and various systems that document progress made toward GHG mitigation program goals, identify program impacts, inform program planning and management decisions, and provide transparent information to the public. In the last five years, EEA has increased staff capacity to analyze the GHG reductions from policy implementation, and developed the Massachusetts Clean Energy and Climate Performance Management System (CCPMS) for tracking and reporting policy implementation progress. These investments help EEA and state agencies estimate how much of the emissions reduction in the GHG inventory is due to policy implementation thus far and how much GHG emissions reduction can be expected in 2020. Information on progress is communicated regularly to external stakeholders and the general public on the GWSA implementation online portal.[10]

For GWSA commitments beyond 2020, EEA and state agencies have begun preparing for the development of the *Massachusetts Clean Energy and Climate Plan for 2030*—due by the end of 2020—and a roadmap of how the Commonwealth can reach the GWSA emissions limit for 2050 in a strategic, equitable, and cost-effective manner. Analyses of what statewide GHG emissions would be in 2050 with only existing GHG mitigation policies implemented (i.e., no new policies) have been conducted by EEA staff in the Long-Range Energy Alternatives Planning (LEAP) modeling tool. Additionally, DOER recently completed a Comprehensive Energy Plan (CEP) that provides guidance to policy makers by examining the impacts of policies to reduce GHG emissions on cost and reliability. The Commission on the Future of Transportation in the Commonwealth, established by Governor Baker in January 2018 as part of Executive Order 579, also recently released a report summarizing the results of their fact finding, scenario development, and recommendations on transportation sector trends, needs, and GWSA compliance between 2020 and 2040.

In early 2019, building upon recent analyses in the LEAP modeling tool, the analyses and subsequent recommendations from the CEP, and recommendations of the Commission on the Future of Transportation, EEA is commissioning a multi-year comprehensive "80x50 Study" to analyze and integrate the development of GHG emissions reduction pathways with a suite of recommended policies for the Commonwealth to set appropriate emissions limits for 2030 and to ultimately best meet the emissions limit of at least 80% below the 1990 baseline level by 2050. The recommended policies and implementation timeline could inform what policies are to be included in the *Massachusetts Clean Energy and Climate Plan for 2030*.

1.4 INTEGRATING CLIMATE CHANGE MITIGATION AND ADAPTATION EFFORTS

Massachusetts has a population of 6.9 million people, about 70% of whom live in coastal shoreline communities that are and will continue to be significantly impacted by a changing climate. Inland communities across the state will also be affected by extreme weather, flooding, and increased heat. Recognizing the importance of addressing global climate change to protect vulnerable populations and ecosystems, Massachusetts has taken important steps to integrate the reduction in GHG emissions with improvement in the adaptive capacity of our built and natural environments. While mitigation is our first line of defense to reduce risks from climate change, adaptation efforts are needed to manage ongoing impacts from climate change. Adaptation and mitigation strategies can work synergistically toward the goals of the GWSA.

In 2016, Governor Baker issued Executive Order 569 Establishing an Integrated Climate Change Strategy for the Commonwealth (E.O. 569). It requires the setting of emissions limits for 2030 and 2040 in 2020 and 2030 respectively, development of a comprehensive energy plan, development of a statewide climate adaptation plan, and assistance to municipalities in the Commonwealth to assess their vulnerability to climate change and build resiliency. EEA launched the Municipal Vulnerability Preparedness (MVP) grant program in the summer of 2017, and published the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) and the Climate Change Clearinghouse website[11] on the second anniversary of E.O. 569 in 2018. The MVP program, the SHMCAP, and other elements of E.O. 569 pertaining to climate adaptation vulnerability assessment and implementation were codified into law by Governor Baker in August 2018 after the Massachusetts Legislature passed *An Act Promoting Climate Change Adaptation, Environmental and Natural Resource Protection and Investment in Recreational Assets and Opportunity* (also known as the Environmental Bond Bill). The bill authorizes over $500 million to climate change resiliency efforts and stipulates that investments made by EEA and its agencies must be consistent with the state climate adaptation plan.

[9] Massachusetts 2011 Periodic Emissions Inventory, https://www.mass.gov/lists/massdep-emissions-inventories
[10] https://www.mass.gov/progress-towards-reducing-greenhouse-gas-emissions
[11] http://resilientma.org/

As EEA and state agencies integrate climate change mitigation and adaptation, one of the priorities is to better understand the carbon flux in natural and working lands in the Commonwealth over time and to better track how human activities are impacting the carbon flux. Carbon sequestration and avoided loss or degradation of natural and working lands have benefits for both climate change mitigation and adaptation. To support these efforts, acquisition of better land use and land cover tracking data is underway. Combining data on the changes between land use and land cover types with carbon stock profiles developed by Abt Associates and Applied GeoSciences in 2015 can provide valuable information on changes to the Commonwealth's carbon stock as a result of human activities or acts of nature.

1.5 CONCLUSIONS AND RECOMMENDATIONS

Recent analyses of GHG emission trends and policy impacts on GHG emissions indicate that the Commonwealth is on the way to meeting the GWSA emissions limit for 2020. Most of the emissions reductions observed in the GHG inventory since passage of the GWSA are directly attributable to the policies listed in the 2015 CECP Update and additional GHG mitigation policies implemented since then. However, there are also reductions in GHG emissions that are from policies implemented before the GWSA, reductions that cannot be directly attributable to policies due to lack of data, or reductions from other factors such as mild weather, relative fuel prices, and changes in consumer preferences. Nevertheless, overall GHG emissions in 2020 are projected to be 25% below the 1990 baseline level.

While analyses indicate a strong likelihood of GWSA compliance in 2020, the Baker-Polito Administration recognizes the importance of sustaining aggressive efforts to reduce GHG emissions in the Commonwealth in order to meet the GWSA emissions limits for 2020 and ultimately for 2050. Below are recommendations for how to focus GWSA implementation efforts over the next five years.

CONTINUE IMPLEMENTATION OF POLICIES IN THE 2015 CECP UPDATE AND ADDITIONAL GHG MITIGATION POLICIES.

Regarding building fuels and energy efficiency:

- Continue aggressive implementation of energy efficiency as proposed in the latest 3-Year Energy Efficiency Plan for 2019-2021 filed with the Department of Public Utilities (DPU):
  - Achieve more aggressive gas savings goals. Increase weatherization measures to improve existing building shell efficiencies and targeted winter gas savings.
  - Achieve electric energy efficiency goals and peak demand reductions. Expand programs to include new cost-effective active demand management programs such as energy storage, residential direct load control, and commercial and industrial (C&I) load curtailment programs.
  - Expand electric efficiency programs to holistically serve customers and promote fuel switching to more efficient and lower GHG emitting heating and hot water systems.
  - Serve more customers through additional efforts to serve moderate income, non-English speaking residents, renters, and small business customers.
  - Drive market/consumer demand for energy efficiency measures and fuel switching by educating consumers about the benefits of energy efficiency and creating a market incentive for consumers to invest in energy efficiency improvements through a "Home Energy Scorecard".
  - Further reduce energy demand in new buildings through promoting high efficiency building construction (such as meeting Passive House or Zero Net Energy standards).
- Explore possible ways to drive additional efficiency in new construction and better support renewable energy, electrification, energy storage, and resiliency policy goals.

Regarding transportation, land use, and smart growth:

- Continue electrification of passenger vehicles, and promote electrification/decarbonization of freight and other vehicles.
- Continue to provide incentives for in transit-oriented development areas and other locations with low car travel.
- Continue regional collaboration through the Transportation and Climate Initiative to develop a framework for a regional program that addresses GHG emissions from the transportation sector.

Regarding energy generation and distribution:

- Continue to increase cost-effective clean electricity supply to meet RPS and CES compliance obligations.
- Continue policies that support distributed resources, including considering policies that will support solar development in the Commonwealth after the SMART program concludes, especially projects that pair renewables with energy storage to align supply and demand and provide grid flexibility.
- Implement policies and programs, including the Clean Peak Standard, that incentivize energy conservation and renewable energy utilization during peak periods.

Regarding non-energy emissions:

- Explore potential strategies to limit use and emissions of HFCs.

Regarding cross-cutting policies:

- Leverage and enhance data collection and analyses to help a diverse portfolio of government offices, public university campuses, and other state buildings track energy use and GHG emissions, as well as prioritize opportunities and strategies for future emissions reductions.
- Assist Green Communities to reduce their energy use by 20% within 5 years of their official designation despite growth in demand for municipal services.
- Identify opportunities to engage more municipalities to participate in the Green Community Designation and Grant Program.
- Revise the Massachusetts Environmental Policy Act (MEPA) GHG Emissions Policy and Protocol including incorporation of climate change adaptation and resiliency and land use.
- Look for opportunities to deploy strategies that achieve adaptation and mitigation goals, such as sustainable forestry practices and urban tree planting.

ANALYZE AND DEVELOP A ROADMAP FOR MEETING THE GWSA EMISSIONS LIMIT FOR 2050, INFORMED BY EXISTING ANALYSES.

- Continue addressing socio-economic and environmental justice equity in policy design and implementation.
- Continue to integrate climate change mitigation and adaptation strategies and policies.
- Explore additional land use strategies and policies and promote nature-based solutions to increase carbon sequestration and avoid GHG emissions from natural and working lands.

INTRODUCTION

2.1 BACKGROUND

The Global Warming Solutions Act (GWSA) was signed into law in 2008, making Massachusetts one of the few U.S. states with ambitious GHG emissions reduction limits of 25% reduction below the 1990 baseline level by 2020 and at least 80% reduction by 2050. Since then, the Commonwealth of Massachusetts has made great strides in implementing feasible and cost-effective GHG emissions reduction strategies, coordinating state agencies, engaging stakeholders, evaluating progress towards the GWSA limits, and integrating GHG reduction strategies with climate change adaptation strategies. Through the combination of reducing and electrifying energy demand and decarbonizing energy sources, Massachusetts is on our way to meeting the emissions limits in the GWSA while continuing to support a vibrant economy, resilient communities, and a growing population.

Since passage of the GWSA in 2008, Massachusetts has created a strong framework of state laws, regulations, and executive orders that guides the Commonwealth's actions to address climate change, notably:

- **Energy Diversity Act of 2016** calling for large procurement of offshore wind and hydroelectric resources;
- **Executive Order 569** establishing an integrated climate strategy for the Commonwealth;
- **Clean Energy Standard** requiring retail electricity sellers to annually demonstrate the use of clean energy to generate an increasing percentage of their electricity sales;
- **State regulations** to set annual declining caps on sources of GHG emissions in the electric, transportation, and non-energy sectors;
- **Environmental Bond Bill** codifying aspects of E.O. 569 such as the development of a statewide climate adaptation plan and a grant program to assist municipalities to assess and address vulnerabilities to climate change and extreme weather;
- **Advance Clean Energy Act of 2018** setting new targets for offshore wind, solar, and storage technologies; expanding RPS requirements for 2020-2029; establishing a Clean Peak Standard; and permitting fuel switching in energy efficiency programs.

The framework provided by these laws, regulations, and executive orders builds on three overarching strategies through which the Commonwealth can effectively reduce GHG emissions: energy use reduction, electrification, and decarbonization. They also enable the Commonwealth to better prepare for climate change and extreme weather events through better coordination and assessment of vulnerabilities both within state government and at each municipality.

In fulfilling with the GWSA requirement to develop an implementation plan to achieve the 2020 emissions limit, EEA published the *Massachusetts Clean Energy and Climate Plan for 2020* (CECP) in 2010 featuring a broad suite of policies that aim to reduce GHG emissions in the Commonwealth across all sectors through increased energy efficiency in buildings and vehicles, the electrification of vehicles and thermal conditioning in buildings, and the replacement of carbon intensive fuels with renewable energy sources. The CECP included estimates of GHG reductions expected in 2020 from the full implementation of each policy. In 2015, as required by the GWSA, the EEA published a 5-year update to the CECP (2015 CECP Update), which included some new policies and their expected GHG reductions in 2020 as well as updates to the existing policies and revisions to their expected GHG reduction estimates.

2.2 PURPOSE AND SCOPE OF 10-YEAR PROGRESS REPORT

The purpose of this GWSA 10-Year Progress Report (Progress Report) is to meet several objectives. First, it is designed to comply with Section 5 of Massachusetts General Law (MGL) Chapter 21N and section 18 of the GWSA. These sections of the GWSA require that: 1) the Secretary of EEA monitor implementation of regulations relative to climate change and publish a report every five years on measures undertaken including recommendations regarding implementation; and 2) publish the first report of progress by January 1, 2014. In addition, Section 5 of MGL c. 21N requires EEA to consider how measures and strategies taken to reduce GHG emissions will affect other criteria and public policy considerations which are important to the Commonwealth, including:

- Equity, cost, and benefits
- Potential impacts on low-income communities
- Treatment of early voluntary emission reductions
- Interaction with federal and state air quality standards
- Other societal benefits
- Potential administrative burden
- Leakage
- Relative contribution to statewide GHG emissions
- Whether GHG reductions are "real, permanent, quantifiable, verifiable and enforceable"

The GWSA 5-Year Progress Report was published at the end of 2013. It provided qualitative discussion of possible effects of the CECP's implementation on these criteria and policy considerations whenever feasible. This Progress Report follows the same spirit as the 5-Year Progress Report, though estimates of GHG reduction from policy impacts can now be provided for each non-cross cutting policy in the 2015 CECP Update. The remainder of this Progress Report is organized as follows:

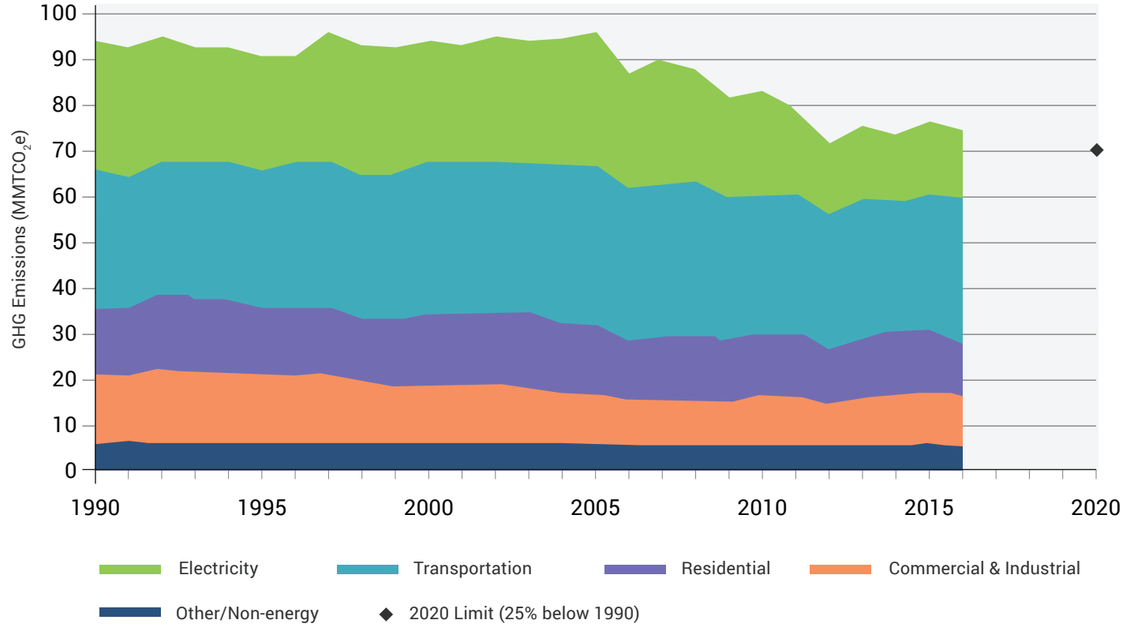
- Section 3: GWSA Implementation
- Section 4: GHG Mitigation Progress
- Section 5: Integrating Climate Change Mitigation and Adaptation
- Appendix A: GHG Reduction Methodologies

GWSA IMPLEMENTATION

3.1 GHG EMISSIONS TRENDS

The implementation of GHG emission reduction policies that were highlighted in the 2015 CECP Update, as well as additional policies and regulations implemented since then, is helping the Commonwealth effectively reduce GHG emissions and stay on track to meet the GWSA GHG emissions limit in 2020. The latest statewide GHG inventory[12] shows that GHG emissions in 2016 were 21.4% below the 1990 baseline level (Figure 2).

FIGURE 2 | MASSACHUSETTS GHG EMISSIONS, 1990 – 2016

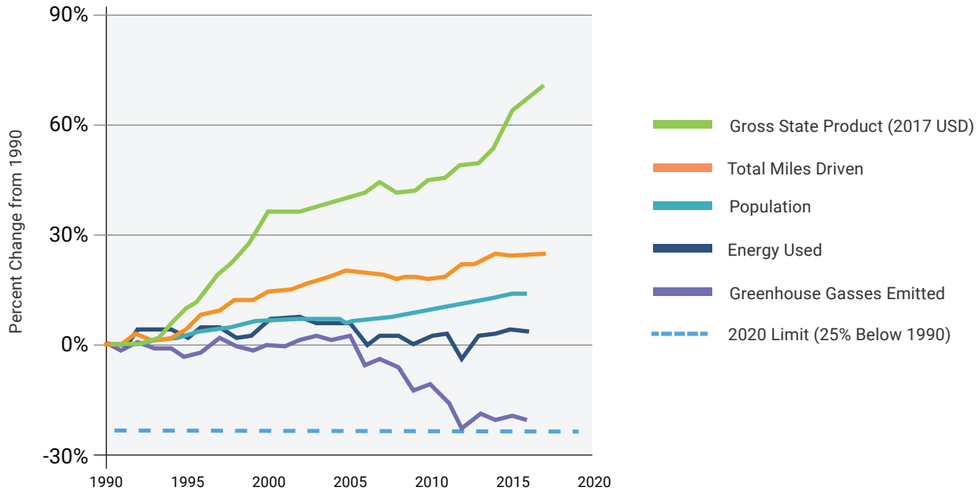


The long-term trend of GHG emissions reduction comes despite a 13% growth in population and 24% growth in vehicle miles traveled (Figure 3). Significant GHG emissions reduction from the electric sector since 2005 has been a major contributor to the drop in gross GHG emissions. Additionally, vehicle standards have lowered the carbon intensity of each vehicle mile traveled while energy efficiency measures in buildings helped control energy demand despite increased economic growth and variable weather conditions.

The trend of decreasing statewide GHG emissions indicates that our GHG mitigation policies are working. Recent analyses of GHG emissions trends to 2020 by EEA and state agencies in the LEAP modeling tool[13] indicate that GHG emissions in 2020 will be 25% below the 1990 baseline. Additional analyses of policy impacts indicate that, of the 20.2 $MMTCO_2e$ reduced in 2016 from the 1990 baseline level, approximately 11.6 $MMTCO_2e$ are attributed directly to the implementation of GHG mitigation policies from 2010 to 2016 (Figure 4). These reductions (represented by the solid colored bars) will grow larger over time as implementation of these policies continues. The remainder of the GHG emissions reductions observed in the GHG inventory (represented by the hashed colored bars) are not directly attributable to policies in the 2015 CECP Update, whether due to lack of available data, policies implemented prior to passage of the GWSA, or other factors such as weather conditions, relative fuel prices, and changes in consumer preferences. The negative reductions in the transportation and non-energy emissions sectors indicate that emissions reduction from policies implemented before the GWSA or from non-policy impacts counteract the GHG reductions from GHG mitigation policies implemented after the GWSA. On the other hand, policies implemented before the GWSA and non-policy impacts in the building and energy sectors have assisted the overall GHG reductions seen in these two sectors.

[12] The MassDEP develops and regularly updates an inventory of statewide GHG emissions, based on a combination of reputable federal data and data reported by regulated entities in Massachusetts. At the time of this Progress Report, the last year with full annual emissions data in the GHG emissions inventory is 2016.
[13] See Appendix A for discussion of analysis and modeling approach.

FIGURE 3 | TRENDS OF GROWTH IN GSP, VMT, AND POPULATION WHILE GHG EMISSIONS ARE DECREASING AND ENERGY USE HAS BEEN STABLE



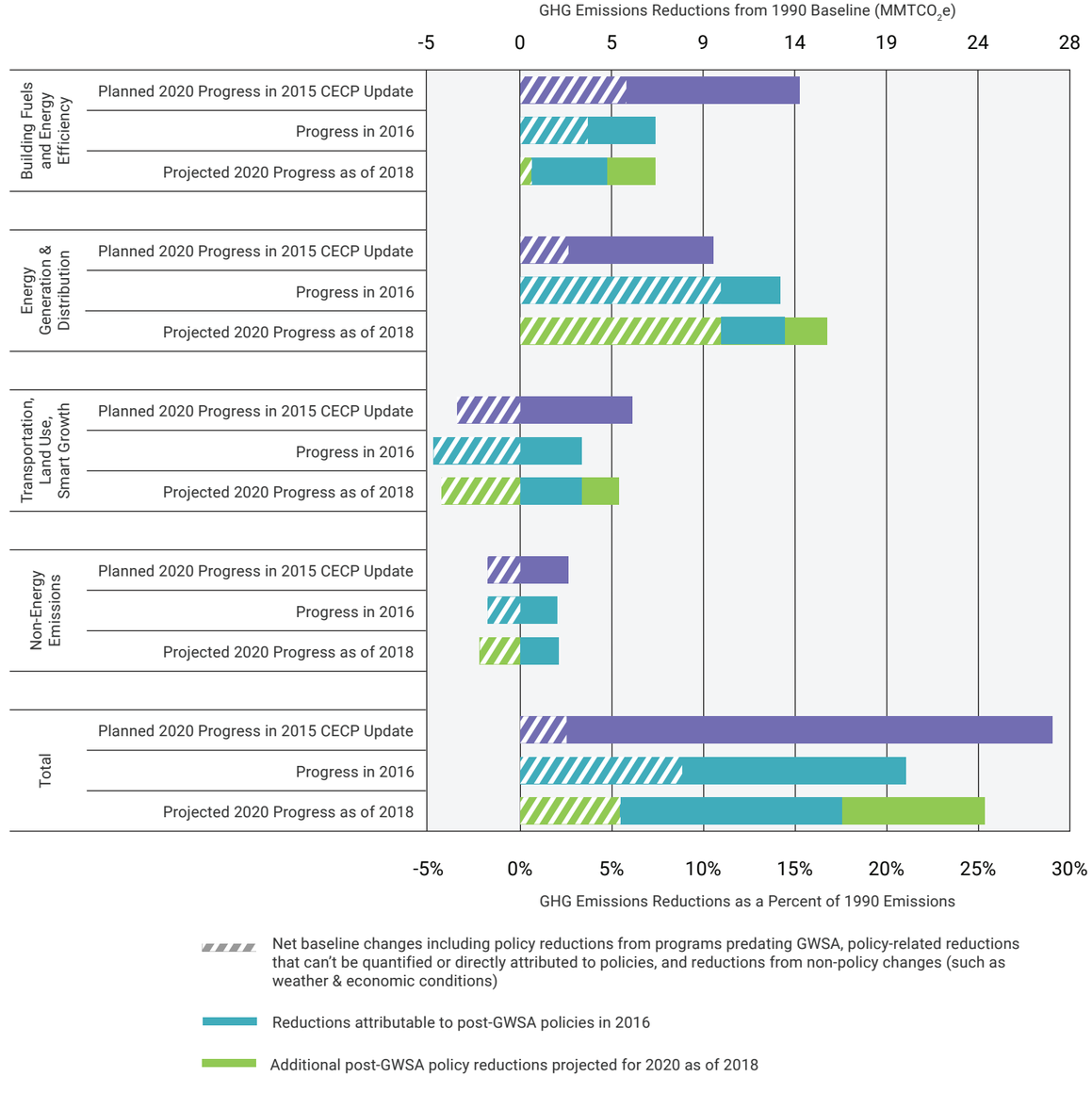
In 2020, post-GWSA policy implementation is estimated to reduce approximately 19 $MMTCO_2e$ or 20% below the 1990 level while the impact of pre-GWSA policies and other factors are estimated to reduce an additional 5 $MMTCO_2e$ or 6% below the 1990 level. These reductions add up to the 25% reductions from the 1990 baseline. Section 4 of this Progress Report discusses the estimates of GHG reductions from each policy and the implementation progress to date.

