Eastern Research Group, Inc.

COST-EFFECTIVE GREENHOUSE GAS MITIGATION IN MASSACHUSETTS: AN ANALYSIS OF 2020 POTENTIAL

DRAFT REPORT

Prepared for:

Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs

Prepared by:

Eastern Research Group, Inc.

With

Synapse Energy Economics, Inc.
Cambridge Systematics, Inc.
Abt Associates, Inc.
Stockholm Environment Institute – U.S.

May 3, 2010

ERG Project No: 0284.00.003.001

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May 3, 2010

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1.0 INTRODUCTION

In August 2008, Governor Deval Patrick signed into law the Global Warming Solutions Act (herein "the Act"), making Massachusetts one of the first states in the nation to move forward with a comprehensive program designed to grow the clean energy economy and address climate change. The Act requires an 80 percent economywide reduction of greenhouse gas (GHG) emissions below 1990 levels by 2050 and also requires the Secretary of Energy and Environmental Affairs to set a GHG emissions reduction requirement for 2020 that is 10 to 25 percent below 1990 levels.

In addition to setting a target reduction for 2020, the Secretary is charged with providing a plan by which the state will achieve that target. An interagency team, aided by the consulting team that authored this report, has been working with the Act's Advisory Committee on Climate Protection and Green Economy to prepare such a plan. The plan is to be completed and the requirement set by January 1, 2011.[1]

Massachusetts has extensive policies in place that are designed to achieve interrelated goals: grow businesses and jobs in the clean energy sector; reduce energy costs for ratepayers; increase our energy independence; and reduce GHG emissions from electricity generation, buildings, industry, transportation, and other sectors. In a draft report issued on February 5, 2010,[2] the consulting team estimated that the state's **existing GHG reduction policies**, along with federal and other policies well underway, would cut Massachusetts' emissions by approximately 19 percent by 2020. Estimating impacts from **existing policies** was the first step in designing a plan. The second step, the topic of this report, is to look at the **potential** for further cost-effective emissions reductions by 2020.

It is important to clarify what is meant by "potential." In this context, the potential emissions reductions represent the combined impact of readily quantifiable measures that could be taken at low or zero cost, or at a net savings. Some of these measures face market barriers, such as lack of awareness, and other hurdles that may make it difficult to realize all the GHG reductions they could produce by 2020. For example, not all consumers are willing to implement available energy efficiency measures, even when these will pay for themselves within a few years or sooner.

The calculation of potential in this report is consistent with other studies on potential for reducing energy use and GHG emissions. For example, identification of cost-effective potential is standard practice in utility-run energy efficiency programs, and is often termed "economic potential." In general, the initial costs of implementing an efficiency measure must be less than the savings over time in energy bills, in order for the measure to be part of a utility's programs.

A second example of estimating potential is found in the widely cited 2007 report "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?," by McKinsey & Company. McKinsey estimated the tons of GHG emissions that could be reduced throughout the economy at various

[1] See: http://www.mass.gov/dep/public/committee/cpge.htm.

[2] "Initial Estimates of Emissions Reductions from Existing Policies Related to Reducing Greenhouse Gas Emissions" at http://www.mass.gov/dep/air/climate/gwsa_docs.htm#implement.

costs per ton in the year 2030. McKinsey found that a large portion of the potential reductions would save money because the energy bill savings would exceed the initial costs. (See Figure 1.)[3]