3.2 CONTINUED COLLABORATION, COORDINATION, AND STAKEHOLDER ENGAGEMENTS

The Commonwealth remains committed to meeting the requirements of the GWSA. In the first five years of GWSA implementation, EEA focused on building substantial institutional capacity, both within EEA and across state agencies, to enable smoother and more rapid implementation of climate and clean energy programs. This includes close collaboration of EEA state agencies and with other Secretariats that continues to date, as well as including valuable external stakeholder engagement and important regional coordination both within and outside the Commonwealth:

- **Interagency GWSA Team Leaders group:** Since 2012, staff representatives from MassDEP, DOER, DPU, the Department of Transportation (MassDOT), the Massachusetts Clean Energy Center (MassCEC), and other staff guests have met two to four times per month to discuss implementation and evaluation of GHG mitigation policies and to plan for the development of the Clean Energy and Climate Plans and the 5-year update, and GWSA Progress Reports.
- **GWSA Implementation Advisory Committee (IAC):** Established by the GWSA, the IAC has met four to six times per year since 2012 to discuss and provide advice on all aspects related to the implementation of the GWSA. Members are representatives from the following sectors: commercial, industrial, and manufacturing; transportation; low-income consumers; energy generation and distribution; environmental protection; and energy efficiency and renewable energy as well as from local government and academic institutions.
- **Zero Emission Vehicle (ZEV) Commission:** The ZEV Commission was established by the FY2015 Budget to recommend policies to expand access to electric and fuel cell vehicle infrastructure and to encourage the purchase and lease of these vehicles. Members of the Commission worked with the Massachusetts legislature to pass *An Act Promoting Zero Emission Vehicle Adoption* in 2016.
- **Commission on the Future of Transportation in the Commonwealth:** Established by Executive Order 579 in January 2018, the Commission was tasked with assessing key transportation trends between 2020 and 2040, developing plausible scenarios for the transportation

FIGURE 4 | PLANNED, ACHIEVED, AND PROJECTED GHG EMISSIONS REDUCTIONS (NEGATIVE REDUCTIONS ARE EMISSIONS, WHICH COUNTERACT THE POSITIVE REDUCTIONS)



sector in 2040, and providing recommendations for the transportation sector based on their analyses. The report by the Commission was published in December 2018.

- **Regional collaboration and coordination:** EEA and its state agencies participate in regional multi-state collaboration such as RGGI, the Georgetown Climate Center's Transportation and Climate Initiative, the Multi-state ZEV Task Force, and the Coalition of Northeastern Governors and Eastern Canadian Premiers. In addition, Massachusetts joined the U.S. Climate Alliance when it was formed in June 2017. State agency staff joins regularly scheduled working group phone calls on policy discussions and coordination.
- **Municipal collaboration and coordination:** EEA and its state agencies coordinate with municipalities on climate mitigation planning and analyses, such as state staff participation in the City of Boston's Carbon Free Boston initiative and state staff leadership of the Data Focus Group on data and assumptions behind GHG emissions pathways modeling and analyses.
- **External stakeholder engagement:** In addition to the GWSA IAC and the ZEV Commission, EEA and its state agencies regularly seek stakeholder input on numerous policy matters, including GHG emissions inventory development and updates, the Volkswagen Settlement Beneficiary Mitigation Plan, and transportation sector policies as part of the Transportation Listening Sessions in the Fall of 2017.

3.3 COMMITMENT TO MEETING GHG EMISSIONS LIMITS FOR 2020 AND BEYOND

The other components of capacity building were 1) the development of systems to track, evaluate, and report on climate change and clean energy programs and 2) the staff and software investments in GHG measurement, reporting, and policy implementation progress evaluation. In the first five years of GWSA implementation, EEA state agencies developed the Massachusetts GHG Registry and Inventory, the EEAC and the Evaluation, Measurement, and Verification (EM&V) framework, the RGGI CO_2 Allowance Tracking System (COATS), and other systems that document progress made toward program goals, identify program impacts, inform program planning and management decisions, and provide transparent information to the public. In the last five years, EEA has increased staff capacity to analyze the GHG reductions from policy implementation, and developed the CCPMS for tracking and reporting policy implementation progress. These investments help EEA and the state agencies estimate how much of the emissions reductions in GHG inventory is due to policy implementation thus far and how much GHG emissions reduction can be expected for 2020. Such progress information is included in this Progress Report, and communicated regularly to external stakeholders and the general public alike on the GWSA implementation online portal.[14]

For GWSA commitments beyond 2020, EEA and state agencies have begun preparing for the development of the *Massachusetts Clean Energy and Climate Plan for 2030*–due at the end of 2020–and a roadmap of how the Commonwealth can reach the GWSA emissions limit for 2050 in a strategic, equitable, and cost effective manner. Staff at EEA recently analyzed a scenario in the LEAP modeling tool projecting what statewide GHG emissions could be in 2050 with only existing GHG mitigation policies implemented (i.e., no new policies). Results were presented to the GWSA IAC throughout 2018 and posted on the GWSA implementation online portal[15] as part of the IAC meeting materials. Additionally, DOER recently completed the CEP that provides guidance to policy makers by examining the impacts of policies to reduce GHG emissions on cost and reliability. The Commission on the Future of Transportation in the Commonwealth also recently released a report summarizing the results of their fact finding, scenario development, and recommendations on transportation sector trends, needs, and GWSA compliance between 2020 and 2040.

In early 2019, building upon the recent analyses in the LEAP modeling tool, the analyses and subsequent recommendations from the CEP, and recommendations of the Commission on the Future of Transportation, EEA is commissioning a multi-year comprehensive "80x50 Study" to analyze and integrate the development of GHG emissions reduction pathways with a suite of recommended policies for the Commonwealth to set appropriate emissions limits for 2030 and to ultimately best meet the emissions limit of at least 80% below the 1990 baseline level by 2050. The recommended policies and implementation timeline could inform what policies are to be included in the CECP for 2030.

TABLE 2 | HOUSEHOLD INCOME AND ENERGY USE

Household Income Level	No. Households	Avg. Energy Use Per Household (kBTU/year)	Avg. Cost of Energy (USD/year)	Approximate Percent of Income
Less than $20,000	1,259,360	72,656	$1,873	9.4%
$20,000 - $39,999	1,323,719	94,072	$2,320	7.9%
$40,000 - $59,999	721,569	97,508	$2,565	5.2%
$60,000 to $79,999	752,101	96,761	$2,735	3.9%
$80,000 to $99,999	418,333	80,311	$2,232	2.5%
$100,000 to $119,999	424,537	128,897	$3,236	3.0%
$120,000 to $139,999	291,612	131,712	$3,440	2.7%
$140,000 or more	437,614	140,687	$3,850	2.7%

Source: EEA analysis, RECS 2015 Microdata, values represent all of New England

3.4 EQUITY

A key component of the GWSA is ensuring equitable impacts on and outcomes for all residents in Massachusetts. Low-income, non-English-speaking, and other vulnerable communities may not have the resources to adapt to climate change. Moreover, the cost of energy represents a larger portion of low-income households' annual income (Table 2), so even small increases in energy prices can be burdensome.

Not only are low-income households more vulnerable to changes in the energy market, they also contribute less to global warming, consuming on average less energy per household than wealthier households. Across New England, the lowest income bracket consumed only half as much energy per household as the highest income bracket (Table 2).

The 2015 CECP Update policies are sensitive to these needs and issues, and the Commonwealth has undertaken several initiatives to bring energy savings to those who need them the most. In 2017, Mass Save's low-income initiatives resulted in more than $220 million in total benefits, from investments of $110 million.[16] Expanding on that success, Governor Baker directed DOER and the Department of Housing and Community Development (DHCD) to collaborate with MassCEC to launch the Affordable Access to Clean and Efficient Energy (AACEE) Initiative with $15 million in committed funding. As an initial step in implementing the Initiative, MassCEC developed a new income-based rebate, among other programs, which sought to improve and expand access to the best and most efficient technologies.

In 2017, the AACEE working group published a report identifying significant barriers and opportunities for improving delivery of energy efficiency programs to low- and moderate-income households. The report identifies three major recommendations:

1. Aligning housing and clean energy processes, especially budget cycles and capital needs assessments.
2. Improving technical assistance and communication of benefits at the community level.
3. Targeting funding initiatives at specific barriers in very low-income communities and households.

The DOER and DHCD are taking steps in implementing the working group's recommendations, such as the Whole Building Incentive Program which is seeking competitive proposals to produce the maximum energy efficiency benefits at subsidized and public housing. Looking further into the future, the Initiative has also looked to expand DOER's Path to Zero grant program with the Zero-Energy Modular Affordable Housing Initiative, a pilot program that will build new homes or replace existing mobile or manufactured units with new affordable zero energy modular homes and provide lessons learned for future programming.

[14] https://www.mass.gov/progress-towards-reducing-greenhouse-gas-emissions
[15] https://www.mass.gov/service-details/the-global-warming-solutions-act-gwsa-public-meetings
[16] Mass Save® data

Additionally, EEA's Greening the Gateway Cities program provides both energy savings and health benefits to low-income urban communities. By buffering houses and neighborhoods against the wind in the winter and shading them from the sun in the summer, tree-planting can help to reduce heating and cooling demands, resulting in lower energy bills. These urban forestry projects also target public health benefits in some of the Commonwealth's most vulnerable communities by reducing the urban heat island effect and absorbing harmful air pollution.

3.5 ADDITIONAL BENEFITS OF GWSA IMPLEMENTATION

3.5.1 ECONOMIC BENEFITS

Massachusetts' experience implementing the GWSA shows that environmental programs can support economic development. According to MassCEC's 2018 Clean Energy Industry Report, the clean energy industry employs more than 110,000 people in Massachusetts (Figure 5), most of whom earn more than $50,000 per year. This sector contributes $13.2 billion to the Commonwealth's economy, or about 2.5% of its annual GSP.[17] Moreover, electric generation companies spent more than $700 million on fuel to run their power plants in Massachusetts in 2017,[18] almost all of which was imported from another state or country. Continuing to build Massachusetts' clean energy portfolio will mean that costs that would have gone to generate electricity via traditional fossil fuels will instead benefit Massachusetts' economy. As the clean energy industry continues to grow, this will benefit the economy of Massachusetts as a whole.

Clean energy innovation has played, and will continue to play, a powerful role in accelerating our progress toward the Commonwealth's GHG reduction goals. Clean energy innovation has reduced the cost of clean energy technologies, thereby facilitating more rapid adoption, and improved the performance of clean energy technologies. Meanwhile, clean energy business and financing model innovation has helped promote broader adoption of climate solutions, helping to impact difficult to reach customer segments. The MassCEC has invested nearly $40 million over the past 5 years in Massachusetts clean energy technology innovation and companies, leveraging nearly $134 million in private investment. These strategic investments in clean energy innovation create jobs, provide more GHG reduction strategy options for the state, attract private investment, and complement our existing portfolio of efficiency, electrification, and decarbonization.

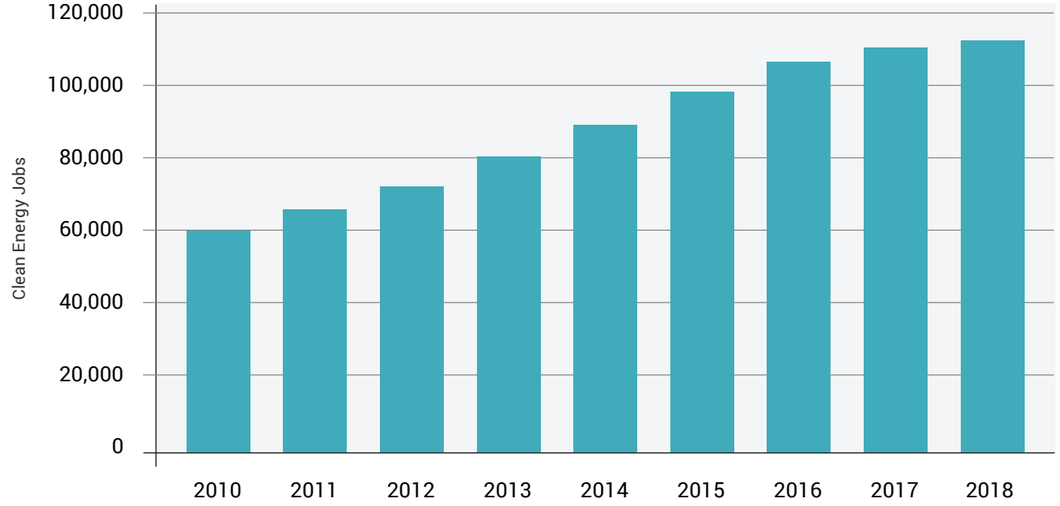
In addition to stimulating economic growth, investing in renewable energy and energy efficiency keeps more of Massachusetts residents' dollars in their wallets. Mass Save® energy efficiency measures investments in 2017 alone will save over 14.4 million megawatt hours of electricity and 371 million therms of natural gas over their lifetime.[19] Net economic benefits from ratepayer and state investment in the Mass Save® programs, since their expansion beginning in 2010 through 2020, are projected to exceed $18 billion through a combination of direct bill savings, avoided supply and infrastructure costs, as well as non-energy benefits such as improvements to building real estate values and health outcomes for low-income populations.

3.5.2 PUBLIC HEALTH BENEFITS

In addition to carbon dioxide, burning fossil fuels can release other pollutants, such as SO_x, NO_x, PM_{10}, $PM_{2.5}$, and Hg. Exposure to Hg, even in trace amounts, can result in severe medical issues, including neurological problems and kidney failure. Once emitted, SO_x and NO_x can cause acid rain, act as respiratory irritants, and combine with other compounds to produce ozone and particulate matter, both of which can also cause or exacerbate respiratory conditions. In 2016, asthma affected over a million Massachusetts residents, including more than 200,000 children, limiting physical activity and causing them to miss work or school, respectively.[20] In 2002, the U.S. EPA's Clear Skies Program estimated that, by 2020, a suite of policies covering SO_x, NO_x, and Hg (including pre-existing state clean air regulations) would result in $340 million to $1.8 billion in health benefits for Massachusetts, including 300-500 fewer premature deaths and 860 fewer hospitalizations.[21]

Since 1990, Massachusetts has followed through on many policies addressing criteria pollutants, and pollutant emissions have dropped precipitously (Figure 6). The Low-Emission Vehicle (LEV) program and Inspection & Maintenance (I&M) Programs administered by MassDEP have led to a 60% decline in NO_x emissions since 1990,

FIGURE 5 | CLEAN JOB GROWTH IN MASSACHUSETTS



even as Massachusetts residents have driven more vehicle miles each year.[22] $PM_{2.5}$ emissions from all highway vehicles fell from 4,934 tons in 2008[23] to 1,101 tons in 2016[24] — a 78% decline. Although any fossil fuel combustion will emit some of these pollutants, coal in particular emits SO_x and Hg in significant quantities.[25] Power plants, a major consumer of coal in Massachusetts, burnt more than 4.2 million tons of coal in 1990.[26] The last coal-fired power plant in the Commonwealth, Brayton Point, retired its final boiler in May 2017. Echoing that decline, sulfur dioxide emissions have fallen from about 1,000 tons per day in 1990 to almost none today.[27]

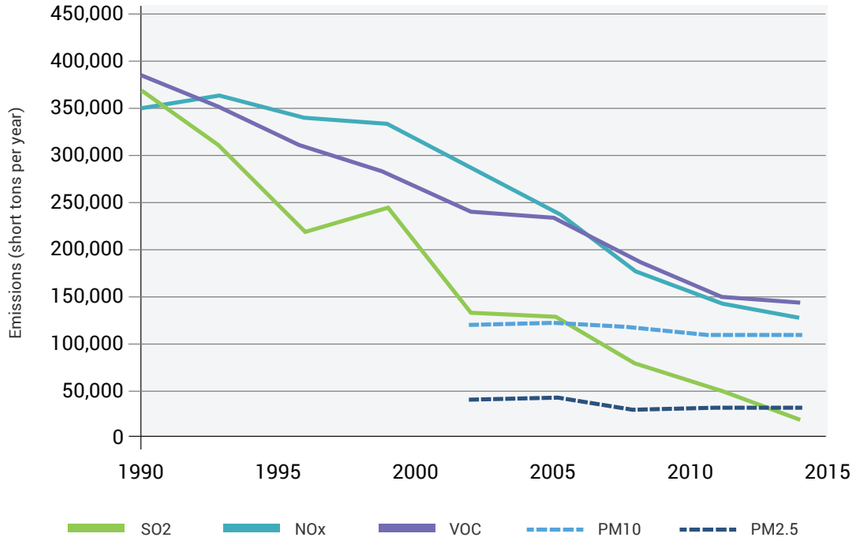
The Complete Streets Program, a major component of the Smart Growth policies and implemented by MassDOT, looks to improve pedestrian and bicycle infrastructure across the Commonwealth, which could help reduce personal vehicle travel and emissions. Two out of three adults in Massachusetts are obese, resulting in $3.5 billion annually in excess health care costs.[28] Developing walkable and bikeable communities can alleviate these health care costs by allowing or promoting active commuting, as well as simply encouraging physical exercise and recreation. Emphasizing dense communities with walkable town centers and easy access to public transit, these programs can reduce carbon emissions as well as foster a greater sense of community and civic pride throughout the Commonwealth.

3.5.3 ECOSYSTEM SERVICES

Several of EEA's GHG mitigation policies also serve to protect natural resources and the built infrastructure. The Greening the Gateway Cities urban tree planting program alleviates the urban heat island effect, and can reduce the energy bills of the residents of these communities. Urban forestry also reduces storm-water runoff and absorbs air pollutants. According to an analysis by the Metropolitan Area Planning Council (MAPC), urban forests in the 15 communities of Metro Boston (i.e., the Metro Mayors Coalition) store 962,000 tons of carbon, worth $125 million,[29] and capture an additional 23,000 tons of carbon per year, worth nearly $3 million. Added benefits include

[17] MassCEC's 2018 Clean Energy Industry Report
[18] U.S. Energy Information Administration, State Energy Data System, https://www.eia.gov/state/seds/data.php?incfile=/state/seds/sep_sum/html/sum_ex_eu.html&sid=MA
[19] Mass Save® data
[20] Massachusetts 2016 Diesel Particulate Matter Inventory, https://www.mass.gov/lists/massdep-emissions-inventories
[21] https://archive.epa.gov/clearskies/web/html/ma.html
[22] Massachusetts 2011 Periodic Emissions Inventory, https://www.mass.gov/lists/massdep-emissions-inventories
[23] Massachusetts 2008 Periodic Emissions Inventory, https://www.mass.gov/files/documents/2016/08/ou/08pei-data.pdf
[24] Massachusetts 2016 Diesel Particulate Matter Inventory, https://www.mass.gov/lists/massdep-emissions-inventories
[25] EPA FIRECHIEF database
[26] U.S. Energy Information Administration, State Energy Data System
[27] Massachusetts 2011 Periodic Emissions Inventory, https://www.mass.gov/lists/massdep-emissions-inventories
[28] Mass in Motion, https://www.mass.gov/files/documents/2016/07/vm/mim-community-overview.pdf

FIGURE 6 | EMISSIONS OF CRITERIA POLLUTANTS IN MASSACHUSETTS



527 million gallons of avoided stormwater runoff, worth $4.7 million,[30] and 1.75 million pounds per year of air pollutants removed, worth $11 million.[31,32]

The suite of policies collectively referred to as Smart Growth seeks to reduce suburban sprawl and make communities physically denser and more interconnected. By reducing total land lost to development, the policy preserves the intrinsic benefits of natural landscapes and ecosystem services, including the land's actual resources and secondary impacts such as storm-water and water quality management. Preserving the remaining agricultural lands in Massachusetts also yields cultural benefits, as well as some ecosystem benefits from low impact, small-scale farming.

[29] Economic value = $143 /metric ton value of carbon storage or capture * social cost of carbon, an economic value quantifying in dollars the long-term damage due to a ton of carbon in a given year (EPA).
[30] iTree Landscape. Economic value of avoided runoff = (The difference between runoff with existing vegetative cover by Land Use Data minus the runoff where impervious surface replaces vegetative cover) * value of runoff (Hirabayashim 2015)
[31] iTree Landscape. Pollution Removal Economic Benefit = pollution removal (g/m_ from tree cover)* value of pollution mitigation ($/m^2 of tree cover where values determined by EPA BenMAP)
[32] iTree Landscape, 2018. Model run on June 19, 2018.

GHG MITIGATION PROGRESS

Concord Highlands, Cambridge, MA 98 Units of Affordable Housing Seeking Passive House Certification and 105 KW Solar PV Array. First floor designed to be resilient to flooding. Owner: Homeowner's Rehab Inc. Architect: ICON Architecture

4.1 BUILDING FUELS AND ENERGY EFFICIENCY

4.1.1 OVERVIEW

Electricity and fossil fuel consumption in residential, commercial, and industrial buildings accounts for more than half of Massachusetts' energy use and half of GHG emissions in the Commonwealth. The 2015 CECP Update outlined a variety of strategies to reduce energy use and GHG emissions from the buildings sector. The primary strategy for reducing building energy use is implementation of 'all cost-effective energy efficiency and demand reduction' as laid out in the Green Communities Act (GCA) of 2008, and subsequently modified by energy legislation in 2012 and 2018.

Aligned with the policy of pursuing all cost-effective energy efficiency and demand reduction are a number of complementary and overlapping policies for managing energy demand in buildings. These include improving building energy codes, adopting updated appliance standards, and accelerating the adoption of renewable thermal heating technologies. The buildings sector has also seen a continuing trend of downward carbon emissions due to residential and commercial conversions from heating oil to natural gas. These fuel conversions have been driven largely by economics, due to the price differential between heating oil and natural gas.

The 2015 CECP Update sets an emissions reduction goal for the buildings sector of 9.0 percent below 1990 emission levels. Progress to date on these policies is summarized in Tables 3 & 4, and described in more detail in the next section. In addition to implementing these policies, the Commonwealth is also pursuing supplemental strategies to further boost consumer awareness and market drivers for energy and carbon savings in the buildings sector.

TABLE 3 | SUMMARY OF ESTIMATED GHG REDUCTIONS FROM POLICY IMPLEMENTATION*

	PLANNED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2015)		2016 PROGRESS		PROJECTED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2015)	
	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL
Building Fuels and Energy Efficiency	9.0	9.5%	4.0	4.2%	6.8	7.2%
All Cost-Effective Energy Efficiency	5.4	5.8%	3.2	3.4%	5.1	5.4%
Advanced Building Energy Codes	1.5	1.6%	0.7	0.7%	0.8	0.9%
Building Energy Rating and Labeling	–	–	Cross-cutting policy; savings reflected elsewhere.			
Expanding Energy Efficiency Programs to Commercial and Industrial Heating Oil	<<0.1	<<0.1%	Reductions to be included in All Cost-Effective Energy Efficiency.			
Appliance and Product Standards	1.0	1.1%	0.1	0.1%	0.8	0.8%
Renewable Thermal Technologies	1.0	1.1%	<<0.1	<<0.1%	0.1	0.1%
Tree Retention and Planting to Reduce Heating and Cooling Loads	<<0.1	<<0.1%	<<0.1	<<0.1%	<<0.1	<<0.1%

* See Appendix A for summary of methodology.

4.1.2 BUILDINGS SECTOR POLICIES

ALL COST-EFFECTIVE ENERGY EFFICIENCY

The Baker-Polito Administration has consistently prioritized energy efficiency as a central component of the Commonwealth's energy policy. In large part, this is due to the recognition that cost-effective delivery of energy efficiency is a win-win strategy which provides substantial economic benefits to consumers and businesses, retains more capital in the local economy, and results in other environmental benefits (e.g., improvements to air quality) in addition to significant and sustained GHG reductions. The policy to implement all cost-effective energy efficiency, primarily through the statewide Mass Save® programs, has the highest projected GHG reduction of all policies in the 2015 CECP Update, at 5.4 percent of the 1990 level. This estimate only includes the additional GHG reductions since 2009 from the expansion of the state's energy efficiency programs under the GCA, recognizing that Massachusetts has established energy efficiency programs dating back to 1990.

Under the requirements of the GCA, investor-owned natural gas and electric utilities in Massachusetts are required to acquire all cost-effective energy efficiency, i.e., energy efficiency which is less costly than securing additional energy supply. The Program Administrators (PAs) [33] begin the implementation process for natural gas and electricity efficiency programs by submitting a Three-Year Plan for approval by the DPU, the first of which covered 2010-2012. In these plans, the PAs outline their intentions for the types of energy efficiency programs (e.g., high-efficiency lighting) and customer classes (i.e., residential, commercial and industrial, and low-income) they expect to reach, the expected costs and benefits of implementing the programs, and the target energy and demand savings.

These plans have matured to the point where they have been delivering sustained GHG savings for the past 5 years after growing dramatically over the first two 3-year plan periods. In the period since 2014, the Mass Save®

[33] The Cape Light Compact is also an energy efficiency provider and participates in the development of the Three-Year plans.

TABLE 4 | IMPLEMENTATION PROGRESS ON BUILDING FUELS AND ENERGY EFFICIENCY POLICIES FROM THE 2015 CECP UPDATE

BUILDING FUELS AND ENERGY EFFICIENCY		
Policies	Key Accomplishments and Highlights	Recommendations and Next Steps
All Cost-Effective Energy Efficiency	• The Mass Save® 3-year plans have saved on average over 800,000 metric tons/year since 2014. The program is on track to deliver over $18 billion in net benefits by 2020. • Electricity savings grew from under 1% of annual sales in 2009 to over 3% in 2017; natural gas savings grew from 0.5% to 1.2%.	• Continue Commonwealth's investment in all cost-effective energy efficiency and demand reduction thru Mass Save®, including new opportunities to increase gas energy efficiency. • Expand programs to promote fuel conversions from oil and propane heating to renewables and efficient electrification. • Focus on peak demand reduction in the summer and winter through new active demand management programs.
Advanced Building Energy Codes	• Widespread adoption of the Stretch energy code by 250 towns and cities as of November 2018 helped offset modest improvements in IECC model energy codes in recent years. • Sharp decline in residential construction during housing-led recession has now returned to historical levels with more multi-family housing units.	• The Baker-Polito Administration has set a goal of 135,000 new housing units by 2025 as part of the Housing Choice Initiative. Explore how best to encourage high efficiency building construction of these units in a cost-effective manner. • Explore possible ways to drive additional efficiency in new construction and better support renewable energy, electrification, energy storage, and resiliency policy goals.
Building Energy Rating and Labeling	• DOER's 'HomeMPG' and 'Home MVP' energy scorecard pilots led to commitment to residential scorecard integration in Mass Save® programs. The Baker-Polito Administration filed proposed legislation in 2018 to require home energy scorecard disclosure during real estate transactions. • Commercial building operational performance is tracked by Cities of Boston and Cambridge, but DOER's commercial asset rating pilot demonstrated challenges in asset rating of diverse range of commercial buildings.	• Create a market incentive for consumers to invest in energy efficiency improvements through a "Home Energy Scorecard".
Expanding Energy Efficiency Programs to Commercial/ Industrial Heating Oil	• The Advance Clean Energy Act of 2018 enables fuel switching to clean energy sources in all sectors, including heating oil in the Commercial & Industrial (C&I) sector.	• Continue to promote fuel switching in the C&I sector.
Appliance and Product Standards	• Federal standards for various household appliances and device chargers are estimated to save Massachusetts residents more than $20 million in energy costs by 2020.	• Consider state-level and regional next-generation appliance and product standards with other US Climate Alliance states.
Renewable Thermal Technologies	• The Alternative Energy Portfolio Standard was modified in 2017 to provide financial incentives for renewable thermal technologies. • The Baker-Polito Administration committed $3 million for the Renewable Thermal Infrastructure Grant Program. • MassCEC launched the HeatSmart Mass program in 2017 in select communities and the Reheat Mass program in 2018 to encourage adoption of renewable thermal technologies.	• Expand utility programs to offer consumer rebate for renewable thermal technologies, especially for air source heat pumps. • Promote fuel switching through expanded public outreach efforts.
Tree Retention and Planting To Reduce Heating and Cooling Loads	• Over 19,000 trees have been planted in 14 Gateway Cities. • The Baker-Polito Administration has committed $1 million annually in planning grants, with tree retention bylaws or incentives encouraged as one of the eligible activities.	• Pursue necessary information and establish systems to track the effectiveness of VMT reductions and changes in land use and land cover change associated with smart growth.

programs have saved on average over 800,000 metric tons/year – a roughly 4-fold increase in annual GHG savings from the baseline year of 2009. During this same time period, the American Council for an Energy-Efficient Economy *(*ACEEE) has ranked Massachusetts as the number 1 state for energy efficiency policy for 8 straight years from 2011-2018.

The recently filed statewide plan covering 2019-2021 projects the Mass Save® programs to maintain this nation-leading rate of GHG reductions through 2020 even as programs begin to undergo a significant shift away from residential lighting savings. Beyond 2020, residential and commercial lighting savings will be accounted for in the Appliance and Product Standards policy. The filed 2019-2021 plan, currently under review at the DPU, proposes the following improvements and shifts from previous plans to ensure a balanced portfolio of programs and continued GHG impacts:

- Additional savings goal on electric energy efficiency to quantify overall MMBtu reductions including electric, oil, and propane savings;
- Emphasis on fuel switching from delivered fuels to the efficient electrification of heating;
- New active demand management programs to educe peak electric consumption in both the summer and winter;
- Among the highest natural gas reduction targets ever seen in the U.S.; and
- New residential sector program design improvements to continue to invest in cost-effective electricity savings as residential lighting savings transition into appliance standards.

The impact of fuel interactions

Table 5 shows the anticipated GHG reductions, fuel savings, and economic benefits to consumers and businesses from all cost-effective energy efficiency.

As Table 5 illustrates, progress on electric energy efficiency has slightly exceeded the forecast for 2020 made in 2015, whereas natural gas and fuel oil savings are significantly lower than originally forecasted. The primary driver of these low gas and oil savings are the unanticipated interactive effects on heating fuels of two dominant electric energy efficiency measures over the past decade: the market shift from incandescent and fluorescent lighting to light emitting diode (LED) lighting across all sectors, and the adoption of combined heat and power in the commercial and industrial sector.

1. LED lighting - indirectly increases heating fuel usage

Improvements in the efficiency of lighting since 2010 have been dramatic. In recent years, the market has rapidly migrated to LED lighting in all sectors. The superior conversion of electricity into useful light enabled by LEDs relative to incandescent, halogen, and fluorescent lighting significantly reduces the heat generated as a by-product of lighting in buildings. Where incandescent lights would previously provide a small percentage of heating in a typical home or business, that heat is now typically provided by a few additional Btu of oil, propane, or natural gas each winter. This interactive effect has led to net increases in oil and propane usage from the electric Mass Save® programs in recent years as lighting retrofits across all buildings counteracted the significant heating fuel savings from the insulation and air sealing of homes, and limited envelope improvements in commercial spaces.

2. Combined Heat and Power – electric savings that increase natural gas usage

Combined Heat and Power (CHP), also known as co-generation, increases system energy efficiency in buildings by generating electricity on-site typically from natural gas as a source fuel, and utilizing much of the waste-heat from the electric generation process to provide building heating and process loads. The net impact of the addition of a CHP system is to significantly reduce electric MWh while increasing natural gas usage. Since 2008, Massachusetts has been recognized as a leading state in the promotion of CHP with the Mass Save® programs, complemented by significant Alternative Energy Certificates (AECs) through the Alternative Energy Portfolio Standard, all while natural gas prices have been at historically low levels. CHP is an important strategy for generating power and heat more efficiently, but does result in significant increases in building natural gas usage, which impacts the GHG savings attributable to natural gas energy efficiency in Table 5.

TABLE 5 | PROJECTED SAVINGS FROM ALL COST-EFFECTIVE ENERGY EFFICIENCY

CUMULATIVE IMPACT OF EE	FORECAST IN 2015 FOR 2020	UPDATED PROJECTION IN 2018 FOR 2020	% OF 2015 FORECAST
GHG Reductions in 2020	5.4 $MMTCO_2e$ (5.8% of 1990 level)	5.1 $MMTCO_2e$ (5.4% of 1990 Levels)	94%
Electricity Savings in 2020 (MWh)	9,000,000	9,700,000	108%
Natural Gas Savings in 2020 (MMBTU)	19,700,000	12,200,000	62%
Heating Oil Savings in 2020 (MMBTU)	3,200,000	1,500,000	47%
Propane Savings in 2020 (MMBTU)	0	130,000	
Cumulative Net Benefits, 2010 to 2020	**$14.4 billion**	**$18.0 billion**	**125%**

Source: DOER 2018

3. Low Natural Gas prices

Low natural gas prices also pose a challenge to gas efficiency programs because low prices dampen the magnitude of energy savings from efficiency, thereby resulting in longer "pay-back" periods on a given investment. Natural gas efficiency program savings goals have grown from 0.5 percent of annual sales in 2009 to over 1.2 percent of annual sales by 2017, but this is a slower rate of growth than experienced in the electric programs that have achieved 3 percent annual sales at the peak of lighting and CHP claimable savings. There continues to be a focused effort on natural gas efficiency, with the 2019-2021 filed targets at the highest levels yet, at 1.25% of annual sales.

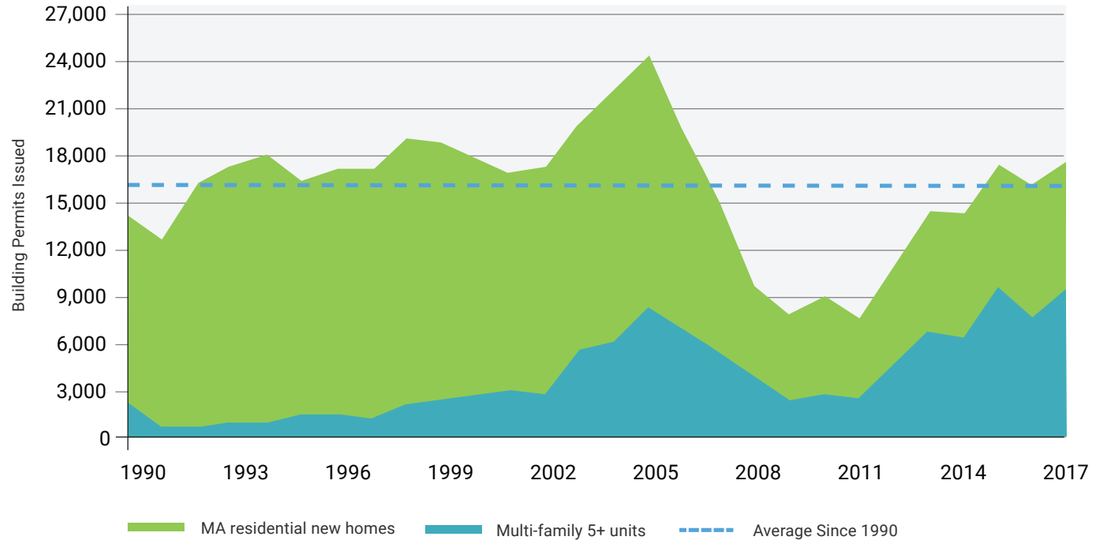
ADVANCED BUILDING ENERGY CODES

The 2015 CECP Update makes clear that a strategy requiring advanced building energy codes is one of the lowest-cost options for reducing GHG emissions. In the GCA, Massachusetts adopted a requirement that building energy codes meet or exceed the International Energy Conservation Code (IECC) and stay current with the IECC's three-year update cycle. An update to the base energy code is currently underway based on the 2018 International Energy Conservation Code (IECC2018). Nonetheless, this update from IECC2015 to IECC2018 only represents a 1% improvement on average for residential homes, as compared to the 15% average improvement made when the Commonwealth moved from the IECC2009 to the IECC2012. The slowing progress of the IECC national model energy codes has been partially mitigated by Massachusetts' nation-leading adoption of a "stretch" energy code at the city and town level. The Stretch Code in Massachusetts has also accelerated the transition from a prescriptive code, which dictates specific energy measures, to a performance code pathway that encourages building designers to focus on a building's overall energy performance. As noted in the discussion of Green Communities later in this Progress Report, 250 communities in Massachusetts, representing more than 2/3rd of the state population, have voluntarily adopted the Massachusetts stretch energy code as of November 2018.

Greenhouse gas reductions from advanced building energy codes were impacted not just by the slow improvements in the IECC model code, but also notably by the national housing sector economic recession. As Figure 7 illustrates, construction of new homes fell precipitously from 2005 to 2009, and remained below historic averages through 2014. Home construction has largely recovered to historic average levels in recent years. Equally significant, the housing recovery has come with an increased percentage of multi-family homes in urban and semi-urban areas, relative to single-family homes. This shift reflects the urban-led 'smart growth' experienced in Massachusetts as in many other states, which has also resulted in a commercial construction boom in metro-Boston.

Despite the recovery of the construction sector, the lean intervening years since 2008 contributed to a reduction in the expected GHG policy impact for this

FIGURE 7 | CONSTRUCTION OF NEW RESIDENTIAL UNITS IN MASSACHUSETTS, 1990 TO 2017



Source data: https://www.census.gov/construction/bps/stateannual.html

strategy to 0.9% of the 1990 baseline by 2020. Going forward, the Comprehensive Energy Plan identified increasing emissions savings from new construction through building envelope efficiency improvements and increased electrification as increasingly critical components of policies for meeting the 2050 emissions limit.

BUILDING ENERGY RATING AND LABELING

Rating and labeling buildings according to their expected energy use provides prospective building owners and tenants with information on the comparative energy costs of potential homes and work spaces. Currently, this information is largely absent from decision-making in real estate markets, even though Massachusetts' residents and businesses use more energy in their buildings than any other sector. In the same way that the familiar "miles per gallon" rating of vehicle fuel efficiency communicates to buyers how much they can expect to spend to operate their vehicle, building energy scorecards seek to address the "market failure" which exists due to the lack of energy information. This in turn would enable better informed decisions and create incentives for the real estate market to invest in more efficient buildings.

As noted in the 2015 CECP Update, the potential GHG reductions associated with this policy are indirect, and GHG reductions will likely be captured through the All Cost-Effective Energy Efficiency policy. It is appropriate then that residential scorecards are being integrated into the Mass Save® residential home assessment program in the recently filed 2019-2021 plans.

In developing the Commonwealth's Building Energy Rating and Labeling policy, DOER implemented two residential pilot programs; the first was a collaboration with Mass Save® partners in the Springfield area in 2013-2014 and the more recent was through the contractor focused Home MVP program[34] available statewide.

For the commercial buildings sector, DOER implemented a Building Asset Rating (BAR) pilot over two phases from 2013-2016 with support from the cities of Boston and Cambridge and the Mass Save® PAs The BAR pilot demonstrated that streamlined asset rating tools are available which can provide energy efficiency investment recommendations at a much lower cost than traditional audit protocols for commercial buildings.

[34] https://www.mass.gov/guides/home-mvp

Commercial and multi-family buildings can be effectively benchmarked using operational tools, most notably using EPA's Portfolio Manager tool. The Cities of Boston and Cambridge have leveraged the U.S. EPA tool to implement energy disclosure ordinances (which apply to commercial buildings greater than 25,000 square feet) to inform and motivate energy performance improvements. However, the diversity of the commercial building stock in the Commonwealth makes it more challenging to create a standardized asset score in the commercial sector than can be done in the residential market.

EXPANDING ENERGY EFFICIENCY TO COMMERCIAL AND INDUSTRIAL HEATING OIL

When the 2015 CECP Update was published in 2015, measures to improve heating oil energy efficiency in Massachusetts were limited to residential customers in 1-4 family homes. The 2015 CECP Update estimated that expanding heating oil programs to commercial and industrial customers would result in GHG reductions of less than 0.1 MMTCO2e (or less than 0.1 percent of the 1990 level). A significant step toward this goal was made in 2018 with new legislation allowing the Mass Save® PAs to expand the scope of heating oil energy efficiency funding to commercial and industrial customers as well as residential customers. The PAs have committed to promoting fuel switching in both the residential and the commercial and industrial sectors in the filed 2019-2021 Mass Save® plan, with a focus on shifting customers away from delivered fuels (heating oil and propane) to efficiency, and in particular cold-climate air source heat pumps (ASHPs). Therefore, moving forward, this policy is being merged with the All-Cost Effective Energy Efficiency policy.

FEDERAL APPLIANCE AND PRODUCT STANDARDS

Federal standards for various household appliances and device chargers are estimated to save Massachusetts residents and businesses hundreds of millions in energy costs each year.[35] Efficiency standards for most products, appliances, and electronics are set by the U.S. Department of Energy (DOE) with a pre-emption on state standards for products covered at the federal level. However, Massachusetts did request a waiver to set its own higher standard for furnaces. While the Massachusetts waiver was denied, it did lead to a new regional efficiency standard for furnaces being proposed under the Obama Administration. Nonetheless, progress at the federal level has been slower than anticipated in the 2015 CECP Update, and has led to renewed interest in state legislation to set appliance and product standards where federal pre-emption does not apply. State standards would provide modest incremental savings, which would accrue steadily after 2020 and could contribute to GHG emissions reduction significantly by 2030. The updated forecast for statewide energy savings by 2020 from updated federal appliance standards is 0.8 $MMTCO_2e$, (0.8 percent reduction from the 1990 level).

RENEWABLE THERMAL TECHNOLOGIES

Thermal energy use for process heat and space conditioning of buildings accounts for over 30% of the GHG emissions in Massachusetts. The trend for this sector has largely remained unchanged, presenting a significant opportunity to reduce GHG emissions by converting existing heating systems to a renewable thermal technology. In Massachusetts, renewable thermal technologies have been supported through the MassCEC incentive programs. These programs have particularly been effective at increasing the use of ASHPs for heating and cooling conditioned spaces. Additionally, the APS supports incentives for renewable thermal technologies. Similar to the RPS, the APS requires a certain percentage of the Commonwealth's electric load to be met by eligible technologies, which for APS includes renewable thermal technologies among others. The annual percentage requirement increases by 0.25 percent per year indefinitely. System owners create AEC when their system generates heat, and these AECs are subsequently sold into the market, producing revenue for the system owner.

In 2017, MassCEC began the HeatSmart Mass program. The program seeks to increase the number of renewable thermal installations by supporting local grassroot awareness campaigns in select communities across the state. Building off of this effort, MassCEC began the Reheat Mass program in 2018 to expand the public awareness campaign across the entire state through

[35] https://appliance-standards.org/sites/default/files/fedappl_ma.pdf

online advertisements focused on specific consumers based on geographic location and socio-demographic profiles. Analysis will be undertaken to refine the advertisement messaging in future years.

The DOER has also undertaken a second round of Renewable Thermal Infrastructure Grants in 2018. The purpose of the funding is to build the supply chain services for renewable thermal technologies, allowing for more businesses to offer systems, and to increase supply of fuels (such as biomass) to ensure demand for the systems can grow.

Going forward, the Mass Save® program will increase its role to incentivize renewable thermal technologies, notably for air source heat pumps.

TREE PLANTING & RETENTION

The Greening the Gateway Cities Program continues to aggressively plant trees. The primary purpose of the Greening the Gateway Cities Program is to reduce building energy consumption, but trees also sequester carbon, reduce stormwater runoff, improve air quality, and enhance property values. As of the Fall of 2018 there are eight active Department of Conservation and Recreation (DCR)planting crews, and the Program is also funding planting being completed by the Cities of New Bedford and Springfield and by the non-profit Groundwork Lawrence on behalf of the City of Lawrence. The Program's current planting rate is about 8,000 trees per year. As of December 2018, more than 19,000 trees have been planted in the 14 Gateway Cities in which the Program is currently active:

- Brockton: 1,378
- Chelsea: 1,880
- Chicopee: 1,531
- Fall River: 2,463
- Haverhill: 1,577
- Holyoke: 1,588
- Lawrence: 1,061
- Leominster: 1,907
- Lynn: 1,213
- New Bedford: 232
- Pittsfield: 1,949
- Quincy: 819
- Revere: 1,302
- Springfield: 286

The intent is to plant in the other 12 Gateway Cities (Attleboro, Barnstable, Everett, Fitchburg, Lowell, Malden, Methuen, Peabody, Salem, Taunton, Westfield & Worcester) by shifting planting crews as soon as the target of at least five trees per acre – set in order to reach sufficient tree canopy density to reduce energy use – is reached in each of the currently active communities. While the target zones in each city vary in size, the Program is generally looking to plant about 2,400 trees in each Gateway City. In several cities, such as Chelsea & Fall River, the Program has started to plant in nearby cities (Revere & New Bedford) as the limit is approached. The Program has recently hired a marketing firm in order to reach additional willing property owners – necessary to attain the minimum trees/acre target.

In regard to tree retention, starting in 2017, the Baker-Polito Administration has committed $1 million annually in planning grants. These planning grants are offered to communities interested in adopting an incentive or regulatory requirement, such as zoning, to encourage or require that trees be retained as a site is developed.

4.1.3 CONCLUSIONS AND RECOMMENDATIONS

With the impetus and authority provided by the GWSA and the GCA, EEA and supporting agencies focused a tremendous amount of energy and attention on the buildings sector and specifically, the All Cost-Effective Energy Efficiency policy. This commitment produced impressive results, establishing Massachusetts as the national leader in state-based efficiency programs. As the implementation of this policy transitions into the fourth Three-Year Plan submitted by the Mass Save® PAs, state agencies led by EEA, DPU, and DOER are identifying ways to enhance the effectiveness of programs in reducing GHG emissions, including a focus on improving thermal sector reductions associated with natural gas, oil, and propane heat.

The EEA and DOER continue to explore new opportunities to reduce GHG emissions from the buildings sector, through the significant changes proposed in the 2019-2021 Mass Save® energy efficiency plans and exploring other additional opportunities:

- Achieve more aggressive gas savings goals. Increase weatherization measures to improve existing building shell efficiencies and targeted winter gas savings.
- Achieve electric energy efficiency goals and peak demand reductions. Expand programs to include new cost-effective active demand management programs such as energy storage, residential direct load control, and C&I load curtailment programs.
- Expand electric efficiency programs to holistically serve customers and promote fuel switching to more efficient and lower GHG emitting heating and hot water systems.
- Serve more customers through additional efforts to serve moderate income, non-English speaking residents, renters, and small business customers.
- Drive market/consumer demand for energy efficiency measures and fuel switching by educating consumers about the benefits of energy efficiency and creating a market incentive for consumers to invest in energy efficiency improvements through a "Home Energy Scorecard."
- Further reduce energy demand in new buildings through promoting high efficiency building construction (such as meeting Passive House or Zero Net Energy standards).
- Explore ways to strengthen building codes that better support renewable energy, electrification, energy storage, and resiliency policy goals.

4.2 TRANSPORTATION, LAND USE, AND SMART GROWTH

4.2.1 OVERVIEW

Transportation is the single largest contributor to GHG emissions in Massachusetts, and the only category of energy use that has not seen significant emissions reductions relative to 1990. Strategies to reduce GHG emissions in the transportation sector usually focus on improving one of three key drivers of transportation energy use: (1) vehicle specific emissions and efficiency, (2) the carbon content of fuel, and (3) travel in vehicles (known as vehicle miles travelled, or VMT).

State government has a somewhat limited set of policy tools to address energy use in the transportation and land use sector. Vehicle GHG and efficiency standards are established at the federal level. Land use decisions, on the other hand, occur at the local level and can be difficult to influence through state-level policies.

Despite the limited toolkit available, the 2015 CECP Update includes a suite of policies targeting all elements of the transportation system – vehicles, fuels, and VMT. Since 2008, increasing fuel economy standards have roughly balanced increasing VMT in Massachusetts (Figure 8), but full implementation of policies in all 3 categories is necessary to reduce transportation emissions. Progress to date on these policies is summarized in Tables 6 & 7, and described in more detail in the next section.

Additionally, Massachusetts continues to be involved with regional and national organizations to address the issue of transportation GHG emissions. For example, the Transportation and Climate Initiative, a collaboration of transportation, energy, and environmental agencies from the Northeast and Mid-Atlantic states, seeks to develop the clean energy economy and reduce GHG emissions from the transportation sector. In December 2018, Massachusetts and other participating states and jurisdiction announced their agreement to work together over the course of 2019 to study the feasibility of a potential program that would reduce climate changing pollution from transportation, create economic opportunity, and improve transportation equity for currently underserved and overburdened populations. At the conclusion of the policy development process, all member states will decide whether to adopt and implement the policy. The announcement of the partnership follows extensive stakeholder engagement which included four listening sessions held across the Commonwealth, after which six regional listening sessions were conducted to solicit feedback in order to gather ideas and information on how best to approach a regional program. Reduction in GHG emissions from the potential regional program is likely to be observed after 2020.