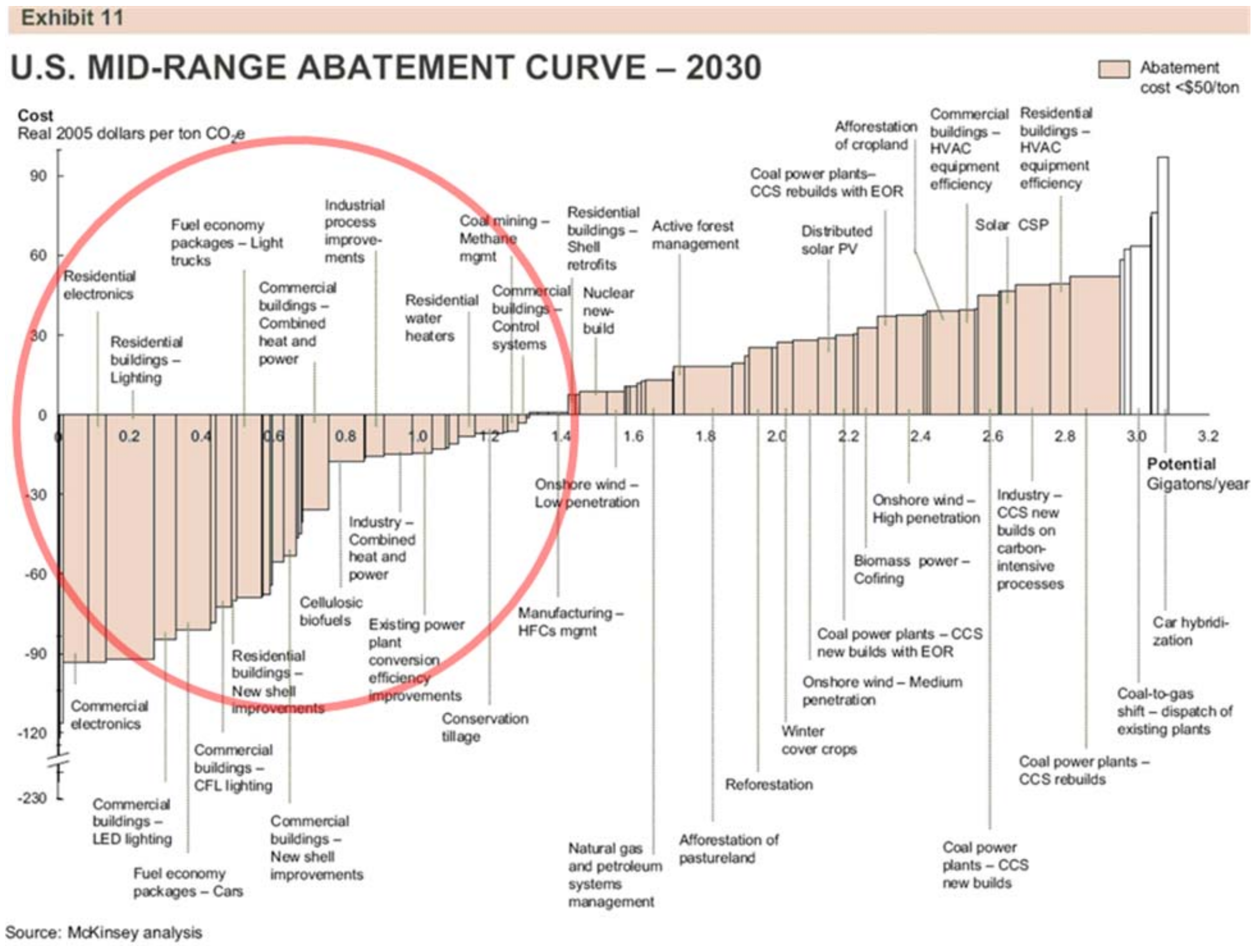

Figure 1. McKinsey & Company Cost Curve (The consultant team focused on the actions that could provide cost-effective reductions, which are shown in the circle.)

Some measures were not included as a basis for this report even though they may be cost-effective. For example, major changes in consumer behavior were not considered because of lack of experience with successfully realizing them on a large scale. Likewise, technologies that are not yet broadly commercially available, such as those under or approaching development, were excluded.

[3] "Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost? U.S. Greenhouse Gas Abatement Mapping Initiative Executive Report," December 2007, Jon Creyts et al., McKinsey & Company and The Conference Board. See Exhibit 11, page 20, "U.S Mid-Range Abatement Curve – 2030."

Most of the additional GHG reduction potential analyzed in this study is cost-effective in the sense described above—the dollar savings over time (in energy bills or other operating expenses) will exceed the costs of the measures themselves. This includes virtually all residential, commercial, and industrial energy-efficiency measures. Some measures require appropriate consumer choices but do not involve any significant upfront costs to achieve GHG savings. Two examples are: 1) making use of programmable thermostats to regulate home heating and 2) choosing one of the more fuel-efficient car models among all those available within the same size class.

A few reduction strategies included here involve small net costs, but the consulting team finds that those costs would have minimal impacts on businesses and consumers. For example, a portion of the emissions savings from taking steps to reduce atmospheric release of refrigerant chemicals is estimated to result in annual net costs on the order of one hundredth of one percent (0.01%) of operating revenues for those businesses involved, while providing significant GHG reductions.