4.2.2 TRANSPORTATION SECTOR POLICIES

FEDERAL AND CALIFORNIA VEHICLE EFFICIENCY AND GHG STANDARDS

Massachusetts has a long history of working with other Northeastern states and California to push for more aggressive GHG standards for light-duty vehicles. At the federal level, fuel economy standards are established by the National Highway Traffic and Safety Administration (NHTSA), and the U.S. EPA sets GHG emissions standards. California also has a waiver under the Clean Air Act allowing it to set emissions standards more stringent than federal requirements. Massachusetts' law requires adoption of California's standards when such standards are more protective than federal requirements.

FIGURE 8 | VEHICLE FUEL ECONOMY OUTPACING VMT GROWTH

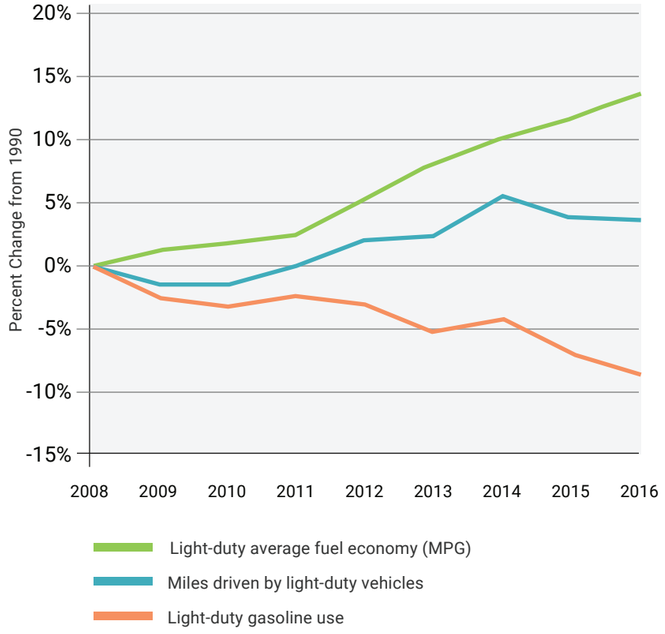


TABLE 6 | SUMMARY OF ESTIMATED GHG REDUCTIONS FROM POLICY IMPLEMENTATION*

	PLANNED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2015)		2016 PROGRESS		PROJECTED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2018)	
	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL
Transportation, Land Use, and Smart Growth	5.7	6.1%	3.2	3.4%	5.0	5.3%
Federal and California Vehicle Efficiency and GHG Standards (CAFE/Pavley)	3.7	3.9%	2.6	2.7%	3.7	4.0%
Federal Emissions and Fuel Efficiency Standards for Medium and Heavy Duty Vehicles	0.4	0.4%	<<0.1	<<0.1%	0.5	0.5%
Federal Renewable Fuel Standard (RFS) and Regional Clean Fuel Standard (CFS)	0.1	0.1%	<<0.1	<<0.1%	0.1	0.1%
Clean/Electric Vehicle Incentives	0.1	0.1%	Reductions included in CAFE/Pavley standards.			
State Transportation Initiatives and Regulations (includes policy formerly called GreenDOT)	1.0	1.1%	Transportation reductions included in CAFE/Pavley standards; Buildings reductions included in All Cost Effective Energy Efficiency.			
Smart Growth	0.4	0.4%	0.6**	0.6%**	0.7**	0.8%**

* See Appendix A for summary of methodology.
** Rough estimate using proxy data.

TABLE 7 | IMPLEMENTATION PROGRESS ON TRANSPORTATION, LAND USE, AND SMART GROWTH POLICIES FROM THE 2015 CECP UPDATE

TRANSPORTATION, LAND USE, AND SMART GROWTH		
Policies	Key Accomplishments and Highlights	Recommendations and Next Steps
Federal and California Vehicle Efficiency and GHG Standards (CAFE/Pavley)	• The U.S. EPA proposed the "Safer Affordable Fuel-Efficient Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks" (SAFE Vehicles Rule) in 2018. This proposed rule would weaken existing federal vehicle efficiency and GHG standards. • On December 12, 2018, California finalized amendments to its LEV in reaction to EPA's rulemaking, in order to ensure that standards for model years 2021–2025 are maintained. MassDEP filed an emergency regulation on December 13, 2018 adopting California's motor vehicle emissions standards amendments.	• Hold a public hearing and comment period to make the emergency motor vehicle emissions regulation permanent. • Challenge any weakening of the federal standards.
Federal Emissions and Fuel Efficiency Standards for Medium and Heavy Duty Vehicles	• First-ever fuel economy standards for medium- and heavy -duty vehicles were established by EPA and NHTSA in 2011. Phase 1 of the federal heavy-duty program covers model years 2014 to 2018, and is expected to provide nearly $50 billion in fuel savings nationally. • Building on the success of the Phase I standards, EPA and NHTSA jointly finalized Phase 2 standards in 2016 for medium- and heavy-duty vehicles through model year 2027.	• Assess EPA's Cleaner Trucks Initiative (CTI), a future rulemaking announced in November 2018 to update standards for nitrogen oxide (NOx) emissions from highway heavy-duty trucks and engines, to see if GHG co-benefits will result.
Federal Renewable Fuel Standard (RFS) & Regional Clean Fuel Standard (CFS)	• Implementation of the federal RFS is ongoing.	
Clean/Electric Vehicle Incentives	• The MOR-EV program has provided approximately $23 million to provide over 11,300 rebates to consumers who purchased or leased plug-in electric vehicles since its start in 2014. • The MassEVIP Fleets program has funded $2.66 million for 267 EVs and 92 publicly accessible EV charging stations for MA municipalities, state agencies, and state colleges and universities. The MassEVIP Workplace Charging Program has funded $1.35 million for 543 EV charging stations at 265 separate locations.	• Allocate $16 million of Massachusetts' VW Settlement funding to projects that support electrification of the transportation network in Massachusetts, including $11 million to support the purchase of electric transit buses by the Pioneer Valley and Martha's Vineyard transit authorities and $5 million for the installation of electric vehicle supply equipment.
State Transportation Initiatives and Regulations (policy formerly called GreenDOT)	• MassDOT has converted tolled highways in Massachusetts to electronic tolling. • MBTA has replaced 50% of the commuter rail fleet with new hybrid diesel-electric locomotives. • MassDEP finalized regulations 310 CMR 60.05 and 310 CMR 60.06 to address transportation emissions.	• Explore the feasibility of using zero emissions bus technology in the MBTA fleet.
Smart Growth	• EEA launched a Planning Grant Program in 2017 to help municipalities update their land use plans and regulations, favoring projects that address climate change. Over $2 million has been provided to advance 68 different planning projects. • The Baker-Polito Administration launched its Housing Choice Initiative in 2018 to promote housing production in sustainable patterns and places.	• Pursue necessary information and establish systems to track the effectiveness of VMT reductions and changes in land use and land cover change associated with smart growth.

In 2010, the Obama Administration agreed to harmonize federal fuel economy and GHG emissions standards for light-duty vehicles with California. Taking effect in the 2012 model year and continuing through 2025, the new federal light-duty GHG standards will result in the most aggressive increase in fuel economy in decades. In December 2012, Massachusetts also adopted California's "Advanced Clean Cars Package," which commits the Commonwealth to California's GHG standards for 2017 to 2025 and also mandates the sale of increasing quantities of advanced ZEVs.

Expected GHG reductions from these GHG standards in 2020 remains at 3.7 MMTCO$_2$e, as estimated in the 2015 CECP Update. However, progress toward these reductions has been counteracted by population and economic growth, which have contributed to increased VMT. Consequently, GHG emissions in the transportation sector have not significantly decreased below the 1990 baseline level.

In 2018, the U.S. EPA initiated a process to significantly weaken the federal standards and California's independent authority. MassDEP has testified and submitted comments in opposition to this rollback of standards. On December 12, 2018, California finalized amendments to its LEV rules in reaction to EPA's rulemaking, in order to ensure that standards for model years 2021-2025 are maintained. MassDEP filed an emergency regulation on December 13, 2018 adopting California's motor vehicle emissions standards amendments. EPA's changes will be challenged in court by California, Massachusetts, and other states.

FEDERAL EMISSIONS AND FUEL EFFICIENCY STANDARDS FOR MEDIUM AND HEAVY DUTY VEHICLES

Because the transportation of goods often crosses state boundaries, federal standards on freight vehicles are integral to addressing GHG emissions from medium- and heavy-duty vehicles especially within state borders. Federal GHG and fuel economy standards for medium- and heavy-duty vehicles were established for the first time by U.S. EPA and NHTSA in 2011. The first phase of the federal heavy-duty program covers model years 2014 to 2018, and is expected to provide nearly $50 billion in fuel savings nationally.[36]

Building on the success of the Phase I standards, U.S. EPA and NHTSA jointly finalized Phase 2 standards in 2016 for medium- and heavy-duty vehicles through model year 2027, covering model years 2018-2027 for certain trailers and model years 2021-2027 for semi-trucks, large pickup trucks, vans, and all types and sizes of buses and work trucks. The Phase 2 standards are expected to lower CO_2 emissions by approximately 1.1 billion metric tons nationally and save vehicle owners about $170 billion in fuel costs.[37] Both Phase 1 and Phase 2 standards are on track to deliver anticipated GHG emissions reductions as expected in the 2015 CECP Update.

In November 2018, U.S. EPA announced the Cleaner Trucks Initiative that aims to further reduce nitrogen oxide emissions from highway heavy-duty trucks and engines. However, the yet-to-be proposed standards are expected to apply to model year 2024 and later.

FEDERAL RENEWABLE FUEL STANDARD (RFS) AND REGIONAL CLEAN FUEL STANDARD (CFS)

The federal Renewable Fuel Standard was established by the Energy Independence and Security Act (EISA) of 2007, and its goal is to reduce fossil fuel use by increasing the volume of renewable fuels in the nation's supply of transportation fuels. The RFS sets minimum volume requirements for specific volumes of conventional biofuels (i.e., corn-based ethanol) and advanced biofuels (e.g., cellulosic ethanol), and requires refiners of transportation fuels to mix RFS-eligible fuels into gasoline and diesel up to certain blend limits. While the U.S. EPA has decreased volume standards for cellulosic biofuels because growth has been slower than envisioned in the EISA, the RFS is still expected to reduce GHG emissions in 2020 by 0.1% of the 1990 baseline, as expected in the 2015 CECP Update.

CLEAN/ELECTRIC VEHICLE INCENTIVES

Massachusetts has established multiple programs to increase the population of electric vehicles in the Commonwealth, thereby displacing emitting vehicles and decreasing emissions of both criteria pollutants and GHGs from the transportation sector. Massachusetts signed onto a multi-state *State Zero-Emission Vehicle Programs* Memorandum of Understanding to achieve a total of 3.3 million ZEVs on the road in participating states by 2025.[38]

Massachusetts has committed significant investments to promote ZEVs, which promotes public health of Massachusetts residents by lowering the level of criteria pollutants (ozone) and GHG, including:

- Since 2012, MassDEP's ongoing ZEV program implementation of the requirements of LEV III regulations (with the phase-out of the "travel provision" starting with Model Year 2018 vehicles, the in-state benefits of the ZEV program will increase).
- Since 2013, MassEVIP Fleets effort has utilized $2.66 million to fund 267 EVs and 92 publicly accessible EV charging stations for Massachusetts cities and towns, state agencies, and state colleges and universities.
- Since 2014, the MassEVIP Workplace Charging Program has utilized $1.35 million to fund 543 EV charging stations at 265 separate street addresses.
- Since 2014, the MOR-EV program has provided $23 million in rebates for 11,300 vehicles, of up to $2,500 each for the purchase or lease of zero-emissions and plug-in hybrid light-duty vehicles, with changes in rebate amounts and structure starting January 2019 and going through at least June 2019.
- Massachusetts' VW Settlement Beneficiary Mitigation Plan (BMP)[39] specifies Year One funding under the program, allocating at least $16 million of the allowed Year One $23.5 million funding to projects that support electrification of the transportation network in Massachusetts, specifically:
  - $11 million to support the purchase of electric transit buses by the Pioneer Valley and Martha's Vineyard transit authorities; and
  - $5 million on the installation of electric vehicle supply equipment (EVSE) to supplement the network of existing EVSE.

These efforts have been highly successful, with the population of EVs in Massachusetts increasing 732% from July 31, 2015 to June 30, 2018, from 3,333 to 15,111 EVs.[40] The GHG reductions from these EVs, however, are included in the Federal and California Vehicle Efficiency and GHG Standards policy as ZEVs in Massachusetts have been sold to comply with these standards.

STATE TRANSPORTATION INITIATIVES AND REGULATIONS

The CECP and the 2015 CECP Update included GreenDOT as a separate policy. Since then, GreenDOT has been incorporated into other policies and programs, recognizing the cross-cutting nature of MassDOT's GHG mitigation measures. Highlights of MassDOT's efforts to reduce transportation sector GHGs include:

- Programmed over $220 million dollars of capital expenditure in the 2017-2021 fiscal year window for increasing the availability of walking and cycling options in Massachusetts.
- Installed publicly available electric vehicle fast charging stations at 6 service plazas along the Massachusetts Turnpike and 30 electric vehicle charging stations in parking facilities.
- Converted tolled highways in Massachusetts to electronic tolling, which reduces emissions as a vehicle using a transponder can pass through a toll plaza more efficiently than one that must slow down or stop and idle to pay a toll.

Highlights of the MBTA's efforts to reduce transportation sector GHGs include:

- Replaced 50 percent of the commuter rail fleet with new diesel-electric locomotives.
- Replacing the aging subway cars on the red and orange lines with new cars that will be more efficient, reduce the emissions associated with traction power, and provide a more attractive service for transit users.
- Replacing old and inefficient buses with newer more efficient buses that use less diesel fuel per revenue mile, including hybrid electric buses.
- Working on a trial involving five articulated, battery electric buses. This trial will help to determine the feasibility of more widespread use of this type of zero emissions bus technology in the MBTA fleet.

In August 2017, in response to E.O. 569, MassDEP finalized new regulatory requirements addressing transportation emissions. First, the 310 CMR 60.06 *CO_2 Emission Limits for State Fleet Passenger Vehicles* regulations impose declining annual emissions limits on fleets of vehicles owned by state agencies, and the 310 CMR 60.05 *Global Warming Solutions Act Requirements for Transportation* regulations impose declining annual limits on emissions from MassDOT vehicles and facilities. Second, MassDOT is required to report on mass-based, annually declining aggregate targets on CO_2 emissions from Massachusetts' multimodal surface transportation system, including the highway and transit networks. The regulated state agencies must comply with annual requirements beginning with emissions that occur in 2018, and the regulations are designed to reduce transportation emissions by 2020. The GHG reductions from these MassDOT's initiatives and MassDEP's regulations, however, are included in the Federal and California Vehicle Efficiency and GHG Standards policy.

[36] https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks
[37] https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-emissions-commercial-trucks
[38] https://www.nescaum.org/documents/zev-mou-9-governors-signed-20180503.pdf
[39] https://www.mass.gov/files/documents/2018/12/07/vw-finalbmp.pdf
[40] https://www.mass.gov/how-to/massevip-fleets

SMART GROWTH

The Commonwealth continues to pursue policies in the five broad categories contained in the 2015 CECP update. Particularly noteworthy progress, detailed below, has been made in regard to offering strong incentives to plan and zone for, invest in, permit, and build smart growth by providing grants and other tools to communities to zone and otherwise regulate for smart growth. The Commonwealth is also using state investments in land, buildings, and infrastructure to promote growth that is consistent with the Sustainable Development Principles. Finally, several zoning reform bills were filed, including the Administration's Housing Choice bill (H. 4075, H. 4290), though none passed.

Overall, the goal of these policies is to encourage development consistent with the Commonwealth's Sustainable Development Principles, recognizing that households in smart growth consistent development drive almost one third less miles than those in single use subdivisions distant from jobs and services. Those who live close to their job or to services have the option of walking or biking, or if they do drive will travel less distance. Although direct measurement of the impacts of these Smart Growth policies on total VMT is not yet available, EEA has estimated their impact by combining data about population growth with the average VMT of each municipality. These data indicate that Massachusetts' population grew by more than 180,000 people from 2010 through 2016, 73% of whom moved into communities classified as "maturing suburbs" (e.g., Billerica), "regional urban centers" (e.g., Northampton), or the inner core surrounding Boston. By moving into high-density communities, Massachusetts residents avoided driving more than 1.5 billion miles in 2016, saving nearly 0.6 $MMTCO_2e$.

Recognizing the critical role that local zoning and other land use regulations play in determining where and how growth occurs, in 2017 the Commonwealth instituted EEA's Planning Grant Program to help municipalities update their land use plans and regulations. As of November 2018, $2,336,878 has been provided to advance 68 different planning projects. The grant criteria favor measures that address climate change. Funded projects include downtown and village center rezoning, natural resource protection zoning, parking studies (intended to help "right size" parking requirements), and accessory dwelling unit bylaws.

In addition, in 2018 the Baker-Polito Administration launched the Housing Choice Initiative to promote housing production in sustainable patterns and places. As municipalities are a key driver for whether or not housing is built because of their role in zoning and permitting, the Initiative encourages them to adopt best practices and zoning that support sustainable housing production and that help attain climate and environmental objectives. Examples include 40R Smart Growth, Starter Home, and by-right multi-family, cluster, and accessory dwelling unit zoning. A Housing Choice Designation rewards communities that are producing new housing and have adopted housing best practices. Communities that achieve designation have exclusive access to a new Housing Choice Grant Program and receive priority access to many state funding programs. Finally, companion legislation pending before the Legislature would enable communities to pass zoning for specific sustainable housing production techniques by a simple rather than a super majority, encouraging positive change.

Important progress has also been made in the provision of data. Unfortunately, it has proven difficult to directly measure how much development has been shifted to higher density mixed use growth with a lower carbon profile. While building permit data indicate that this is the case, Massachusetts has not updated its land use and land cover data in over ten years. Fortunately, EEA, through MassGIS, has developed a methodology to routinely update this information, and paid for the first iteration. The product is a combined land use/cover map that is based on MassGIS integrating 20 categories of land cover mapping done by the National Oceanic and Atmospheric Administration's (NOAA) Office for Coastal Management with statewide land use mapping derived from assessors use codes contained in the statewide land parcel data layer. The data, to be released in the Winter of 2018, provides baseline conditions for 2016. Going forward, updated versions of the same map will allow year-to-year comparisons to assess land use and land cover changes. Looking at this year-to-year comparison will allow EEA to directly measure the impacts of transportation, carbon storage, smart growth, and other policies and programs in the context of GWSA compliance.

4.2.3 CONCLUSIONS AND RECOMMENDATIONS

Aggressive federal and state vehicle regulations for both light-duty and medium/heavy-duty vehicles are the primary success story in this sector to date. Moving forward, EEA and supporting agencies will continue to prioritize strategies to address transportation GHG emissions, including:

- Continue electrification of passenger vehicles, and promote electrification/decarbonization of freight and other vehicles.
- Continue to incentivize development in transit oriented development areas and other locations with low car travel.
- Continue regional collaboration through the Transportation and Climate Initiative to develop a framework for a regional program that addresses GHG emissions from the transportation sector.

Initial progress on Smart Growth, including the Sustainable Development Principles and Housing Choice Initiative, seems to position these strategies well for delivering on their goals, but developing credible metrics for evaluating and validating these strategies is a formidable challenge. EEA and supporting agencies are currently pursuing necessary information and establishing systems to track the effectiveness of VMT reductions and changes in land use and land cover change. Mapping tools released by MassGIS in 2018 represent significant progress toward this goal.

4.3 ELECTRICITY GENERATION AND DISTRIBUTION

4.3.1 OVERVIEW

Historically, the energy generation and distribution sector has played a very prominent role in the GHG emissions profile of Massachusetts. In 1990, power sector emissions were comparable to emissions from combustion of fuels in buildings and in vehicles, but they have since fallen by nearly 50%. While this change was driven largely by federal regulations, changes in relative fuel prices, and energy efficiency investments, policies that support renewable energy are becoming increasingly important.

Since the passage of Massachusetts' first RPS in 1997 requiring electricity suppliers to increase their supply of electricity from renewable resources, Massachusetts has been at the forefront of state-based efforts to diversify the electricity supply, use locally-sourced fuels, reduce GHG emissions, and advance clean energy technology. The GCA expanded the RPS to establish even greater incentives for new renewable energy sources, and added

TABLE 8 | SUMMARY OF ESTIMATED GHG REDUCTIONS FROM POLICY IMPLEMENTATION*

	PLANNED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2015)		2016 PROGRESS		PROJECTED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2018)	
	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL
Electricity Generation and Distribution	7.8	8.2%	2.4	2.5%	4.7	5.0%
Coal-Fired Power Plant Retirements	2.7	2.9%	1.7	1.7%	2.7	2.9%
Regional Greenhouse Gas Initiative (RGGI)	–	–	Cross-cutting policy; reductions counted elsewhere.			
Renewable Portfolio Standard (RPS)	1.1	1.1%	0.7	0.8%	1.0	1.1%
Clean Energy Standard (CES)	–	–	0.0	0.0%	1.0	1.0%
Clean Energy Procurements	4.0	4.2%	Some reductions to be counted in RPS and CES after 2020.			
Electric Grid Modernization	–	–	Cross-cutting policy; reduction counted elsewhere.			

* See Appendix A for summary of methodology.

TABLE 9 | IMPLEMENTATION PROGRESS ON ELECTRICITY GENERATION AND DISTRIBUTION POLICIES FROM THE 2015 CECP UPDATE

ELECTRICITY GENERATION AND DISTRIBUTION		
Policies	**Key Accomplishments and Highlights**	**Recommendations and Next Steps**
Coal-Fired Power Plan Retirements	• A reduction of 5.0 MMTCO$_2$e was accomplished by 2018, but closure of Pilgrim nuclear plant in 2019 will give a net GHG reduction of 2.7 MMTCO$_2$e by end of 2020. • MassDEP promulgated 310 CMR 7.74 in 2017 to impose annually declining limits on emissions from Massachusetts' remaining fossil fuel-fired power plants.	
Regional Greenhouse Gas Initiative (RGGI)	• RGGI allowance auctions have raised more than $500 million for Massachusetts. • RGGI delivered a clear "price signal" to electricity markets, which, in combination with falling natural gas prices, has reduced the regional electricity sector's emissions by more than 50% since it began in 2009.	• Participate in regional discussions on bringing in new states and planning for 2021 program review.
Renewable Portfolio Standard (RPS)	• An Act to Advance Clean Energy of 2018 raises the RPS annual incremental increase by an additional 1% for 2020–2029.	• Implement the RPS change in regulation and continue to advance policies that promote renewable energy, including the SMART solar program with the prioritization of further pairing with electric storage. • Develop a Clean Peak Standard to reduce demand for oil-fired power during periods of peak electricity demand starting in 2019 and ending in 2050, as required by An Act to Advance Clean Energy Act of 2018.
Clean Energy Standard (CES)	• MassDEP promulgated 310 CMR 7.75 in 2017 settings a minimum percentage of electricity sales that utilities and competitive suppliers must procure from clean energy sources, beginning at 16% in 2018 and increasing 2% annually to 20% in 2020 and 80% in 2050.	• Partner with municipal light plants to advance GHG emission reductions, including review of phasing in CES. • Explore expanding eligibility to include existing (pre-2010) generators.
Clean Energy Procurements	• Governor Baker signed the Energy Diversity Act of 2016 requiring utilities to competitively solicit and contract for 1,200 MW of clean energy generation and 1,600 MW of offshore wind. • The New England Clean Energy Connect project (delivering hydroelectric generation in New England from Quebec) and Vineyard Wind (delivering 800 MW of offshore wind) have been selected and are in contract negotiations. Both projects are expected to be online in the 2020s.	• Investigate the necessity, benefits, and costs of an additional procurement of up to 1600 MW of offshore wind, as required by the Advance Clean Energy Act of 2018.
Electric Grid Modernization	• DPU issued an Order in May 2018 authorizing Massachusetts' investor-owned utility companies to invest $220 million in grid modernization technologies over the next three years to improve the efficiency and reliability of the electric grid.	• Facilitate stakeholder outreach and investigate investments in advanced metering infrastructure, or "smart meters."

the APS to spur development of highly efficient non-renewable technologies such as CHP. These programs, along with the new Clean Energy Standard, will deliver necessary emissions reductions by 2020.

As explained in the 2015 CECP Update, continuing reductions after 2020 will require actions to "reduce, decarbonize, and electrify" the energy system, with electrification driving significant electricity demand. Recognizing that emissions could increase if this demand is not met using clean generation, the 2015 CECP Update includes a full portfolio of strategies to support clean generation. New clean energy from Canadian hydroelectric generation and largescale wind energy are the keystone of the Commonwealth's strategy for further reducing GHG emissions from energy generation. Grid modernization strategies have the potential to reduce emissions from the electricity distribution system. The Regional Greenhouse Gas Initiative is another important tool for reducing emissions at the regional level. Progress to date on these policies is summarized in Tables 8 & 9, and described in more detail in the next section.

4.3.2 ELECTRIC SECTOR POLICIES

COAL-FIRED POWER PLANT RETIREMENTS

Federal rules on power plants have contributed to a general trend away from coal-based generation. Since 2009, U.S. EPA has implemented new rules addressing air pollution transported across state boundaries, limiting emissions of mercury and air toxics, addressing cooling water intake at power plants, and addressing carbon dioxide emissions. While recent U.S. EPA proposals could roll back some of these rules, the changes will not affect the regional trend away from coal, as Massachusetts' last coal-fired power plant closed in 2017.

New England hosts one of the cleanest electric power grids in the U.S. in terms of GHG emissions per unit of generation. Even though natural gas-fired power has been a key piece of the region's electricity supply for decades, its role has expanded in recent years, displacing generation by coal-fired power plants. Even more than federal rules, this shift is largely attributable to the fuel price differential between natural gas and coal, which began in 2008 as shale-derived gas became available in the U.S. and shifted the commodity price of gas downward.

In August 2017, in response to E.O. 569, MassDEP finalized a new regulation, 310 CMR 7.74 *Reducing CO_2 Emissions From Electricity Generating Facilities*, that imposes annually declining limits on emissions from Massachusetts' remaining fossil fuel-fired power plants. These regulations limit emissions in 2020 to 8.5 MMTCO$_2$e, an amount calibrated to ensure reductions needed to implement the 2015 CECP Update and ensure that reductions from other clean energy policies are realized in Massachusetts. A cap-and-trade structure is used to enforce the program, while allowing flexibility for facilities that must operate to ensure the reliability of the electricity grid. Declining limits extend to 2050 to encourage long term planning for decarbonization of the electric sector.

REGIONAL GREENHOUSE GAS INITIATIVE

The Regional Greenhouse Gas Initiative (RGGI), a cap-and-trade program among nine New England and mid-Atlantic states, was the first mandatory market-based regulatory program in the U.S. to require reductions in GHG emissions. The RGGI places a limit on CO_2 emissions from power plants larger than 25MW in size, and allows trading of CO_2 allowances among regulated power plant owners for purposes of compliance with the program. The program has been very successful, and has contributed to regional reductions in electricity sector emissions of more than 40% since it began in 2009. Regulatory amendments finalized in September 2018 require an additional 30% reduction between 2020 and 2030. Discussions are underway regarding the expansion of RGGI to include New Jersey and Virginia, which would result in additional reductions over the 2020-2030 time frame.

The RGGI allowance auctions also raise revenue that supports state energy efficiency and clean energy programs. Massachusetts received $501 million of allowance revenues through September 2018, which it has used to support investments in cost-effective energy efficiency. Recent program changes to extend the program through 2030 ensure that RGGI will remain a reliable source of funding over the long term. By statute, the Commonwealth must invest at least 80% of its allowance proceeds in energy efficiency, so this policy could in turn further boost the All Cost-Effective Energy Efficiency policy. It will also provide more funding for the Green Communities Designation and Grant program, renewable energy, and consumer benefit programs.

The RGGI is a key program that supports decarbonization of the electric sector by limiting emissions, raising funds, delivering a "price signal" to electricity markets, supporting regional collaboration, and providing a model that jurisdictions throughout the world look to when designing carbon reduction programs. Because these benefits are impossible to isolate from other programs that reduce electricity emissions, GHG emissions reductions from RGGI are attributed to these other programs instead of to RGGI in the 2015 CECP Update and in this Progress Report.

RENEWABLE PORTFOLIO STANDARD

Massachusetts maintains a Renewable Portfolio Standard (RPS) requiring retail electricity suppliers to procure a percentage, increasing each year, of their power from renewable resources. In Massachusetts, RPS compliance is split by resource type and vintage into the following classes and subclasses: Class I, Class II - Renewable, and Class II - Waste-to Energy (WTE). Eligible RPS Class I resources include post-1997 renewable generation units located in New England or in adjacent electricity control areas. Eligible resources for RPS Class II Renewable Energy include pre-1998 renewable plants (primarily small hydropower) located in New England or in adjacent electricity control areas. Eligible Class II Waste Energy facilities must be pre-1998 waste-to-energy plants located in Massachusetts. In order to achieve RPS compliance, each retail electricity supplier must obtain enough renewable energy certificates (RECs) to satisfy its renewable load obligation. In 2016, the retail load was 46,864,429 MWh and the RPS Class 1 obligation was 11%, for a total obligation of 5,155,123 MWh. Retail suppliers met over 99% of the obligation through RECs, showing an abundance of clean energy supply to meet RPS demand.

In 2008, the RPS was modified to increase the percentage obligation from a 0.5% increase each year to a 1% increase each year. The rate of RPS increase was modified again as part of the Advance Clean Energy Act of 2018. Beginning in 2020, the RPS obligation will increase 2% per year until 2030 with the obligation in 2020 at 16% and the 2030 obligation at 35% of retail electric supply. The increase in obligation increases the demand for clean energy and may continue to support the growth of regional renewable generation.

Solar and SMART

As part of the RPS, Massachusetts has operated the solar carve-out program since 2010, requiring a portion of the RPS obligation be met through solar energy tracked through certificates called SRECs. The solar carve out program successfully incentivized the development of solar in Massachusetts. In December of 2018, the Commonwealth achieved a solar milestone with over 2,300 MW of installed capacity through 89,193 projects across the Commonwealth. The success of solar development in Massachusetts was also driven by a decline in the cost of installation. In order to continue the growth of solar while reducing the cost impact to ratepayers, the Commonwealth has developed and commenced a new solar incentive program. The Solar Massachusetts Renewable Target (SMART) Program is the Commonwealth's latest major initiative to promote solar energy deployment. Established as part of Energy Diversity legislation signed by Governor Baker in 2016, the SMART program will support an additional 1,600 MW of behind-the-meter solar by providing incentives in the form of a declining block tariff. The goal of this block tariff is to promote clean energy generation from distributed solar energy projects by providing a predictable, financeable, incentive payment, while keeping programmatic costs for ratepayers low. Approximately the first 200 MW of solar projects will receive compensation at specified rates, with the second 200 MW of solar projects being compensated at a lower rate, depending on project size, type, and utility service territory. This progression continues until all 1,600 MW is reserved, likely well in advance of 2025. This quantity of solar is expected to produce the equivalent of 2.1 TWh, or about 2% of regional electricity demand. This is enough electricity to power 293,000 households in Massachusetts annually.

The SMART program is designed to promote cost-effective and diverse solar energy projects that serve residents, businesses, and institutions located in investor owned utility service territories. The program includes additional incentives for projects that are optimally sited, such as those on brownfields/landfills, rooftops, and parking lots, as well as projects that serve particular groups of customers, such as community solar, low-income populations, and public facilities. Lastly, the program also provides additional incentives to facilities that combine solar with energy storage to maximize benefits to the grid.

CLEAN ENERGY STANDARD

In August 2017, as part of its response to EO 569, MassDEP finalized the 310 CMR 7.75 *Clean Energy Standard* (CES) regulation. The CES requires the purchase of additional clean energy, above and beyond the

RPS requirements, and is designed to help ensure achievement of the 2020 GWSA limit in combination with the other CECP measures, such as the new 310 CMR 7.74 *Reducing CO_2 Emissions From Electricity Generating Facilities* limits on emissions from in-state generators. The CES regulation defines eligible clean energy to include all RPS Class I-eligible renewables and any other new (post-2010) generators with very low emissions. In 2020, the combined RPS-CES requirement is for electricity sellers to procure clean energy equivalent to 20% of sales, a requirement that is expected to be met using RPS Class I-eligible renewable energy.

The CES standard increases by 2% per year until it reaches 80% in 2050. Once new imported hydropower becomes available in the 2020s, it will count toward CES compliance, and the quantity will be sufficient to ensure CES compliance well into the 2030s. In the 2040s, assuming existing clean resources such as regional nuclear power plants and pre-2020 imported hydropower remain on line, the 80% standard will be sufficient to ensure that Massachusetts' electricity supply is almost completely decarbonized in 2050. A program review scheduled for 2021 will allow re-assessment of all aspects of the program.

In late 2017, MassDEP solicited input from stakeholders on options for expanding the CES to extend clean energy procurement requirements to municipally-owned electricity sellers, and also to potentially expand eligibility to cover existing (pre-2010) clean generators. MassDEP received over 400 pages of comments on these issues, showing strong interest in these topics.

CLEAN ENERGY PROCUREMENTS

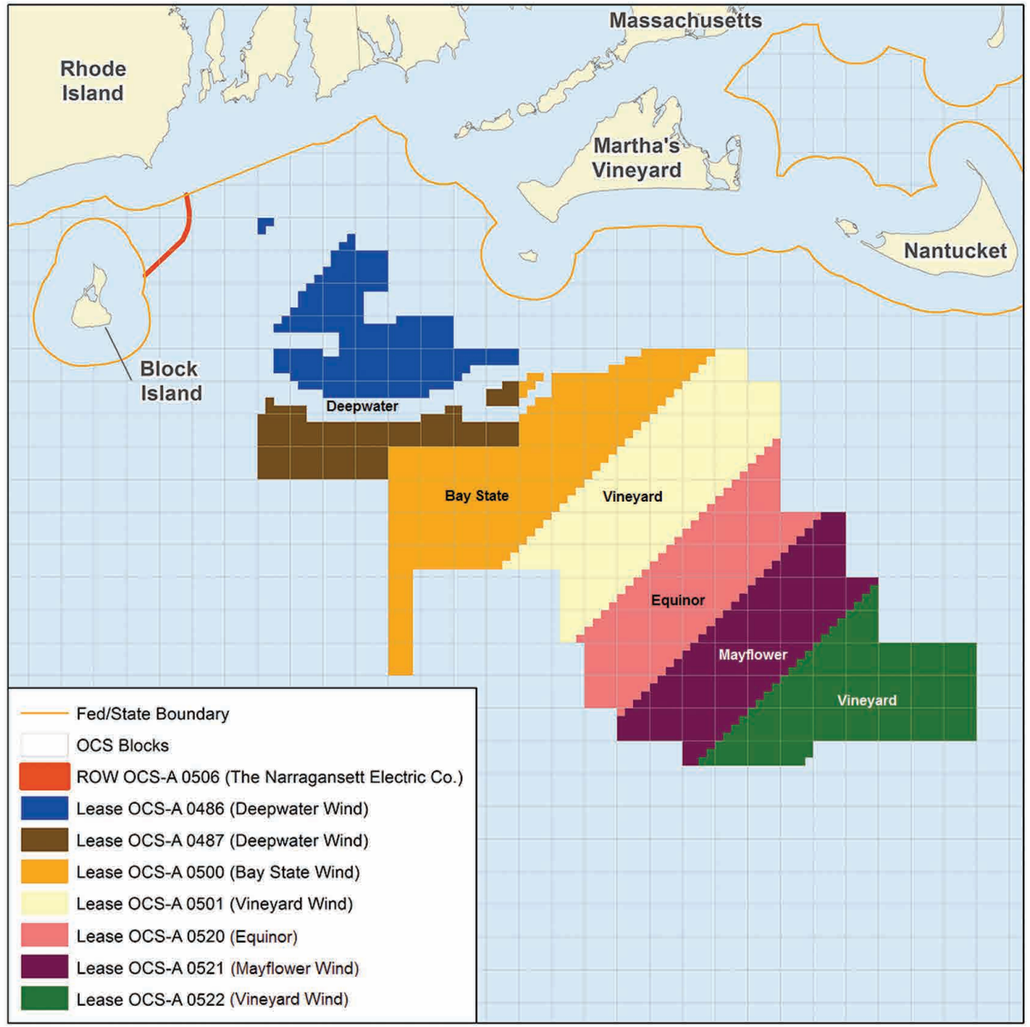
In the CECP and the 2015 CECP Update, the Clean Energy Imports policy were estimated to produce a GHG reduction of 4.2% of the 1990 baseline by 2020. This policy is renamed to Clean Energy Procurement to reflect the procurement of hydroelectricity resources and offshore wind, both of which will be online in the 2020s and help meet the RPS and CES requirements.

Offshore Wind

In addition to supporting the growth of solar, the development of new offshore wind projects will increase the amount of renewable clean energy generation for Massachusetts and the RPS. Since 2009, Massachusetts has participated in federal processes with the U.S. Bureau of Ocean Energy Management (BOEM) and stakeholders to establish federal lease areas off the coast for the development of offshore wind energy projects. In July 2013 and in January of 2015, BOEM conducted competitive lease sales, opening the regional waters for renewable energy development. U.S. Department of Energy's National Renewable Energy Laboratory (NREL) estimated the lease areas held a potential for 12-14 gigawatts of commercial wind capacity.

In Chapter 188 of the Acts of 2016, An Act to Promote Energy Diversity, the Commonwealth created the largest procurement for offshore wind nationally at the time. Section 83C required the Massachusetts electricity distribution companies (EDCs) with DOER to competitively solicit 1,600 MW of cost-effective offshore wind energy by June 2027. In June 2017, the EDCs issued a request for proposals (RFP) for 400 MW and up to 800 MW of offshore wind energy generation. After the evaluation of the received proposals, in July of 2018 the EDCs announced the selection and contract execution with Vineyard Wind for 800 MW of offshore wind from one of the BOEM leased areas. The project represents a significant increase in renewable energy generation for Massachusetts, competitive pricing that holds significant benefits for ratepayers, and a step forward in securing economic development and job creation for the Commonwealth. Soon after the Massachusetts project selection, Connecticut and Rhode Island announced separate offshore wind project selections, increasing the amount of offshore wind regionally. The growth of offshore wind in New England is expected to continue. In December 2018, BOEM conducted another competitive lease sale for the remaining Massachusetts lease areas, The response from developers was historic, leading to over $405 million in winning bids. The auction resulted in two new developers, Equinor and Mayflower Wind (a joint venture between Shell New Energies and EDP Renewables entering the market), and Vineyard Wind secured a second lease area. The three new lease areas encompass approximately 390,000 acres and, if fully developed, the sites could produce as much as 4,100 MW of wind generation. Figure 9 is a map of the lease areas and the developers associated to each site.

FIGURE 9 | MAP OF BOEM'S REMAINING MASSACHUSETTS LEASE AREAS AND THE OFFSHORE WIND DEVELOPERS ASSOCIATED TO EACH SITE



Section 83D – Clean Energy Generation

Also part of Chapter 188 of the Acts of 2016, An Act to Promote Energy Diversity, Section 83D required the EDCs with DOER to competitively solicit for 9.45 TWh of clean energy generation, including both new RPS Class I generation or firm hydroelectric generation. In March 2017, the EDCs issued an RFP. After evaluating the proposals received, the EDCs announced the selection and contract execution of the New England Clean Energy Connect (NECEC) Project which will deliver firm incremental hydroelectric generation in New England from Quebec with anticipated commercial operation in the mid-2020s. This energy will provide low cost energy and clean energy certificates for compliance with the CES, providing significant cost and emission reduction benefits to ratepayers. Additionally, the hydroelectric energy will be delivered year-round, provide firm and reliable energy to the region. By providing firm delivery

of clean hydroelectric generation, the NECEC Project will be particularly beneficial during the winter months when the region experiences high energy prices due to reliance on natural gas for both electricity and heating.

ELECTRIC GRID MODERNIZATION

The DPU issued an Order in May 2018 authorizing Massachusetts' investor-owned utility companies to invest $220 million in grid modernization technologies over the next three years to improve the efficiency and reliability of the electric grid. These investments include an advanced distribution management system and distribution automation that will improve the resiliency and efficiency of the grid system and better integrate distributed energy resources. An intelligent electric grid system will enhance the utilities' climate adaptation capabilities. These investments will also reduce energy consumption, peak demand, and line losses, leading to GHG emissions reduction from grid system operations.

As the next step, the DPU will facilitate stakeholder outreach and an investigation into potential investments in advanced metering infrastructure, or "smart meters." The DPU's investigation will consider the adoption of dynamic pricing products for all customers, and a targeted deployment of advanced metering functionality to certain customer groups, including net metering and electric vehicle customers. These potential future investments will facilitate consumer behavior change to conserve energy and reduce peak demand, contributing to economy-wide GHG emissions reduction.

4.3.3 CONCLUSIONS AND RECOMMENDATIONS

Progress in the electricity sector to date has been dominated, in quantitative terms, by power plant closures driven by changes in relative fuel costs and, to a lesser degree, federal and state regulations. However, this process is now complete. EEA and supporting agencies will continue to decarbonize the electric generation and distribution sector, including:

- Continue to increase cost-effective clean electricity supply to meet RPS and CES compliance obligations. This effort will include continued support of the clean energy and offshore wind energy procurements, resources that are available in winter to provide both cost and emission benefits to customers.
- Continue policies that support distributed resources, including considering policies that will support solar development in the Commonwealth after the SMART program concludes, especially projects that pair renewables with energy storage to align supply and demand and provide grid flexibility.
- Implement policies and programs, including the Clean Peak Standard, that incentivize energy conservation and renewable energy utilization during peak periods. Reducing energy demand at times of peak use creates the most value because it reduces reliance on the highest cost, less efficient generating resources.

4.4 NON-ENERGY EMISSIONS

4.4.1 OVERVIEW

Greenhouse gas emissions from activities not related to energy use, like refrigeration, insulation, and waste disposal, represent a small but important part of statewide GHG emissions. Many of the gases released from these activities have a global warming potential (GWP) thousands of times higher than CO_2. The 2015 CECP Update includes a number of strategies to address these emissions. Progress to date on these policies is summarized in Tables 10 & 11, and described in more detail in the next section.

4.4.2 NON-ENERGY SECTOR POLICIES

REDUCING GHG EMISSIONS FROM PLASTICS COMBUSTION

Increasing recycling rates in Massachusetts will decrease GHG emissions associated with the disposal and incineration of plastics and other high-carbon materials. While direct emissions from solid waste management are only a small percent of Massachusetts' baseline 1990 emissions, the GHG emissions generated over the lifetime of disposed materials are much larger. Recycling also results in additional environmental and economic benefits, like reducing the use of virgin materials and the releases of toxics into the environment, creating green jobs, and reducing our reliance on and need for solid waste facilities.

The Massachusetts 2010–2020 Solid Waste Master Plan (SWMP), published in April 2013, sets a goal of decreasing solid waste disposal by 30 percent by 2020 and by 80 percent by 2050. The 2020 Master Plan identifies a diverse and comprehensive set of strategies to reduce waste from

TABLE 10 | SUMMARY OF ESTIMATED GHG REDUCTIONS FROM POLICY IMPLEMENTATION*

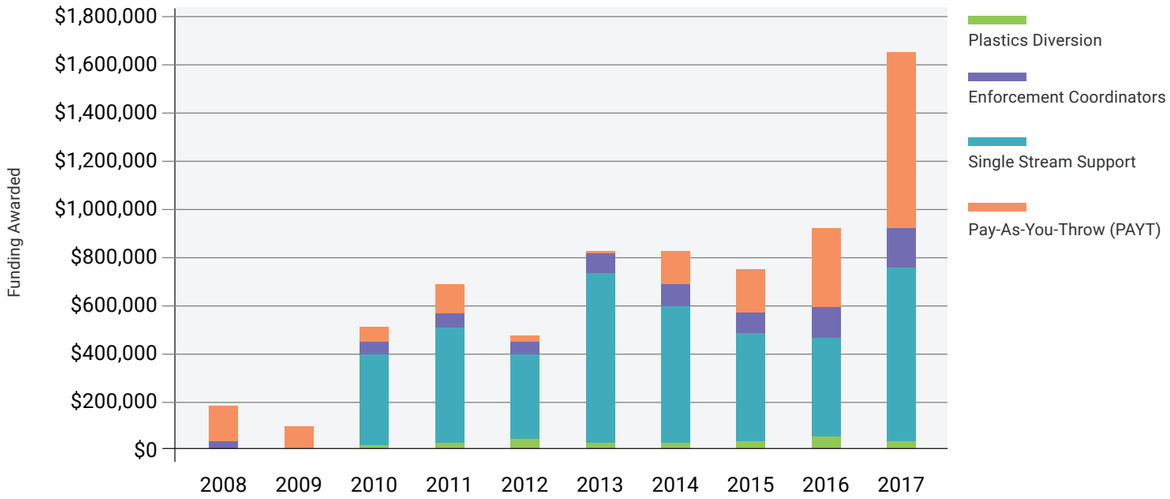
	PLANNED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2015)		2016 PROGRESS		PROJECTED 2020 GHG EMISSIONS REDUCTION (ESTIMATED IN 2018)	
	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL	$MMTCO_2E$	% OF 1990 LEVEL
Non-Energy Emissions	2.5	2.6%	2.1	2.2%	2.2	2.3%
Reducing GHG Emissions from Plastics Combustion	0.3	0.3%	0.1	0.1%	0.1	0.1%
Reducing SF6 Emissions from Gas-Insulated Switchgear	0.4	0.4%	0.4	0.4%	0.4	0.4%
Reducing Emissions from the Natural Gas Distribution Network	1.7	1.8%	1.7	1.8%	1.7	1.8%
Stationary Equipment Refrigerant Management	0.1	0.1%	Policy not yet pursued.			

* See Appendix A for summary of methodology.

TABLE 11 | IMPLEMENTATION PROGRESS ON NON-ENERGY POLICIES FROM THE 2015 CECP UPDATE

NON-ENERGY EMISSIONS		
Policies	Key Accomplishments and Highlights	Recommendations and Next Steps
Reducing GHG Emissions from Plastics Combustion	• The Massachusetts 2010–2020 Solid Waste Master Plan (SWMP), published in April 2013, sets a goal of decreasing solid waste disposal by 30% by 2020 and by 80% by 2050. • MassDEP has awarded over $7.5 million in Sustainable Materials Recovery Program Municipal Grants since 2010.	• Develop the 2020-2030 Solid Waste Master Plan, with a goal of completing the 2020–2030 SWMP by the end of 2020.
Reducing SF6 Emissions from Gas-Insulated Switchgear	• MassDEP amended the regulation 310 CMR 7.72 Reducing Sulfur Hexafluoride Emissions from Gas-Insulated Switchgear to add declining annual limits on total SF6 emissions from large electric utilities.	• Continue to implement 310 CMR 7.72.
Reducing Emissions from the Natural Gas Distribution Network	• The replacement of aged cast-iron, wrought-iron and non-cathodically protected steel pipes has been accelerated, especially to repair natural gas leaks that pose significant public safety or environmental impact, in response to the Natural Gas Leaks Act of 2014, the Energy Diversity Act of 2016, and DPU directives.	• Expected promulgation of regulations that concern the investigation and identification of natural gas leaks that pose significant public safety or environmental impact. • Continue accelerated replacement of aged cast-iron, wrought-iron and non-cathodically protected steel pipes.
Stationary Equipment Refrigerant Management	• Some hydrofluorocarbons (HFCs) were added in 2018 to the list of regulated chemicals under the Toxics Use Reduction Act, which requires large toxic chemical users in Massachusetts to submit a Toxics Use Report annually, develop a plan to reduce their use of regulated chemicals, and pay an annual Toxics Use Fee. • Massachusetts joined other members of the U.S. Climate Alliance in committing to the Short-Lived Climate Pollutant Challenge to develop and implement state-specific strategies to reduce short lived climate pollutants, which include HFCs.	• Explore potential strategies to limit use and emissions of HFCs.