The projections in this report may understate the true potential for cost-effective emissions reductions in 2020. For example, they do not account for new technologies that may emerge by 2020, or for possible declines in the price of existing technologies, such as LED lighting, as they mature. Both of these factors could cause the true potential to be far higher than that stated here.

During the remainder of 2010, state agencies, the Advisory Committee, and the consulting team will be working on the analysis and design of a framework to guide strategies that could help obtain clean energy economic benefits while reaching the 2020 target determined by the Secretary. In addition, a robust public hearing and input process will be conducted to garner public comment. That framework must also put us on a path to achieve the long-term target in the Act of an 80 percent reduction in GHG emissions from 1990 levels by 2050.

2.0 SUMMARY OF METHODOLOGY AND RESULTS

This report presents numerical results for three cases concerning the Commonwealth's GHG emissions in 2020, focusing primarily on the third ("potential") case:

- **"Reference" Case** – emissions forecasted for 2020 considering the state's GHG reduction policies adopted until 2007, but not policies adopted since then.
- **"Existing Policies" Case** – emissions forecasted for 2020 considering all of the state's existing GHG reduction policies, along with federal policies, state policies that are underway but not yet fully implemented, and independent factors that will influence 2020 emissions.
- **"Potential" Case** – emissions forecasted for 2020 assuming all of the cost-effective emissions reduction potential described in this report is achieved.

The reference case was constructed by breaking down the sources of GHG emissions in the state by sector and examining the "drivers" of future GHG emissions within each sector, such as population and employment growth, development and transportation patterns, energy use in buildings, and changes in industrial processes.[4] This yielded a set of parameters for estimating emissions through 2020. As a calibration exercise, the model was also used to reproduce historical emissions going back to 1990, yielding a historical emissions inventory that was broadly consistent with the state's earlier "Business as Usual" (BAU) inventory published in July 2009 (http://www.mass.gov/dep/air/climate/1990_2020_final.pdf).

The existing policies case quantifies the expected impacts on Massachusetts GHG emissions of policies that were enacted since 2007, including some policies that are currently under development. This forecast builds on the results presented in the February 5 report by providing a more detailed examination of each emitting sector and how each sector is likely to be affected by the post-2007 policies. Again, our findings were consistent with the findings of the February 5 report.

Finally, the potential case estimates the additional potential for cost-effective reductions in GHG emissions, going beyond existing policies. The main body of this report explains how these potential reductions were developed for each of the major emitting sectors—transportation, electricity, residential and commercial buildings, industry, and solid waste.

The projected emissions in all three cases are based on a number of assumptions about future economic activity, demographic changes, and technology availability and cost. Because of the variability of these factors, the projections have an inherent degree of uncertainty. The uncertainty is difficult or impossible to quantify, but it is significant—actual emissions in any particular case may be a few million tons lower or higher than the projected values. However, while the projections contain uncertainty, the consulting team believes that they provide an appropriate basis for comparing the reference, existing policies, and potential cases to each other and to 1990 emissions.

Projections of 2020 GHG emissions in Massachusetts, along with total 1990 emissions and the impact of all cost-effective reductions, are shown in Figure 2. The reference case—without the policies enacted since 2007—is projected to result in a small (3 percent) decrease in emissions relative to 1990 totals. The net effect of policies enacted since 2007 is projected to be a reduction in 2020 emissions in the state to 81 percent of 1990 levels, or a reduction of approximately 19 percent. Finally, implementing all the cost-effective reduction measures identified by the consulting team would cut emissions to just 65 percent of 1990 totals, a 35-percent reduction.[5]

[4] The original BAU was constructed using historical data, mainly from U.S. EPA, on GHG emissions by sector and projected historical trends out to 2020. The reference case in this report is based on a more detailed examination of the factors influencing emissions within each sector.

[5] In 2009 the state identified a baseline emissions level for 1990 of 94.4 million metric tons of CO_2 equivalent ($MMtCO_2e$) per year. The consulting team has confirmed and adopted this value, within the inherent range of uncertainty for such estimates, as the Massachusetts emissions baseline. All emissions reductions presented in this report are based on emissions as forecast by the consultants, relative to the state's 1990 baseline emissions.