FIGURE 10 | SUSTAINABLE MATERIALS RECOVERY PROGRAM - MUNICIPAL GRANTS AWARDED FOR DIVERTING PLASTICS FROM MA WASTE STREAMS



residents, businesses, and construction and demolition activities. MassDEP has made significant progress implementing these strategies, including ramping up waste ban compliance and enforcement programs, establishing new and expanded municipal recycling grant initiatives, establishing a statewide business recycling assistance program, developing a nationally recognized food waste reduction strategy, launching a new recycling business grant program, and establishing a new recycling education initiative. Since 2010, MassDEP has awarded over $7.5 million in Sustainable Materials Recovery Program Municipal Grants, which include grants for collecting bulky plastics and increasing recycling enforcement (Figure 10). However, during this time, the Commonwealth has also been faced with new challenges, including global recycling market disruptions for paper and plastic, along with losing local recycling capacity for glass. As a result, GHG reductions expected from this policy in 2020 are revised accordingly.

The MassDEP is currently developing Massachusetts' 2020-2030 Solid Waste Master Plan, which will establish updated waste reduction goals, priorities and strategies for the next decade. This new Master Plan is an opportunity for MassDEP to step back and assess the effectiveness of existing strategies, continue to invest in strategies that have proven to be effective, and develop new or modified strategies to address the challenges and opportunities that the Commonwealth will face in the next decade.

REDUCING SF_6 EMISSIONS FROM GAS-INSULATED SWITCHGEAR

Sulfur hexafluoride, or SF_6, is a GHG that has a GWP 23,900 times higher than CO_2 and has an atmospheric life of 3,200 years. One pound of SF_6 has the same global warming impact as 11 metric tons of CO_2 emissions. SF_6 emissions result from the electricity transmission and distribution systems, where it is used to insulate high voltage switchgear, known as gas-insulated switchgear (GIS).

In 2013, Massachusetts finalized a 310 CMR 7.72 *Reducing Sulfur Hexafluoride Emissions from Gas-Insulated Switchgear* regulation to reduce these emissions. The regulation requires large electric utilities to gradually reduce emissions beginning in 2015, such that a 1 % leakage rate is achieved by 2020. Other key requirements ensure that all new SF_6-containing GIS meets the 1% leak rate, and that SF_6 is not released when GIS is discarded.

In August 2017, in response to E.O. 569, MassDEP amended the regulation to add declining annual limits on total SF_6 emissions from large electric utilities. The change addressed the requirements of Section 3(d) of the GWSA, which requires that regulations be structured to control the total amount of emissions from regulated sources, instead of the emission rate.

The regulated utilities are on track to comply with their 2020 limits, at which time this source category will account for less than 0.1% of statewide GHG emissions.

REDUCING EMISSIONS FROM THE NATURAL GAS DISTRIBUTION NETWORK

Methane is the main component of natural gas and has a much higher GWP than carbon dioxide. There are thousands of miles of aged cast-iron, wrought-iron and non-cathodically protected steel in the natural gas distribution pipelines in the Commonwealth. While regulators and operators work to minimize leaks on the distribution system to minimize risks to health and public safety, gas leaks from these pipelines are a contributing source of GHG emissions.

Under the Natural Gas Leaks Act of 2014, the Energy Diversity Act of 2016, and DPU directives, distribution pipeline replacement schedules have been accelerated to repair leaks that pose significant public safety or environmental impact. A new MassDEP regulation 310 CMR 7.73 *Reducing Methane Emissions from Natural Gas Distribution Mains and Services*, promulgated in August 2017 in response to E.O. 569, addresses the associated GHG emissions by imposing declining annual limits on methane emissions from this emissions source. These regulations help to ensure compliance with the GWSA.

STATIONARY EQUIPMENT REFRIGERANT MANAGEMENT

Common refrigerants used in refrigeration systems include several types of hydrofluorocarbons (HFCs), which have a GWP thousands of times greater than CO_2. In 2014, MassDEP met with stakeholders to gather more information regarding the use of these refrigerants in Massachusetts, but did not proceed with new regulations. In June 2018, Massachusetts signed onto the U.S. Climate Alliance's Short Lived Climate Pollutant Challenge, pledging to explore potential policies to reduce emissions of short lived climate pollutants, which include HFCs. Furthermore, in the Fall of 2018, the Administrative Council of the Toxics Use Reduction Act (TURA) program voted to add the category C1-C4 Halogenated Hydrocarbons/Halocarbons Not Otherwise Listed (C1-C4 NOL), which will include HFCs with 1 to 4 carbon atoms, to the list of regulated chemicals under TURA. This addition will be effective starting on January 1, 2019. The TURA program requires large toxic chemical users in Massachusetts to submit a Toxics Use Report annually, develop a plan to reduce their use of regulated chemicals, and pay an annual Toxics Use Fee.

The 2015 CECP Update identified reducing refrigerant emissions as a potential policy, and noted that careful review of international, federal, and California actions would be necessary to determine next steps. These policies address refrigerant emissions by reducing leaks and also by encouraging or mandating the use of refrigerants with lower GWPs. Review of policy options is ongoing, but likely could not be implemented in time to reduce emissions in 2020.

4.4.3 CONCLUSIONS AND RECOMMENDATIONS

Massachusetts has made significant progress on non-energy emissions. Regulations are in place to address methane emissions from the natural gas distribution system and sulfur hexafluoride emissions from the electricity distribution system. To address the rapid increase in refrigerant emissions, EEA and supporting agencies will explore potential strategies to limit use and emissions of HFCs.

4.5 CROSS SECTOR POLICIES

4.5.1 OVERVIEW

Cross-cutting policies drive GHG emission reductions across all sectors through a wide variety of initiatives and projects. The 2015 CECP Update identifies three existing policies – the Massachusetts Environmental Policy Act (MEPA) Greenhouse Gas Emissions Policy and Protocol (GHG Policy), the Leading by Example Program (LBE), and the Green Communities program – that have had a significant impact on GHG emissions. However, to avoid double-counting of their GHG reductions, these reductions were included in estimates for other policies, such as the All Cost-Effective Energy Efficiency policy and the Federal and California Vehicle Efficiency and GHG Standards. Table 12 lists the key accomplishments in these three programs.

TABLE 12 | IMPLEMENTATION PROGRESS ON CROSS-SECTOR POLICIES FROM THE 2015 CECP UPDATE

CROSS-SECTOR POLICIES		
Policies	Key Accomplishments and Highlights	Recommendations and Next Steps
Leading By Example (LBE)	• Heating oil consumption at state facilities has decreased 84% from 2006 to 2017. • Electricity production from on-site solar PV and wind at state facilities has grown to 25 million kWh in 2017.	• Leverage and enhance data collection and analyses to help a diverse portfolio of government offices, public university campuses, and other state buildings track energy use and GHG emissions, as well as prioritize opportunities and strategies for future emissions reductions. • Continue to pursue innovative approaches to moving away from fossil fuels and increasing building efficiencies, as well as drive further growth of renewable and alternative energy.
Green Communities	• 27 Green Communities (out of 112 eligible communities) have reached their 20% energy reduction goal. • 210 of 351 cities and towns in Massachusetts have adopted the Stretch Code. • Green Communities have saved more than $170 million in municipal energy costs.	• Explore how best to maintain equity in opportunity for both long tenured and newly designated Green Communities. • Assist Green Communities to reduce their energy use by 20% within 5 years despite growth in demand for municipal services. • Identify opportunities to engage non-participating municipalities.
MEPA GHG Policy and Protocol	• Over the past 10 years, a total of 166 projects have completed MEPA review and a GHG analysis, and made commitments to reduce GHG emissions by over 356,584 metric tons of CO2e per year. • MEPA review has secured commitments to design and construct the first Passive House office (750,000 sf) in MA; replace HFCs in refrigeration and SF6 in utility infrastructure; and install EV charging infrastructure and reserve parking for EVs.	• Revise the MEPA GHG Policy and Protocol to incorporate climate change adaptation and resiliency and land alteration. • Continue to require analysis of Passive House certifiable design in EIRs as an integrated approach to climate adaptation and GHG reductions while lowering energy costs.

4.5.2 CROSS SECTOR POLICIES

LEADING BY EXAMPLE

The Leading by Example (LBE) Program within the Department of Energy Resources was established in 2007 and is overseen by EEA. The LBE Program continues to support development and implementation of clean energy initiatives designed to reduce emissions and overall environmental impacts associated with state government operations. Given that state government is the single largest user of energy in the Commonwealth, consuming over 1 billion kWh of electricity and emitting over 900,000 metric tons of GHG emissions per year, efforts to reduce emissions at state facilities can play an important role in meeting statewide emissions reduction targets. The LBE Program has several ambitious targets for state government operations, including:

- Reduce energy consumption 35 percent by 2020;
- Reduce GHG emissions 40 percent by 2020, and 80 percent by 2050; and
- Obtain 30 percent of total electricity from renewable sources by 2020.

Through a broad set of energy and environmental initiatives, some of which are highlighted in the following sections, LBE has made significant strides in implementing programs to help move toward meeting these goals.

Energy Reduction

Since 2013, the Division of Capital Asset Management and Maintenance (DCAMM) has overseen the completion of 75 energy projects in over 33.3 million square feet of state buildings, more than half the state building portfolio. These completed projects represent an investment of $242.3 million and will save the Commonwealth approximately $12.4 million and 448,000 MMBtu annually. The 75 energy projects consist of 41 Comprehensive Design-Build/Retro-Commissioning projects and 34 bundles of small energy projects at 336 sites. Collectively, these projects reduce GHG emissions by almost 36,000 metric tons annually. Efficiency measures include, but are not limited to, LED lighting retrofits and lighting controls, insulation and weatherization, window replacements, boiler replacements, heating, ventilation and air conditioning and mechanical upgrades, and more. Many of these projects also include the installation of renewable heating and cooling technologies, including biomass, air and ground source heat pumps, and solar thermal.

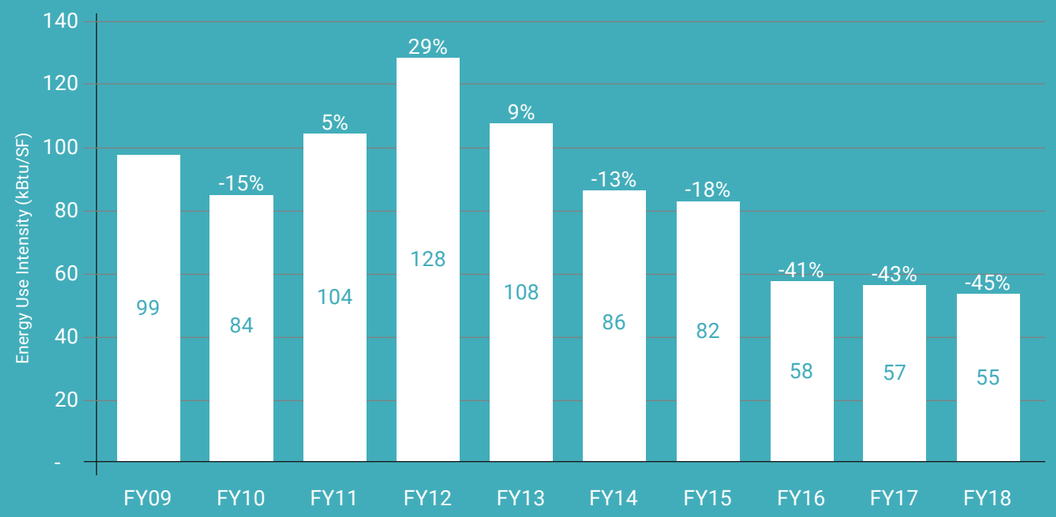
The LBE Program also collaborates with DCAMM on the Commonwealth Building Energy Intelligence (CBEI) program, an advanced energy metering and analytics program to reduce energy consumption and costs at state facilities. At more than 20 million square feet of state buildings, CBEI provides access to real-time metering, building management system integration, utility bill management, and building energy analytics, thus enabling facilities to optimize day-to-day energy management, identify energy anomalies as they occur, prioritize energy projects that target under-performing buildings, and identify errors on utility bills. This granular view into energy consumption patterns has enabled some state agencies to save tens of thousands of dollars annually, sometimes at a single building.

CASE STUDY: EDWARD W. BROOKE TRIAL COURT

The Edward W. Brooke Courthouse is a clear example of how energy and operational efficiencies can significantly reduce a building's energy use intensity (EUI). The 425,000 sq. ft. building has reduced energy consumption using 5-minute interval real-time metering that provides detailed insight into the building's energy use. Utilizing this advanced metering, the Court facilities team adjusted the building schedule in 15 minute increments over multiple weeks, eventually reducing building daily run time by two hours, without impacting occupant comfort and operations. This effort helped the building reduce annual electricity consumption by an estimated 388,000 kWh and annual energy costs by $64,000.

Over the years, through improved operations, high-efficiency lighting upgrades, and other efficiency projects, the Brooke Courthouse has reduced its EUI by 45 percent since 2009.

EDWARD W. BROOKE COURTHOUSE ENERGY USE INTENSITY WITH % CHANGE FROM FY09



SOLAR CANOPIES AT STATE FACILITIES

From 2006 to 2014, the Commonwealth of Massachusetts installed just over 8 MW of roof and ground mounted solar PV at State Facilities. In the subsequent four years, following the launch of the LBE Solar Canopy grant program, more than 9.7 MW of solar canopy capacity was installed, more than doubling total solar arrays at state facilities in less than half the time.

As of September 2018, more than 10 MW of solar canopy capacity are installed at state facilities, comprising more than 40% of the 24 MW of solar PV installed at state facilities across the Commonwealth, with many more canopy projects in the pipeline. Given the Commonwealth's vast portfolio of large parking lots, solar PV canopies will continue to support statewide and LBE renewable energy goals.

Through these initiatives and others, overall energy use intensity (EUI) among the agencies tracked by LBE has decreased from 158 to 135 kBtu per sq. ft., a 15% decline from the 2004 EUI baseline. This decrease has occurred even though many agencies and campuses have either expanded their hours, built new energy intensive buildings (e.g., laboratories) or both. Although still shy of the EUI reduction target of 35% by 2020, state facilities continue to see progress in energy efficiency.

Renewable and On-Site Energy Generation

Massachusetts has made tremendous strides in increasing electricity generation from renewable sources, and state agencies have played a significant role in this success. Electricity production from on-site solar PV and wind at state facilities has grown from less than 1 million kWh in 2007 to more than 25 million kWh in 2017.

Combined heat and power at state facilities continues to generate a significant amount of clean on-site electricity. Since CHP systems produce both electricity and heat from the same fuel source, overall efficiency is increased, GHG emissions are reduced, the Commonwealth saves on energy costs, and overall reliance on the electricity grid is diminished. Together, on-site renewable and CHP resources at state facilities generated some 273 million kWh in Fiscal Year 2017, equivalent to 20 percent of total electricity consumption at state facilities. Since 2006, state facilities have reduced consumption of grid electricity by 13.6 percent, despite growth in square footage and, in some cases, increased operating hours.

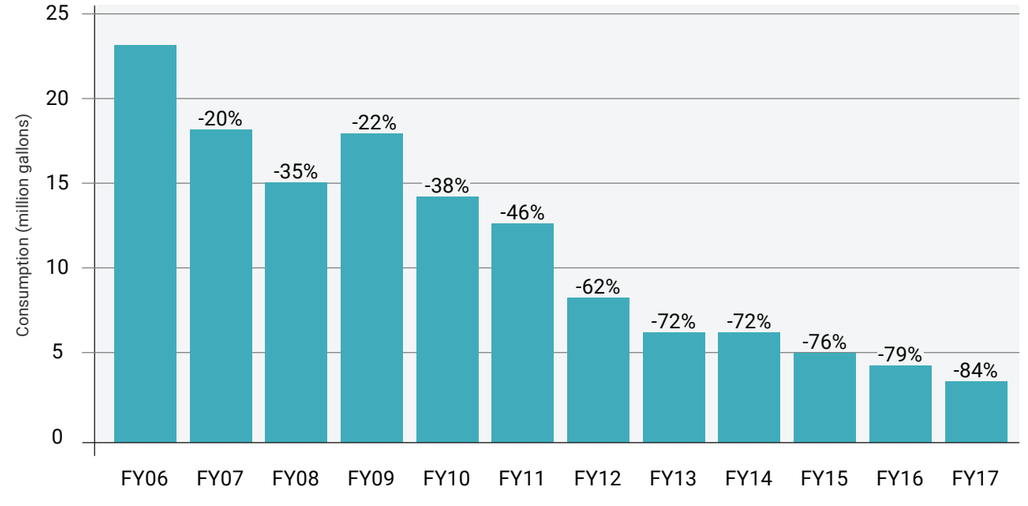
High Performance Buildings

In addition to LBE's energy targets, all new state construction is required to meet the Massachusetts Leadership in Energy and Environmental Design LEED) Plus Standard, which requires new buildings to perform 20% better than Massachusetts energy code requirements.

In this capacity, LBE collaborates with DCAMM and other state construction agencies that design and construct LEED certified buildings. Eighty LEED buildings have been constructed to date at state facilities, with 64% of these certified at the Gold and Platinum levels, LEED's two highest certification levels. In 2017 alone, 14 buildings achieved LEED certification, and 50 buildings have been certified in the past 5 years.

Beyond LEED, 5 state buildings designed to a Zero-Net Energy (ZNE) standard have been constructed. To achieve ZNE, these high-performing buildings must generate as much energy from clean, on-site renewable sources as they consume in a year. In 2017, three of these state-owned buildings met their zero-net energy targets. The LBE Program continues to track energy consumption and generation at state-owned LEED and ZNE buildings in order to analyze post-occupancy performance and help identify opportunities for improvement.

FIGURE 11 | HEATING OIL CONSUMPTION IN STATE FACILITIES: FY2006–FY2017



Fleet Efficiency

The LBE Program's efforts also reach beyond the built environment by targeting opportunities to increase fuel efficiency of the state vehicle fleet. As the transportation sector is the largest contributor to GHG emissions in the Commonwealth, replacing inefficient and conventionally-fueled vehicles with highly efficient hybrid, alternative fuel, or electric vehicles can help to reduce GHG emissions, while also minimizing tailpipe emissions of air pollutants and reducing the total cost of vehicle ownership.

In collaboration with the Office of Vehicle Management (OVM) at the Operational Services Division (OSD) and with MassDEP, the Fuel Efficiency Standard for the State Fleet (FES) was released in 2016. The FES requires executive branch agencies to meet average fuel efficiency minimums for all new vehicle acquisitions and purchase a minimum percentage of hybrid, alternative fuel, or electric vehicles each year. For vehicle types that do not currently have alternative fuel options available on the market, the FES incorporates strategies, such as idle reduction technologies and after-market hybrid conversions, which can help agencies meet the standard.

Other LBE efforts include encouraging agencies to implement low-cost strategies such as reducing the number of VMT by employees, increasing the use of public and non-vehicle transportation, and educational efforts to reduce idling.

Greenhouse Gas Emissions

The past ten years have seen a host of implemented projects and programs that target GHG emissions reductions at state facilities. One key effort includes the switch away from dirtier to cleaner fuels, with a particular focus on reducing use of heating oil. Between 2006 and 2017, the use of heating oil at state facilities decreased by over 19 million gallons, or 84% (Figure 11).

By the end of Fiscal Year 2017, emissions related to state government operations dropped by 349,398 metric tons, equivalent to a 28% decline from the LBE baseline (3-year average from FY02-FY04). As a group, the Commonwealth's 15 community colleges have shown the greatest reductions, decreasing emissions by 39%.

Looking Ahead

As the LBE program approaches its 2020 targets and begins to look to more aggressive goals in later years, opportunities and challenges remain. Tracking energy consumption, renewable energy generation, emissions, and cost data across such a large and diverse portfolio, while critical to LBE's ability to measure progress,

can still be difficult and can require a multi-pronged approach. The LBE Program mitigates this challenge by accessing various energy data sources, including CBEI and Mass Energy Insight (MEI), as well as developing customized tracking tools for state agencies, colleges, and universities. Along with cost data from state accounting records and state contract vendor reports for various fuels, LBE has been able to successfully track the vast majority of energy use data associated with state government facilities.

Additionally, with the majority of large energy efficiency projects completed or underway, as well as dwindling fuel oil consumption in buildings, state facilities have targeted much of the low hanging fruit that result in significant reductions in GHG emissions. As such, LBE and its state partners will need to continue pursuing innovative approaches to moving away from fossil fuels and increasing building efficiencies, as well as drive further growth of renewable and alternative energy. Support for LBE activities across state government continues to expand, with a growing understanding of how important state government leadership can be in the effort to address climate change across the Commonwealth and region.

GREEN COMMUNITIES

Both created by the GCA, the Green Community Division of DOER manages the Green Communities Designation and Grant Program, which is one of the successful programs in the Commonwealth and leads the nation in demonstrating how a state can encourage and guide climate action at the municipal level. Since 2010, 210 municipalities – representing 70% of the Commonwealth's population – have become designated Green Communities by meeting the following five criteria:

- Pass zoning ordinances to encourage renewable or alternative energy generation;
- Adopt an expedited application and permit process for these facilities;
- Develop a plan to reduce energy use by 20% within five years;
- Adopt a fuel efficient vehicle energy policy for municipal use; and
- Adopt the Stretch Code, so that newly constructed homes and will use significantly less energy.

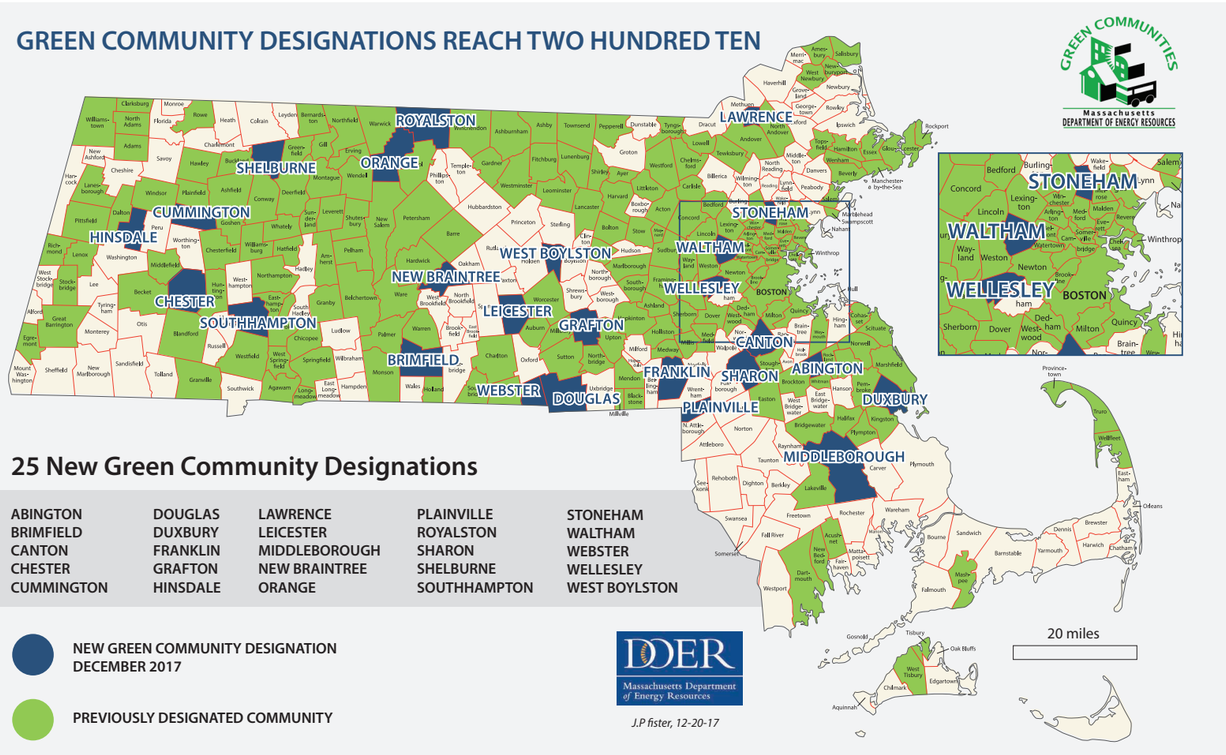
Green Communities are of many sizes and socio-economic types, and are located around the Commonwealth as shown in Figure 12. The Green Communities Division also serves all Massachusetts cities and towns as a hub for energy related issues and activities, helping communities increase energy efficiency and the use of renewable energy.

Activities and projects supported by the Green Communities Division have created significant GHG reductions and energy savings. All designated Green Communities must commit to lowering municipal energy use by 20% from their baseline value over five years. To date, the designated municipalities have reduced their cumulative energy demand by more than 15%, including 27 communities (out of 112 eligible communities) who have reached their 20% goal. This reduction has resulted in GHG emissions reductions of more than 300,000 metric tons of CO_2e.

The Green Communities Division also administers a grant program for participating municipalities. So far, grants totaling nearly $100 million have funded energy conservation measures, energy performance contracts, solar photovoltaic installations on municipal and school facilities, hybrid vehicle acquisitions, and other projects. In 2016, Massachusetts paid an average of $14.80 per million Btu of energy consumed (EIA SEDS). At that rate, the 11.5 trillion Btu of energy reductions in Green Communities equates to more than $170 million in avoided municipal energy costs.

The Green Communities Designation and Grant Program has been successful largely due to the interest and engagement of municipalities. A 2011 survey of Green Communities found that the largest share of respondents had a pre-existing desire to reduce the municipality's energy use, which saves taxpayer money and reduces GHG emissions. Although the Program requires ambitious action on the part of communities, most municipalities perceive these steps to be achievable and worthwhile. Buildings represent, on average, 70% of a municipality's total energy use and building-level measures, such as lighting upgrades, weatherization and other efficiency

FIGURE 12 | GREEN COMMUNITIES AS OF DECEMBER 2017



improvements, have contributed more than 80% of the Green Communities' total energy use reductions. Beyond government buildings, the Green Communities Act is saving residents energy and money: one municipal representative noted that "homeowners continue to report that the Stretch Code has saved them money on their utility bills and are satisfied with the result of it at their homes." The success of the Green Communities Designation and Grant Program is being used as a model for other states, including New York and Maryland, who are starting similar municipal clean energy programs.

As the Green Communities Designation and Grant Program matures, there are important opportunities for continued engagement and improvements. The significant growth of participating municipalities in the last four years necessitates an effort to maintain equity in opportunity for both long tenured and new communities. In addition, Green Communities that have been in the program for more than five years and not yet achieved their goals provide important test cases in how to address growth in demand for municipal services while simultaneously working to reduce overall energy consumption and GHG emissions. Finally, the Green Communities Division will need to identify opportunities to engage non-participating municipalities to recognize their efforts at energy and GHG emission reductions, and find opportunities to partner through technical assistance, grant making, or information sharing.

MEPA GHG EMISSIONS POLICY AND PROTOCOL

The Massachusetts Environmental Policy Act (MEPA) requires that certain projects within the Commonwealth assess their environmental impacts, analyze alternatives and adopt all feasible means to avoid environmental impacts or, to the extent that impacts cannot be avoided, to minimize and mitigate impacts to the maximum extent practicable. The MEPA review applies to projects requiring state permitting and which meet or exceed environmental review thresholds identified in the MEPA

regulations (301 CMR 11.00). The MEPA GHG Emissions Policy and Protocol (GHG Policy) was established in 2007 and revised in 2008 and 2010. The GHG Policy requires that Environmental Impact Reports (EIR) submitted to MEPA should include an analysis of project-related GHG emissions and identify measures to avoid, minimize, or mitigate these effects. Project proponents provide a comparison of GHG emissions associated with a project baseline and a preferred alternative that incorporates energy efficiency and GHG reduction mitigation measures.

From 2008 through November 2018, 166 projects have completed MEPA review in accordance with the MEPA GHG Policy. These projects have resulted in commitments to reduce GHG emissions by over 356,584 metric tons of CO_2e per year to date. Since 2015, 75 projects have completed MEPA review and resulted in commitments to reduce GHG emissions by over 181,728 metric tons of CO_2e per year.

Because alteration of land, including excavation, clearing and grading can have a significant impact on GHG emissions, the GHG Policy includes assessment of the effect of land alteration on GHG emissions. Projects that will result in more than 50 acres of new land alteration are required to quantify GHG emissions associated with the alteration, including loss of carbon sequestration. Staff from EEA and the MEPA Office have developed a draft protocol that includes: assumptions regarding current and proposed land uses, forest types, and soil types; assumptions regarding carbon sequestration of soils and trees; and the ability to consider a one-time loss of sequestration (e.g. tree clearing) as well as loss of potential sequestration over a certain time period. This protocol will be incorporated into the GHG Policy.

The MEPA review includes assessment of the vulnerability of projects to the effects of climate change and measures to improve adaptation and resiliency in the face of these vulnerabilities. In 2013, the draft Climate Adaptation and Resiliency Policy was issued for public comment. This policy has guided the assessment of climate change impacts and evaluation of opportunities to increase resiliency of infrastructure and natural resources. In consultation with state agencies and stakeholders, MEPA continues to integrate climate impacts and evaluation of sea-level rise, precipitation, and air temperature into project reviews. Revision of the GHG Policy will incorporate the draft MEPA Climate Adaptation and Resiliency Policy. In addition, it will be reflect E.O. 569, the Massachusetts State Mitigation and Climate Adaptation Plan, and other relevant resources (e.g., MVP Program, downscaled data, local assessments and plans).

CASE STUDY: WINTHROP SQUARE TOWER - PASSIVE HOUSE OFFICE IN BOSTON

Winthrop Square Tower will contain the first office use of this scale to be built to Passive House standards in Massachusetts; it may be the first in the country. Winthrop Square Tower consists of a 1,592,000 sf mixed-use high rise building. It will contain 750,000 sf of office space and 500 residential units within a single tower located on a podium comprised of retail, restaurant, and public spaces. The office component of the project will be designed and constructed to be certifiable per the Passive House Institute's Passive House standards. This amounts to approximately 50% of the project's use, at 750,000 sf and 20 floors.

Artistic rendering by Handel Architects LLP/ Steelblue LLC

The office portion of the building will achieve a 54% GHG emissions reduction compared to an office built to the base energy code. The entire building, including office and residential units, is designed to achieve a 31% stationary source GHG reduction level compared to the base energy code through incorporation of the following measures:

- Improved windows (U = 0.22, SHGC = 0.29) and aggregate wall R-value of R-7.9 for the office space;
- Reduced Lighting Power Densities (LPD) (Total Building = 0.74 W/sf; commercial – 0.59 W/sf; Office – 0.58 W/sf);
- Building envelope with improved roof insulation (R-40; U = 0.025);
- Energy efficient condensing boilers with 97% efficiency;
- Reduced heating loop temperatures (supply = 150°F, return temp = 110°F);
- Improved chiller performance (COP = 6.4);
- Improved Energy Recovery (65% efficiency);
- Energy Management System; and
- Enhanced building commissioning.

As appropriate, MEPA is requiring analysis of Passive House design due to its resiliency; lower energy demand; GHG emissions; and comfort (including soundproofing which is a particularly important consideration within urban areas).

4.5.3 CONCLUSIONS AND RECOMMENDATIONS

Leading by Example, Green Communities Program, and MEPA demonstrate how cross-cutting policies, which take a comprehensive approach to reducing GHG emissions, can be extremely effective at reducing GHG emissions. After years of success, all three programs are looking towards future actions and next steps that will continue to reduce GHG emissions from state-owned facilities, municipalities, and new development projects. Future actions include:

- Leverage and enhance data collection and analyses to help a diverse portfolio of government offices, public university campuses, and other state buildings track energy use and GHG emissions, as well as prioritize opportunities and strategies for future emissions reductions.
- Assist Green Communities to reduce their energy use by 20% within 5 years of their official designation despite growth in demand for municipal services.
- Identify opportunities to engage more municipalities to participate in the Green Community Designation and Grant Program.
- Revise the MEPA GHG Emissions Policy and Protocol, including incorporation of climate change adaptation and resiliency and land alternation.These steps will be critical to meeting the GWSA emissions limits, and will build on the programs' successes.

These steps will be critical to meeting the GWSA emissions limits, and will build on the programs' successes.

INTEGRATING CLIMATE CHANGE MITIGATION AND ADAPTATION

5.1 OVERVIEW

Massachusetts has a population of 6.9 million of people, about 70% of whom live in coastal shoreline communities that are and will continue to be significantly impacted by a changing climate. Inland communities across the state will also be affected by extreme weather, flooding, and increased heat. Recognizing the importance of addressing global climate change to protect vulnerable populations and ecosystems, Massachusetts has taken important steps to integrate the reduction in GHG emissions with improvement in the adaptive capacity of our built and natural environments. While mitigation is our first line of defense to reduce risks from climate change, adaptation efforts are needed to manage ongoing impacts from climate change. Adaptation and mitigation strategies can work synergistically toward the goals of the GWSA.

Fulfilling the requirement of the GWSA, EEA established an Adaptation Advisory Committee in 2009 to review potential approaches to help Massachusetts become more resilient in the face of growing evidence of climate change impacts. The Committee led the publication of the Climate Change Adaptation Report in 2011, which included an overview of the observed and predicted changes to Massachusetts' climate and the anticipated impacts, key vulnerabilities to climate change, and adaptation strategies that could increase resilience and preparedness.

Since then, EEA has hired a Director of Climate Adaptation and created the position of Assistant Secretary of Climate Change to oversee both climate change mitigation and adaptation efforts. Additionally, Governor Baker issued Executive Order 569 in 2016 establishing an integrated climate strategy for the Commonwealth. It requires:

- The EEA Secretary to set emissions limits for 2030 and 2040 in 2020 and 2030 respectively;
- The development of a comprehensive energy plan within 2 years;
- The development of state-wide climate adaptation plan within 2 years;
- The establishment of a framework for each Executive Office and for each municipality in the Commonwealth to assess its vulnerability to climate change and extreme weather events and to identify adaptation options for its assets;
- Technical assistance to Cities and Towns to complete vulnerability assessments, identify adaptation strategies, and begin implementation of these strategies.

Two years later, in August of 2018, Governor Baker signed into law the Environmental Bond Bill, codifying elements of E.O. 569, such as the development and updates of the state climate adaptation plan and the establishment of vulnerability assessment framework and grant program for municipalities. The bill authorizes over $500 million to climate change resiliency efforts and stipulates that investments made by EEA and its agencies must be consistent with the state climate adaptation plan.

This section discusses the implementation of E.O. 569, particularly the development of the State Hazard Mitigation and Climate Adaptation Plan, the Municipal Vulnerability Preparedness Program, and the Climate Change Clearinghouse website. This section also discusses the opportunity to integrate climate change mitigation and adaption priorities through land use GHG mitigation and carbon sequestration.

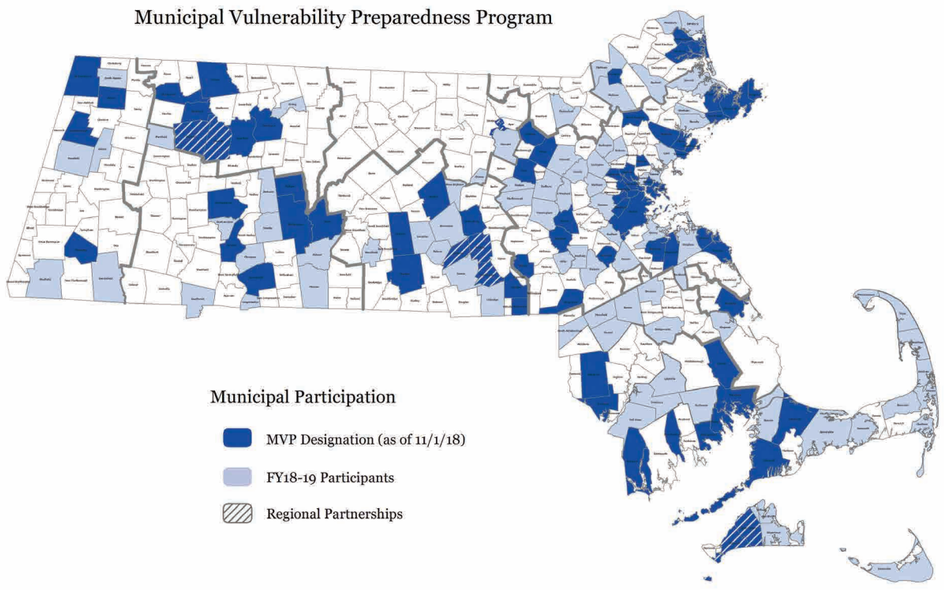
5.2 CURRENT PROGRESS

5.2.1 MUNICIPAL VULNERABILITY PREPAREDNESS PROGRAM

The EEA launched the Municipal Vulnerability Preparedness (MVP) program in the summer of 2017 to provide support for cities and towns in Massachusetts to plan for resiliency and implement key climate change adaptation actions for resiliency. The Commonwealth awards communities with funding to complete vulnerability assessments and develop action-oriented resiliency plans. For help completing their assessment and resiliency plan, communities can choose from a list of MVP certified providers trained on The Nature Conservancy's Community Resilience Building Framework. Communities who complete the MVP program become certified as an MVP community and are eligible for MVP Action grant funding and other opportunities. As of November 2018, 74 municipalities have been designated MVP communities, with another 83 communities currently completing the MVP planning grant as part of the designation process (Figure 13).

Since its establishment, EEA has provided $7.88 million in MVP Action and Planning Grants for municipalities to complete a workshop process that identifies climate change related hazards, and develops strategies to improve resilience and to implement priority actions. In 2018, EEA released the second round of MVP planning grants and the first round of MVP Action grants. The total funding awarded for both programs equaled nearly $7.24 million. The MVP Planning grants awarded totaled $4.9 million and are currently being used by municipalities to complete a community-driven process to identify hazards and develop strategies to improve resilience, and host listening sessions across the Commonwealth to discuss solutions and engage the public. Action grant funding (implementation) totaled nearly $2.3 million and are being used for a variety of projects that address the priority actions municipalities identified in their planning processes.

FIGURE 13 | MVP COMMUNITIES AS OF NOVEMBER 2018



5.2.2 MASSACHUSETTS CLIMATE CHANGE PROJECTIONS

In 2017 and 2018, researchers from the Northeast Climate Science Center (NRCC) at the University of Massachusetts Amherst developed downscaled projections for changes in temperature, precipitation, and sea level rise for the Commonwealth of Massachusetts. EEA provided support for these projections to enable municipalities, industry, organizations, state government and others to utilize a standard, peer-reviewed set of climate change projections that show how the climate is likely to change in Massachusetts through the end of this century.

The temperature and precipitation climate change projections were based on simulations from the latest generation of climate models[41] from the International Panel on Climate Change and scenarios of future greenhouse gas emissions. The models were carefully selected from a larger ensemble of climate models based on their ability to provide reliable climate information for the Northeast U.S., while maintaining diversity in future projections that capture some of the inherent uncertainty in modeling climate variables like precipitation. Future sea level projections were provided for the Massachusetts coastline at established tide gauge stations with long-term records at Boston Harbor, MA, Nantucket, MA, Woods Hole, MA, and Newport, RI. The projections are adjusted to each station's mean sea level and converted to the North American Vertical Datum of 1988 (NAVD88).

5.2.3 CLIMATE CHANGE CLEARINGHOUSE

The EEA officially launched the Massachusetts Climate Change Clearinghouse[42] in September 2018 as a gateway for policymakers, local planners, and the public to identify and access climate data, maps, websites, tools, and documents relevant to climate change adaptation and mitigation across Massachusetts. The goal of the website is to support scientifically sound and cost-effective decision-making and to enable users to plan and prepare for climate change impacts. The website includes information about GHG emissions and atmospheric concentrations, projected temperature and precipitation changes, climate effects such as sea level rise and extreme weather events, and more. It also catalogs specific vulnerabilities, risks, and strategies for and across industry sectors including agriculture, forestry, local government, education, energy, recreation, and transportation; and for local governance priorities including public health, public safety/emergency management, infrastructure, coastal zones, natural resources/habitats, and water resources.

The development of the resilient MA site was supported by EEA and DOER. Original development of the website was initiated and supported by the New York State Energy Research and Development Authority (NYSERDA). The project team includes Northeast States for Coordinated Air Use Management (NESCAUM), Cornell University, the NRCC, the State University of New York Environmental Sciences and Forestry's (SUNY ESF) Department of Forest and Natural Resource Management, and the Northeastern Regional Climate Services Director of NOAA.

5.2.4 MASSACHUSETTS STATE HAZARD MITIGATION AND CLIMATE ADAPTATION PLAN

The EEA, in partnership with the Massachusetts Emergency Management Agency (MEMA) and state agencies, released the Massachusetts State Hazard Mitigation and Climate Adaptation Plan (SHMCAP) in September 2018 in fulfillment of E.O. 569. The Plan, the first of its kind to comprehensively integrate climate change impacts and adaptation strategies with hazard mitigation planning, also complies with current federal requirements for state hazard mitigation plans and maintains the Commonwealth's eligibility for federal disaster recovery and hazard mitigation funding under the Stafford Act. As part of this planning effort, every state agency (over 70) completed an initial vulnerability assessment to better understand how climate change will impact their operations, mission, and function. These assessments are helping agencies identify actions needed to build resilience and continue to meet their mission as the climate changes. Collectively, state agencies identified over 100 initial actions to begin to adapt to a changing climate. An interagency implementation team will start work in 2019.

5.3 LAND USE GHG MITIGATION AND CARBON SEQUESTRATION

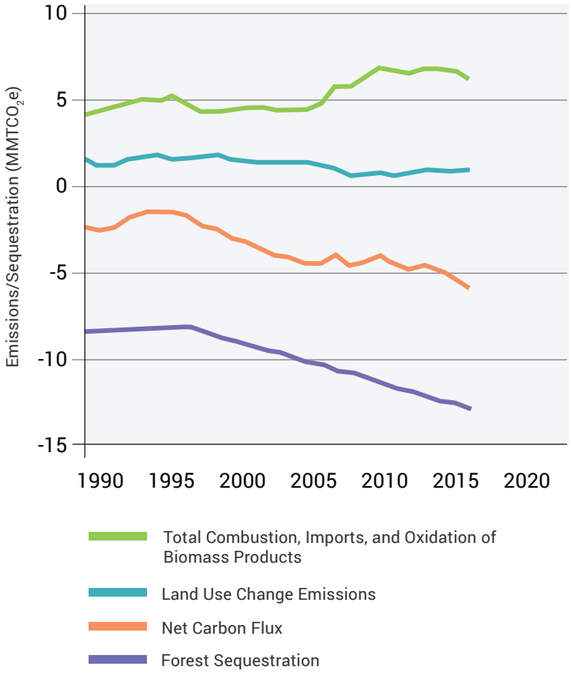
Nature stores carbon in plant material and in soil. Altering cultivated, forested, herbaceous, and other land releases stored carbon, and, if the alteration includes impervious development such as a road or building, it also precludes future sequestration which remove the GHG in the atmosphere that causes global warming and extreme weather events. The avoided loss or degradation of natural and working lands has benefits for both climate change mitigation and adaptation. Recognizing this, Massachusetts has land use and other policies that seek to reduce the loss of natural and working land cover types. Yet, to date the Commonwealth's ability to measure the efficacy of those policies is limited. That is why work has been undertaken to gather data and develop a methodology to track the carbon implications of land cover change. Such analysis can inform the development and evaluation of mitigation and adaptation policies not only on a statewide basis but also within specific geographic areas of interest.

The Massachusetts GHG inventory does provide estimates of carbon sequestration for forests and of land use emissions annually since 1990 (Figure 14), though EEA and state agencies do not count those biogenic emissions and sequestration toward GWSA compliance. Those estimates indicate that, after accounting for estimated emissions from land use change, natural and working lands in the Commonwealth are sequestering 11.9 $MMTCO_2e$ in 2016, which represents a steady increase from a net sequestration of 6.7 $MMTCO_2e$ in 1990. Adding in the combustion of woody materials, the consumption of ethanol in gasoline, and other biogenic emissions, the net carbon flux in 2016 is approximately 5.8 $MMTCO_2e$ sequestered.[43]

While estimates of net carbon flux in the GHG inventory provide a long term trend of sequestration, land use change emissions, and other biogenic emissions, the methodology does not provide information on how natural and working lands are being impacted, especially from human activities (principally the development of farm and forest land) and acts of nature such as tornadoes, hurricanes, and forest fires. The primary interest of EEA is to obtain at regular intervals a calculation of the impact of human alterations on the amount of carbon present on the land, with the objective of developing or enhancing policies intended to keep, or even increase, carbon on the land.

[41] These latest generation of climate models are included in the Coupled Model Intercomparison Project Phase 5 (CMIP5), which formed the basis of projections summarized in the IPCC Fifth Assessment Report (2013).
[42] http://resilientma.org/
[43] Methodology to estimate the carbon flux in Massachusetts is documented in the MA GHG inventory and supporting documents.

FIGURE 14 | OVERALL BIOGENIC EMISSIONS AS ESTIMATED IN THE MA GHG INVENTORY



In 2015, EEA hired Abt Associates and Applied GeoScience (AGS) to provide an alternative method to track carbon flux in the Commonwealth going as far back as 1990. As part of that analysis, Abt/AGS produced carbon stock profiles for 15 land cover types and for each county. The intention was to use these carbon stock values to calculate carbon flux from detected changes between the different land cover types over time. However, the use of the National Land Cover Databases (NLCDs) in Abt/AGS's analysis proved to be limited.

Therefore, the MassGIS Office, in consultation with outside experts, is developing a detailed combined land use/cover map that is based on MassGIS integrating 20 categories of land cover mapping done by NOAA's Office for Coastal Management with statewide land use mapping derived from assessors use codes contained in the statewide land parcel data layer. The combined land use and land cover data, to be released in the Winter of 2018/2019, provides baseline conditions for 2016. Going forward, updated versions of the same map will allow year-to-year comparisons to assess land use and land cover changes. A key concern is the ability to produce a new iteration of the data and maps at regular intervals going forward. To that end, funding has been set aside from the Planning line item in EEA's capital budget to iterate the data and maps every few years. Other ources of money and an interagency agreement are being discussed, with the intent being to secure funding sufficient to iterate the land cover/use data every other year.

As soon as a new version of the land cover/use data becomes available, it will be possible to measure the change in cover types over the intervening period. By applying the carbon stock value for each cover type to the net change in each type, the carbon implications of land cover change will be known. Based on the change, policies and programs meant to reduce carbon emissions and increase sequestration can be adjusted accordingly. It appears that suitable aerial photography will be taken in 2019, meaning that the first interval will be the three years between 2016 and 2019. Ultimately, the land cover/use data can be used for a wide variety of tasks beyond carbon measurement. An example would be tracking the amount and location of housing produced.

5.4 NEXT STEPS AND RECOMMENDATIONS

As EEA and state agencies integrate climate change mitigation and adaptation, one of the priorities is to better understand the carbon flux in natural and working lands in the Commonwealth over time and to better track how human activities are impacting the carbon flux. Having such understanding is important as EEA and state agencies:

- Look for opportunities to deploy strategies that achieve adaptation and mitigation goals, such as sustainable forestry practices and urban tree planting; and
- Explore additional land use strategies and policies and nature-based solutions to increase carbon sequestration and avoid GHG emissions from natural and working lands.

APPENDIX A: GHG REDUCTION METHODOLOGIES

GENERAL APPROACH

COMPUTING REDUCTIONS

Approaches to estimating greenhouse gas emissions reductions generally fall into one of two methodology types: direct computation and indirect attribution. Direct computations require actual measurements of program outputs, which are not always available on a timely basis, if at all. Indirect estimation, on the other hand, attributes observed emissions reductions to policies on the basis of that policy's assumed outcomes.

Direct methodologies represent a computation of an emission that *did not* happen directly because of a program, and require specific program data. To track compliance with the Renewable Portfolio Standard, for example, the Department of Energy Resources keeps track of how many megawatt-hours of eligible electricity were supplied per year. Since this clean power generally replaces a marginal natural gas-burning unit, we can reasonably compute the amount of greenhouse gas emissions that unit would have created had it not been displaced by new renewable sources.

Many policies and programs do have such direct data, and so reductions must be estimated from proxies, indirect indicators, or average values. Fuel economy standards, for example, decrease GHG emissions by reducing fuel consumption. We can measure this change by looking at changes in total miles driven each year and total gasoline consumed each year. But it would be impossible to individually measure every new car sold and compare it to the old car it replaced. Instead, we create a hypothetical "no-policy" scenario in which we assume the measurable impact if the policy never occurred: for Corporate Average Fuel Economy (CAFE) standards, this means asking what would emissions look like if the average fuel economy of the statewide fleet did not improve from our GWSA-specified 2009 benchmark. The emissions reduction from the fuel standards policy can then be calculated as the difference between that hypothetical and the estimated emissions that actually occurred.