This report focuses on the potential case—that is, highlighting our projection of the potential for cost-effective emissions reductions beyond those that would result from existing policies. The following sections describe the sources of the potential cost-effective reductions identified and quantified for each sector of the economy. Figure 3 shows the potential impact of these emissions reductions, compared to and combined with the impact of existing policies, in million metric tons of avoided emissions per sector in 2020 (relative to the reference case projection).

Table 1 shows the 2020 projected emissions by sector for each of the cases considered.

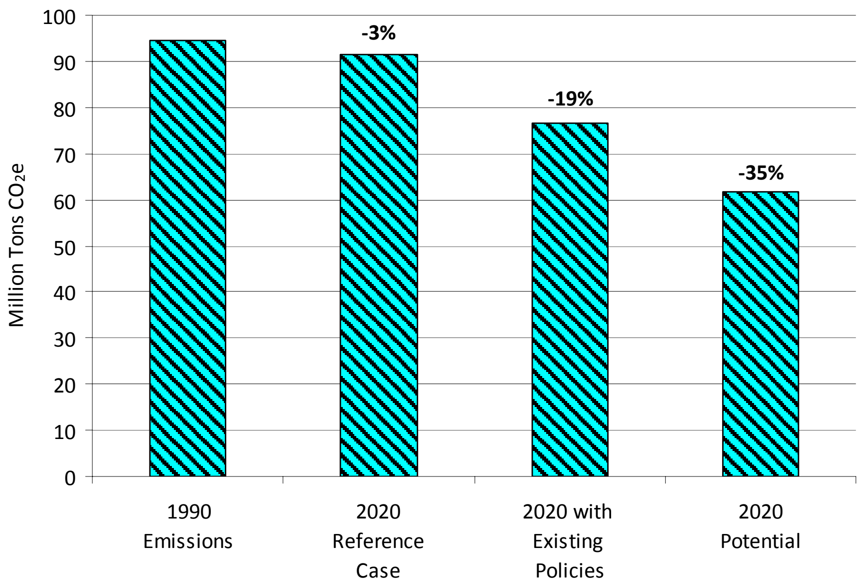

Figure 2. Total GHG Emissions in Massachusetts (Bars show total GHG emissions in Massachusetts, while percentages show reductions in each case as compared to 1990 emissions.)

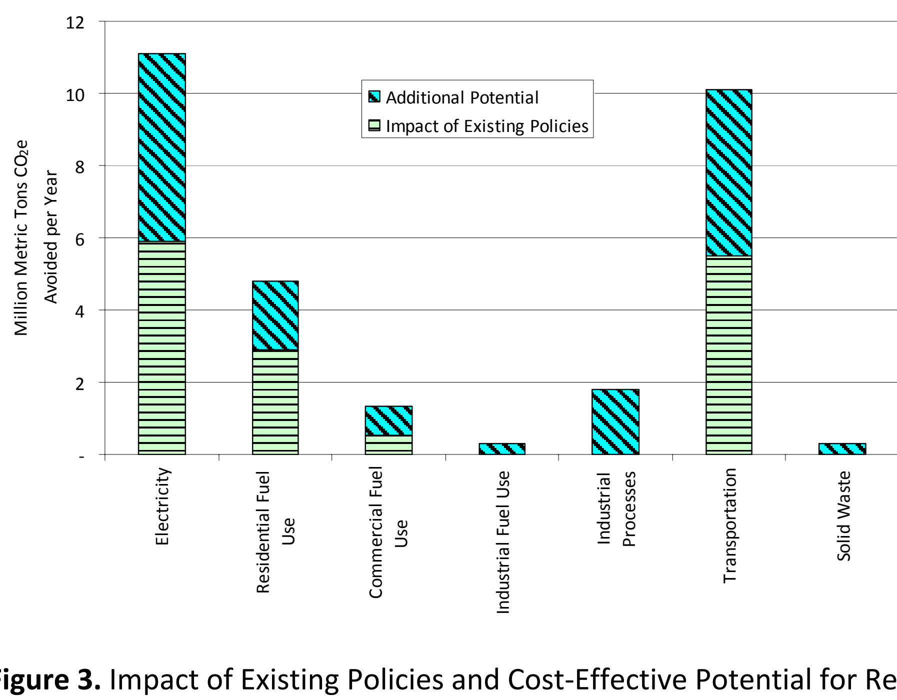

Figure 3. Impact of Existing Policies and Cost-Effective Potential for Reducing Massachusetts GHG Emissions

Table 1. Projected Massachusetts GHG Emissions and Emissions Reduction Potential

Sector, Policies, Potential Areas	2020 Reference Case ($MMtCO_2e$)	2020 Existing Policies ($MMtCO_2e$)	Identified Potential Cost-Effective Reductions ($MMtCO_2e$/year)	2020 Potential Emissions ($MMtCO_2e$)
Transportation (Section 3.1)	**34.4**	**28.9**	**-4.6**	**24.3**
Reduce Vehicle Miles Traveled			*-1.6*	
Improve Vehicle Efficiency (including Fuel-Efficient Driving Practices)			*-3.0*	
Electricity (Section 3.2)	**23.3**	**17.4**	**-5.2**	**12.2**
Residential & Commercial Bldgs. Efficiency			*-1.9*	
Industrial Efficiency			*-0.3*	
Increased Imports from Canada			*-2.7*	
Industrial Combined Heat and Power			*-0.3*	
Residential Fuel Use (Section 3.3)	**14.1**	**11.2**	**-1.9**	**9.3**
Natural Gas Efficiency			*-0.3*	
Oil and Liquefied Petroleum Gas Efficiency			*-1.6*	
Commercial Fuel Use (Section 3.3)	**5.3**	**4.7**	**-0.8**	**3.9**
Natural Gas Efficiency			*-0.2*	
Oil Efficiency			*-0.6*	
Industrial Fuel Use (Section 3.4)	**4.6**	**4.6**	**-0.3**	**4.3**
Industrial Processes (Section 3.4)	**6.3**	**6.3**	**-1.8**	**4.5**
Reduce Loss of ODS Substitutes			*-1.5*	
Reduce Loss of SF_6			*-0.3*	
Solid Waste (Section 3.5)	**1.5**	**1.5**	**-0.3**	**1.2**
Agriculture[a]	**0.3**	**0.3**		**0.3**
Wastewater Treatment[a]	**0.4**	**0.4**		**0.4**
Natural Gas and Oil Systems[a]	**1.3**	**1.3**		**1.3**
TOTAL	**91.4**	**76.6**	**-14.9**	**61.7**
Reduction Relative to 2020 Reference Case (%)		*16%*		*33%*
Reduction Relative to 1990 Emissions (% below 94.4 $MMtCO_2e$)		*19%*		*35%*

[a] No analysis of cost-effective potential emissions reductions was performed for these sectors.

3.0 ANALYSIS OF EMISSIONS REDUCTION POTENTIAL

This section describes the approach used for, and results of, the analysis of cost-effective emissions reduction potential in the five highest emitting sectors (i.e., transportation, electricity, residential and commercial buildings, industry, and solid waste).

3.1 Transportation Sector Emissions Reduction Potential

Transportation is projected to account for more than one-third of the state's total GHG emissions in 2020. There are several "drivers" of transportation emissions and correspondingly, several sources of potential emissions reductions. First, the growth rate of vehicle miles traveled (VMT) can be reduced, in favor of other methods for meeting mobility needs. Second, the fuel efficiency of vehicles can be improved. Third, the carbon content of the fuel used in vehicles can be reduced. Finally, driving behavior can be changed in ways that improve miles per gallon. Existing state and federal policies address all of these sources and "drivers" to some degree, but additional potential exists beyond those policies.

Vehicle Miles Traveled. Increases in VMT result in part from patterns of new housing development, where residences are isolated and distant from shopping, employment, schools, and public transit connections. "Smart growth," in which new development is clustered closer together, with a more robust mix of different uses, results in shorter distances between travel origins and destinations. This can reduce the length of automobile trips, as well as the number of trips, as it allows for walking, bicycling, and public transit to replace automobile trips. Massachusetts already has policies designed to encourage smart growth, and such growth could be further fostered by the use of transportation planning and funding priorities overseen by the state's Department of Transportation (MassDOT). Under the terms of the Act, MassDOT is required to consider GHG impacts in its transportation planning, and efforts are underway to institutionalize this requirement.