These "no-policy" hypotheticals are similar to the "business-as-usual" projections included in the original CECP as well as the 2015 CECP Update, but differ slightly in that they reflect updated information. For the Transportation Sector, for example, the hypothetical calculated today is slightly higher than the BAU projected in 2015 for a variety of reasons, but largely because vehicle-miles traveled increased more than was anticipated. This reflects, generally, the strong economic growth experienced in the Commonwealth over that period and illustrates the challenges in modeling any system as complex as the Massachusetts economy.

A NOTE ON ACCOUNTING AND DOUBLE-COUNTING

When ascribing GHG reductions to any set of policies, it is crucial to review all policies within a sector to ensure that there is no overlap, and, thus, no double-counting of emissions reductions. Many of the policies targeted at reducing carbon emissions from buildings overlap. For example, MassCEC issues rebates for renewable heating and cooling systems, including biomass heating systems, ASHPs, and other technologies. The Mass Save® energy efficiency programs also provide incentives for ASHPs. When adding in programmatic energy (and thus emissions) savings, therefore, it is important to recognize where the two policies overlap and ensure that one heat pump's GHG reductions are not counted twice. Additionally, electricity savings from policy implementation are assigned to the Electricity Sector, while savings of primary fuels are in the Buildings Sector.

COMPUTING EMISSIONS

In most instances in this report, reductions in GHG emissions from policies are juxtaposed with total emissions. These are computed in several different ways. First, emissions in 2020 were projected as part of the development of the 2015 CECP Update. These emissions levels are generally labeled as "Planned for 2020," indicating their role in that planning document; planned baseline changes also reflect the values published in the 2015 CECP Update.

Actual emissions in 2016 are reported from the most recent update of the MassDEP GHG Inventory, for which 2016 is the most recently finalized data year [A]. Baseline changes in 2016 [B] represent the difference between computed reductions [C] and each Inventory sector's emissions from 1990 [D]. That is, using the residential sector as an example:

[A] Residential emissions in 2016 (MassDEP)
\+ [C] Policy reductions from the Residential Sector in 2016 (EEA)
\+ [B] Baseline changes in the Residential Sector in 2016

[D] Residential emissions in 1990 (MassDEP)

Currently projected emissions come from EEA's LEAP modeling. This software tool populated with Massachusetts-specific data compiles energy consumption activities and varies them according to a variety of inputs, resulting in a comprehensive analysis of likely emissions in the future. For the purposes of this Progress Report, the outputs used represent EEA's "Reference Scenario" which includes GHG inventory data from 1990 to 2015, and a continuation of many historical trends in population and economic growth as well as the effects of Massachusetts' current suite of policies.[44] Thus, the net difference between 1990 emissions and LEAP's 2020 emissions can be attributed to the combined effects of GWSA policy reductions, as well as baseline changes from pre-GWSA policy reductions, non-policy changes, and other effects. Policy reductions are computed as described in the following sections, while baseline changes for each sector represent the difference between the sector reduction from 1990 to 2020 and the policy reductions computed for that sector.

ENERGY EFFICIENCY AND RENEWABLE ENERGY IN HOMES AND BUSINESSES

ALL COST-EFFECTIVE ENERGY EFFICIENCY

The impacts of energy efficient technologies can be measured directly. The Mass SAVE® Program Administrators (PAs) collect and compile information about every rebate, audit, etc. each year. Through a series of "screening calculations" performed by PA staff, each specific measure results in some savings of electricity, natural gas, propane, or fuel oil. The calculations include "snap-back" issues, such as the new heating load required (a negative reduction) when a building switches over from incandescent light-bulbs (which inefficiently emit a lot of heat) to LEDs (which create less waste heat).

These energy savings can then be converted into equivalent emissions avoided, and summed up into a total annual reduction. Since a measure, once installed, continues to reduce energy use each year of its operation, the total reductions from these programs are cumulative. However, each year the total reduction of any specific measure is discounted slightly to represent the depreciation of the technology as well as any performance degradation that might be expected.[45]

In order to avoid double-counting with the Advanced Building Energy Codes policy, savings from Mass Save®'s "new construction" initiatives are subtracted out of the All Cost-Effective Energy Efficiency policy. Conversely, savings from appliance standards that apply to residential lighting are included in All Cost-Effective Energy Efficiency, but excluded from the Appliance and Product Standards policy.

APPLIANCE AND PRODUCT STANDARDS

All appliance and product standards included in the 2015 CECP Update were set nationally, promulgated by the U.S. Department of Energy (DOE). As part of the rulemaking process, DOE staff developed complex models to forecast the total national expected savings of each measure by certain dates. The Appliance Standards Awareness Project (ASAP) collects and aggregates these outputs into total projected national energy savings, by standard, in 2025 and 2035.

[44] The 2016 GHG emissions inventory was made available to EEA in mid-December of 2018, which was late in the development of this Progress Report. EEA staff were able to quickly incorporate the 2016 data into our analyses of policy impacts and projection of future GHG emissions under the "Reference Scenario." However, additional analyses are needed to understand the GHG emission trends from 2015 to 2016 and their potential implications for future GHG emissions projection.

[45] Performance degradation of the technology is a reduced efficiency as the product ages. Depreciation reflects that the measure will eventually die and be replaced. EEA combine the two together in a single discount factor that accounts for both.

These savings are downscaled to Massachusetts by a series of specific downscaling factors: each factor is computed individually and reflects a real ratio, such as Massachusetts' share of the entire country's stock of natural gas boilers. Some factors, particularly those for standards covering heating and cooling technologies, adjust for the fact that Massachusetts' climate is colder than the national average.

Next, the savings are amortized according to when the standard went into effect (i.e., if a standard implemented in 2010 is expected to save two hundred million KWh of electricity in 2025, then each year of savings builds up linearly from zero in 2009 to two hundred million in 2025). We are careful to only include savings from standards that are actually implemented, and exclude any that have yet to be finalized.

Appliance standards generally represent minimum product requirements, rather than best-in-class efficiency. In fact, most EnergySTAR rating labels indicate an energy performance some percentage better than the appliance standard (often 20%). When computing energy efficiency gains, the PAs' screening calculations assume a certain baseline of performance. For most household appliances, this baseline – where energy efficiency begins – is approximately where appliance standards end. However, the savings Mass Save® computes for lighting measures extend further than the benchmark of appliance standards. Since removing lighting as a specific measure from Mass Save®'s initiative-level data is quite difficult, to avoid double-counting, the impacts of lighting standards are not counted in the Appliance and Product Standards policy, as we assume that they are included under the umbrella of the All Cost-Effective Energy Efficiency policy.

ADVANCED BUILDING ENERGY CODES

The gradual adoption of new building codes results, primarily, in homes and businesses with more insulation and better windows, though additional parts of the codes also affect energy consumption through electrical and plumbing requirements. Estimating the impact of specific new construction built with or without specific building codes is extremely difficult, since the new unit's appliances, envelope, and performance are irrevocably intertwined. This methodology, therefore, takes a more holistic approach, simply evaluating the emission reductions associated with new construction more generally.

Mass Save®'s savings database includes all savings associated with measures supported under its new construction initiatives. Although projects in the Mass Save® database account for a large portion of new construction, using only those reductions would undercount the total new construction savings in the Commonwealth. Mass Save®'s database, however, allows the computation of an average savings per unit, which can be multiplied by the total number of new construction permits each year to estimate the actual total savings associated with new buildings. (The number of construction permits is scaled down somewhat to account for permits pulled for projects that were not completed.)

There is some evidence to suggest that new construction not included in Mass Save®'s database, although adhering to building codes, may not show the same level of savings as those buildings that did apply for and receive Mass Save® incentives. This would mean that this methodology is over-estimating savings from new construction which is compliant with building codes. However, major renovations and retrofit projects are also required to bring older units up to code. Some of this renovation is included in Mass Save®'s database, and thus counted under "All Cost-Effective Energy Efficiency," but much is not, leading to an under-estimation of the impact of advanced building energy codes. Although both of these caveats lend to a reduction in precision, directionally, the two sources of error approximately offset, resulting in an approximate estimate of emissions reductions from building codes.

RENEWABLE THERMAL TECHNOLOGIES

The umbrella of renewable thermal covers a broad range of technologies and strategies, from geothermal wells to increasing the biofuel component of fuel oil. The impact of each technology must be measured separately.

The MassCEC maintains a database of rebates for renewable thermal technologies, including ground-source heat pumps (GSHPs), efficient biomass heating systems, and ASHPs. Each database entry includes the old heating system displaced or replaced (often a relatively small heat pump will serve as primary heat for most days with the older system remaining as a supplemental backup), the thermal output of the new system, and a factor indicating the system's average efficiency. Combined with data on average use, these data can be used to compute the expected electricity or fuel requirements of both the new system and the old system. Multiplying by carbon intensities yields a net benefit of the new technology.

Air-source heat pumps are not, strictly speaking, a renewable technology. When installed in a home or business which previously used electricity as a source of heat, any energy savings and associated emissions reductions could very likely be included in Mass Save®'s programmatic efforts to improve efficiency. Any electricity-to-electricity savings from MassCEC rebates are excluded from this policy as they likely appear under the All Cost-Effective Energy Efficiency policy.

In addition to these technologies, DOER began implementing the biofuel blending provisions of the Alternative Portfolio Standard in 2018. Although no reductions will be officially counted until 2019, DOER can estimate the reduction impact of this program in 2020. The 2020 APS requirement is 5% of retail load obligation, currently projected to be 45,000 GWh. DOER currently expects about 15% of the APS's 2,250 GWh (7.7 trillion Btu, or 1.4 million barrels of oil equivalents) alternative energy standard to be fulfilled by biofuels. This will result in the displacement of 1.2 trillion Btu (210,000 barrels) of fuel oil by biofuels that meet certain life-cycle carbon reductions. Multiplying by a simple carbon-content conversion factor for the displaced fuel oil results in a direct emissions reduction forecast which can be added to the results of the renewable thermal calculations described above.

HIGHWAY VEHICLES

CORPORATE AVERAGE FUEL ECONOMY (CAFE) & LOW-EMISSION VEHICLE (LEV) PROGRAM

It is not possible to measure the actual on-road savings directly. Instead reductions from fuel economy standards, such as CAFE are indirectly ascribed by asking the hypothetical: what would emissions look like if cars' engines had not gotten more efficient since 2009?

The MAPC collects and reviews vehicle inspection and maintenance data from the Registry of Motor Vehicles to build an annual vehicle census. This anonymized database includes total vehicle mileage and estimated fuel economy for almost every registered vehicle in the Commonwealth annually from 2009 through 2014. Combined, these two data points can be used to compute weighted average fuel economy for the entire state each year. For years beyond 2014, this annual bulk fuel economy is projected from a linear regression.

Separately, MassDOT tracks the total number of miles driven by cars across the entire Commonwealth through the Highway Performance Management System (HPMS), which it operates in partnership with the Federal Highway Administration (FHWA). In addition, MassDOT forecasts VMT out to 2040 to inform transportation planning. The HPMS methodology changed in 2015, resulting in a more accurate and higher estimation of VMT in 2015 and 2016. Although MassDOT cannot go back and re-measure VMT in previous years with the new methodology, it supplies the EEA with adjusted historical estimates that better align with the new methodology.

Dividing miles driven by miles per gallon, we compute for each year (and in 2020) an estimate of the gasoline actually consumed by light-duty vehicles and an estimate of the total fleet's total gasoline consumption if all the miles driven in any given year were driven by the average car in 2009. The difference in gallons of gasoline not consumed is the result of the policy, which can estimate reduction in greenhouse gas emissions due to fuel economy improvements.

MassDEP's LEV program also includes several incentive programs and placement requirements for ZEVs, such as plug-in hybrids and battery-electric vehicles. Since these vehicles represent a relatively small percentage of the total fleet, the emissions reductions they result in are, for now, lumped in with CAFE standards. However, in the future, ZEV sales could improve average fuel economy well beyond current standards for internal combustion engine vehicles, and would need to be broken out as a separate reduction. Finally, the electricity required to run

ZEVs does have some small emissions associated with it, which are reflected in a negative reduction in the 2020 electricity sector.

SMART GROWTH

Smart Growth policies result in many different benefits, particularly non-greenhouse gas related benefits, the benefits of reducing emissions of carbon stored on undeveloped (natural) lands, and the emissions savings associated with reduced driving needs especially in denser communities. Although the reduction in driving due to Smart Growth policies cannot be measured directly, this methodology indirectly ascribes reductions on the basis of observed changes in population and driving patterns.

The MAPC collects and reviews vehicle inspection and maintenance data to build an annual vehicle census, which tracks the number of miles driven by cars in every city and town in the Commonwealth. In addition, Massachusetts' regional planning associations (RPAs) have classified each city and town into one of five categories (Table 14), and, for each city and town projected population growth out to 2020.

From 2010 to 2016, the population of Massachusetts grew by more than 180,000 people. A full third of that population growth occurred in the 16 cities and towns that make up the Boston area's "inner core" where a large number of trips can be made without a car. An additional 40% moved to relatively dense suburbs where trip distances are relatively shorter. This methodology asks the hypothetical question: what if people had moved to the next less dense category of city or town? That is, what if the 42,529 people who moved to Medford and Arlington (inner core) actually moved to regional urban centers like Brockton or Framingham and needed to drive, on average, an extra 2,000 miles per year; and then what if people who moved to Framingham instead moved to Dedham (a maturing suburb) and needed to drive an extra 1,500 miles per year.

Adding up these what-ifs, population growth in less-dense communities would have resulted in more than a million extra vehicle-miles traveled per year in 2016 and more than two million more in 2020. Dividing by average fuel economy and multiplying by conversion factors, such as the carbon-content of gasoline, results in a net carbon dioxide emissions reductions annually and projected in 2020.

PHASE 1 STANDARDS FOR MEDIUM- AND HEAVY-DUTY VEHICLES

The U.S. EPA's Phase 1 Standards for Medium- and Heavy-duty Vehicles are more technical and more complex than CAFE standards for light-duty vehicles. Reflecting that medium- and heavy-duty vehicles must do more than simply get from point A to point B, rather than miles per gallon or grams of CO_2 per mile, these standards apply to two aspects of more holistic vehicle performance:

1. Grams of CO_2 per ton-mile of freight
2. Grams of CO_2 per brake-horsepower-hour (BHP-hr)

Both standards are set individually for various classifications of truck. The standards under 1) are most important for Class 8 trucks (i.e., semis or tractor-trailers), which carry 97% of Massachusetts' freight, while the standards under 2) are more relevant to "light-heavy" vocational trucks (i.e., large pick-up trucks, work trucks, etc.) and "medium-heavy" buses and box trucks.

TABLE 13 | VMT AND POPULATION BY RPA

RPA CATEGORY	AVERAGE MILES DRIVEN PER PERSON* PER YEAR	POPULATION CHANGE, 2010 TO 2016	TOTAL POPULATION IN 2016	PROJECTED 2020 POPULATION
Inner Core	3,813	62,267	1,453,474	1,522,528
Regional Urban Center	5,790	29,194	2,110,091	2,129,955
Maturing Suburbs	7,478	40,330	1,306,261	1,297,518
Developing Suburbs	8,731	48,556	1,756,073	1,768,300
Rural Towns	10,889	1,239	87,564	89,466

*These values are less than a car's average annual mileage, because these reflect per-person mileage, not per car

The U.S. Federal Highway Administration's (FHWA's) Freight Analysis Framework (FAF) analyzes historical freight data and forecasts future freight demands. FAF data play a central role in MassDOT's recent Freight Plan. The standard can be computed as an annual reduction in grams of CO_2 per ton-mile, so multiplying by total annual ton-miles of freight yields a net GHG emissions reduction in that year. Some adjustments are made to account for the freight impacts of smaller box-trucks, though, again, these are quite small in comparison to the standard's effect for Class 8 tractor-trailers.

Unlike total ton-mileage, average brake-horsepower of various classes of trucks is difficult to determine directly. Brake-horsepower is a unit of power. Where horsepower measures the power of the engine alone, brake-horsepower measures the power output of the entire drive chain, essentially accounting for inefficiency that occurs between the engine and the wheels. Multiplying a power by hours of operation results in a unit of energy (much like how a kilowatt is a measure of an instantaneous draw of electrical power, and a kilowatt-hour is a measure of total energy required).

Barring substantive changes to fuel content, carbon emissions are directly proportional to fuel consumption. In addition, hours of operation are simply total mileage divided by average speed. Thus, as long as truck fleets do not, on average, become significantly more powerful over time or find themselves driving at significantly different average speeds, grams of CO_2 per BHP-hr is directly proportional to the ratio of total gallons over total miles – that is, it is inversely proportional to fuel economy (MPG). Thus, where the standard calls for a 4% reduction in grams of CO_2 per BHP-hr for light-heavy trucks from 2014 to 2017, this can reasonably be computed as a 4% increase in light-heavy trucks' fuel economy over that same timespan.

From there, it is simply a matter of applying the Phase 1 Standards, as a percentage, to the average fuel economies of Massachusetts' various truck fleets (which were computed in MassDEP's 2016 Massachusetts Diesel Inventory) in order to estimate the standards' impact on fuel economy historically and projected for 2020. These historical and projected fuel economy improvements are then divided by total mileage ascribed to each truck class to arrive at an estimated fuel reduction by class, per year, which are aggregated up for the entire fleet and converted into CO_2 emissions.

Since the two sets of standards apply to different types of trucks with little to no overlap, the two emissions reductions calculated can simply be added together for a total Phase 1 reduction.

PHASE 2 STANDARDS FOR MEDIUM- AND HEAVY-DUTY VEHICLES

Federal Phase 2 standards cover a wide variety of vehicles and requirements as far out as 2035, but only one requirement will result in a net benefit by 2020: the phase-in of a requirement for tractor-trailers to install "skirts" which reduce drag and therefore increase fuel efficiency. Quantifying the reduction is relatively straightforward: the number of applicable trucks times the percentage estimated to be converted by 2020 times the average annual fuel consumption of such trucks times the expected percent improvement in fuel efficiency from installing the skirt yields an expected decrease in fuel consumption due to the rule. This is easily converted from gallons of diesel into metric tons of carbon dioxide equivalent.

RENEWABLE FUEL STANDARD (RFS)

The U.S. EPA has mandated the production and blending of a variety of bio-based fuels into conventional motor gasoline. Cellulosic ethanol, in particular, has extremely low life-cycle emissions. The EPA's mandate called for production of 3 billion gallons of cellulosic ethanol in 2015, ramping up to over 10 billion gallons in 2020. However, as production has failed to grow to meet this mandate, EPA has issued further guidance aligning the mandate with available supply. This guidance places the cellulosic fuel standard at 123 million gallons in 2015, headed toward 500 million gallons in 2020.

Massachusetts consumes about 2% of the nation's motor gasoline, so it is expected to receive 2% of the available cellulosic ethanol, or about 10 million gallons. Ethanol blends into gasoline at a rate of 1.5 gallons of ethanol per gallon of displaced gasoline, so that 10 million gallons in 2020, for example, should displace about 6.7 million gallons of gasoline. That quantity of displaced fuel is then

multiplied by a standard gasoline conversion factor to estimate the associated emissions reduction of about 0.1 $MMTCO_2e$ in 2020. The same calculation is performed in 2016, resulting in a reduction of approximately 30,000 metric tons of CO_2 in 2016.

ELECTRICITY GENERATION

POWER PLANT RETIREMENTS

Estimating the emissions reductions from power plant retirements is relatively straightforward. Power plants report, annually, their total energy generation and their annual carbon emissions.

Simply enough, this methodology calculates the emissions change from a power plant not operating; since that electricity is still required, the methodology assumes that its generation will be replaced with generation from a relatively new natural gas-fired combined cycle (NGCC) power plant. Currently these NGCC plants represent the majority of New England's grid supply and are both easy and inexpensive for ISO-NE to dispatch. On average, the large Massachusetts RGGI natural gas-fired units emit approximately 931 pounds of CO_2 per MWh of electricity produced, which is considered for this, and other electricity sector emissions policies, the marginal unit of electricity emissions.

In Massachusetts a series of four large coal-fired power plants were retired between 2008 and 2018. However, in 2019, the Pilgrim Nuclear Station in Plymouth will go offline, removing a large source of carbon-free electricity from the grid-supply. Assuming that all of these power plants are displaced by natural gas, which emits at approximately 931 pounds of CO_2 per MWh, the net reduction in emissions is 1.65 $MMTCO_2$ in 2016 and 2.71 $MMTCO_2$ in 2020.

RENEWABLE PORTFOLIO STANDARD (RPS)

Each year, DOER publishes its annual report indicating the number of renewable energy credits (RECs) produced. Since some RECs may be banked for compliance with RPS in a later year, this methodology looks at only the number created, not the number retired, thus capturing the actual emissions that did not occur. (In an extreme example, an entity could bank all its credits from years of production and then use them all in one compliance year, which would not accurately portray the actual renewable generation occurring in a particular year.)

The reduction calculated is simply the number of credits generated (measured in MWh) multiplied by the same emissions factor assumed in other methodologies for the marginal unit of electric power in New England (931 lb. CO_2 per MWh). The RPS program was first established in 2003 and expanded in the Green Communities Act alongside the GWSA, so the CECP only "takes credit" for reductions resulting from the expanded RPS levels. In 2010, for example, the total RPS requirement was 10% of retail load obligation, but 7% of that is from the original 2003 standard. That 7% is considered to be in the baseline (or business as usual) while only 3% is credited as an outcome of GWSA policy. This represents one, of many, sources of downward-sloping BAU trajectories that fall outside of reductions attributed to the CECP and GWSA programs.

For the 2020 projection, DOER has forecasted a total retail load obligation of 45,000 GWh, and it assumes compliance with the RPS requirement in that year (15% total, of which 4.5% is from pre-GCA standards).

CLEAN ENERGY STANDARD (CES)

First implemented in 2018, there is not yet a full year of reduction data available for the CES, but the methodological treatment is essentially the same as the methodology for RPS. In 2020, the total CES will be 20%, of which 15% will be fulfilled by RPS. The remaining 5% represents an incremental reduction which is attributable beyond RPS, again at 931 lb. CO_2 per MWh to the CES policy.

NON-ENERGY EMISSIONS

PLASTICS COMBUSTION

Municipal waste combustors (MWCs) in Massachusetts burn about 3 million short tons of municipal solid waste (MSW) each year. MSW is generally a mixed composition, primarily made up of organic (i.e., food) waste, paper, cardboard, and plastics. It also includes smaller amounts of ceramics, metals, electronics, and other materials. When burnt, plastics emit more CO_2 per ton than other components of MSW. MassDEP triennially surveys the plastics composition and total tonnage of MSW combusted (2010, 2013, and 2016). Any reduction in total plastic combusted (total MSW combustion does not change significantly from year-to-year, rather the percentage of it which is plastic has fallen) results in a modestly lower overall emissions profile of that combustion. Multiplying the total tonnage of MSW combusted by the difference in plastic composition yields a reduced tonnage of plastic combusted. Using a bulk emissions factor based on the average composition of plastics in the MSW stream, this can then be converted to a GHG reduction. However, the weight of plastics not combusted is replaced with an equal tonnage of average bulk MSW, which has its own emissions factor. These emissions are added back in, but, because bulk MSW is much less carbon intensive than plastics, there is a net GHG emissions reduction. Triennial MSW surveys show Massachusetts has seen modest success in diverting plastics from the waste stream between 2009 and 2016.

REFRIGERANTS, GAS-INSULATED SWITCHGEAR (SF_6), AND NATURAL GAS DISTRIBUTION PIPE LEAKS

Emissions of various non-CO_2 greenhouse gases, such as SF_6 from gas-insulated switchgear and ozone-depleting substance substitutes used as refrigerants and aerosols, are tracked directly in the Massachusetts Greenhouse Gas Inventory. Emissions changes for each of these sources, therefore, are simply computed as the difference between emissions levels today and emissions levels when the GWSA was enacted.

Projections to 2020 reflect previous forecasts from MassDEP as well as the incremental emissions caps set under MassDEP's response to the Kain ruling. For further information on how MassDEP calculates emissions of non-CO_2 gases, see the technical documentation of the Massachusetts GHG Inventory.[46]

[46] https://www.mass.gov/lists/massdep-emissions-inventories#greenhouse-gas-baseline,-inventory-&-projection-

Massachusetts Global Warming Solutions

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