It is estimated that about 200,000 new housing units will be built in Massachusetts between 2010 and 2020—about 7 percent of the state's existing housing stock. Given appropriate planning and incentives, the consulting team estimates that there is *potential* to locate 80 percent of these new housing units in smart growth neighborhoods, with residents of these neighborhoods driving about 30 percent less than the average Massachusetts resident. About half this development would be in locations with population densities of 4,000 to 10,000 residents per square mile (roughly four to 10 dwelling units per residential acre), with the other half in locations with over 10,000 residents per square mile (over 10 units per acre). Although the state's current transportation planning scenario forecasts that most future development will be in lower density areas, recent experience suggests that actual development patterns have already begun to shift more toward smart growth. During 2000–2010, about two-thirds of development was in areas with population density over 4,000 residents per square mile. The consulting team estimates that achieving the 80 percent "smart growth" target would reduce VMT for light-duty vehicles by 2.1 percent in 2020.

Another possible benefit of smart growth that is not considered here is that housing units in such communities can be designed to use less energy, in part due to a portion being in multi-family buildings rather than single-family ones. Detailed modeling conducted for the state in relation to building codes shows that multi-family homes consume about 20 percent less energy per square foot of living space than do single-family homes.[6]

Case Study—Smart Growth in Canton Center

In the past, downtown Canton was divided into three zoning districts, mixed-use was not encouraged, and residential development was limited. In the late 1990s, hoping to reverse an economic decline, the town developed a strategy that identified its downtown commuter rail station as a key catalyst for redevelopment. Thereafter, it adopted a bylaw to encourage transit-oriented development and better connect the station to the downtown. The new bylaw increases allowable densities, encourages mixing residential and commercial uses, and allows shared parking for uses with different peak demand. Canton also improved conditions for pedestrians by installing new brick sidewalks, signage, traffic lights, and enhanced pedestrian crossings. Since 2000, the zoning changes have resulted in five new housing projects—totaling 207 units—being built within a 5-minute walk of the train station.

Source:
http://www.mass.gov/envir/smart_growth_toolkit/pages/CS-tod-canton.html

Because new development each year is a small fraction of all existing development, and seeing that 2020 is less than a decade away, we project smart growth to have a relatively small impact by that year. However, the state's long-term target is to reduce emissions at least 80 percent by 2050, and due to the longer time period involved, smart growth policies enacted now will play a much larger role in meeting that target.

VMT can also be reduced through strategies that address travel behavior. One strategy is employer-based programs that encourage alternatives to single-occupancy vehicle commuting. This includes options such as transit subsidies, rideshare support, an option to receive cash instead of free parking, and compressed work weeks. At the present time, MassDOT aids employer efforts through Travel Demand Management, including the MassRides program. Based on analysis done for the *Moving Cooler* report, the consulting team estimates that intensified use of such strategies could reduce light-duty vehicle GHG emissions by about 1.5 percent in 2020.[7] In addition, statistics indicate that most driving is not done for commuting to work, but rather for other trips such as shopping, bringing children to activities, and leisure travel. There is potential to reduce the least essential trips through consumer choices such as shifting travel modes, carpooling, and combining several errands into one trip. With appropriate incentives to reduce single-occupancy vehicle travel, another 1.5 percent of VMT could be reduced. Finally, it appears likely that within the next few years some version of federal climate policy will be

[6] "Massachusetts Stretch Code Analysis," Vermont Energy Investment Corporation, April 2010.

[7] "Moving Cooler: An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions." For the Urban Land Institute, Washington D.C., by Cambridge Systematics, Inc. 2009.

enacted that includes a price on carbon emissions. Such federal action would be expected to yield about a 1 percent reduction in VMT.

Vehicle Efficiency. The second “driver” of transportation emissions is the efficiency of the vehicles themselves. The existing policies case includes large savings anticipated through the effects of stricter federal Corporate Average Fuel Economy (CAFE) standards, and a return to California’s GHG emissions standards (known as Pavley) beginning with model year 2017 (January 2016). These standards require the auto industry to manufacture cars and light trucks that have higher average miles per gallon (mpg) and lower average GHG emissions. Because the standards deal with averages, they allow some variation within vehicle classes (e.g., compact cars, mid-size cars, minivans, SUVs, standard pickups); in any given class, some models may be more efficient and some less efficient. Thus, beyond the impact of the standards themselves, additional cost-effective emissions reductions may result from consumers choosing a more efficient model in the class that meets their needs. Modeling of generalized incentives or other programs that encourage consumers to choose efficient vehicles shows a potential improvement of 10 percent in average fuel economy.

Case Study—Cities and Towns to Buy Fuel-Efficient Vehicles and Save Money

To be eligible for grant funding under the state’s Green Communities Program, cities and towns must purchase only fuel-efficient vehicles for municipal and school district use (fire trucks, ambulances, police cruisers, and public works trucks are exempt). The program has specific miles per gallon (mpg) requirements for each class of vehicles, such as 29 mpg for two-wheel drive cars and 18 mpg for four-wheel drive small pickup trucks. The mpg levels have been set so that at least five non-luxury brand automatic transmission models within each class will meet the requirement. At least two dozen communities had adopted fuel-efficient vehicle purchasing policies as of April 2010.

Source:
http://www.mass.gov/Eoeea/docs/doer/green_communities/grant_program/buying_fuel_efficient_vehicles.doc

Carbon Content of Fuel. Regarding the third “driver” of transportation emissions—the carbon content of the fuel—the existing policies case includes an estimated reduction of 5 percent in emissions by 2020 through implementation of the regional Low-Carbon Fuel Standard (LCFS) that is currently under development by 11 northeast and mid-Atlantic states. At this time, the consulting team does not project further potential in this area by 2020, although it is likely that savings will rise in subsequent years.

Fuel-Efficient Driving Practices. A fourth way to improve the efficiency of auto travel is through what some have termed “smart driving”—changing driving behavior and vehicle maintenance practices so as to improve mpg. Fuel efficiency can be improved greatly by moderating speed and by accelerating less aggressively. For example, the office supply company Staples has reduced fuel consumption 20 to 30 percent by limiting the speed and acceleration of its nationwide fleet of delivery trucks (see the case study). In addition, the U.S. Environmental Protection Agency (EPA) and U.S. Department of Energy (DOE) estimate that fuel consumption can be reduced 8 to 9 percent through appropriate maintenance, including proper tuning, using recommended grades of motor oil, and keeping tires inflated correctly. The consulting team

Case Study—Staples Saves Gas, Reduces Costs

The office supply company Staples reports that "By limiting the top speed of our delivery fleet trucks and implementing idling management technologies, Staples has improved fleet fuel economy by more than 25 percent since 2007. We're saving nearly 1 million gallons of diesel fuel annually due to these changes." Another fuel-saving technique Staples has used is to change the speed points at which vehicles shift into higher gears, which limits acceleration. Staples says that its cost savings through lower diesel expenses and time saved in fill-ups outweighs the slight increase in time needed to make trips.

Source: *http://www.staples.com/sbd/cre/marketing/ecoeasy/our_commitment.html*

estimates that a modest portion of these benefits constitute realistic potential, because many drivers already drive in a fuel efficient manner and practice proper maintenance, and not all others can be induced to do so. Fuel efficient driving practices can improve fuel efficiency by an estimated 5 percent for light-duty vehicles and 3 percent for heavy-duty vehicles. (This is counted as part of vehicle efficiency in Table 1.)

All told, the consulting team projects that the total cost-effective potential for reductions in transportation sector emissions in 2020 associated with reduced VMT growth, improved fuel efficiency, and improved driving practices is **4.6 $MMtCO_2e$ of avoided GHG emissions.**

3.2 Electricity Sector Emissions Reduction Potential

Most of the potential for further cost-effective reductions in electricity sector GHG emissions, beyond those contained in the state's existing policies, lies on the "demand side" of electricity, specifically in increasing the efficiency of electricity use in buildings and industry. The consulting team has identified potential cost-effective electric efficiency opportunities in residential and commercial buildings, primarily associated with further improvements in lighting, appliances, air conditioning, and building envelopes. If fully implemented, these energy improvements would yield a reduction of almost 2 $MMtCO_2e$ emissions per year. In addition, cost-effective electric efficiency improvements in the industrial sector would yield a reduction of about 0.3 million metric tons. These savings are in addition to the savings expected from existing state policies.

Existing Massachusetts policy contains strong targets for development of low-carbon generating resources, and it is unlikely that additional renewables will be available from within New England that are less expensive than conventional generation during the next decade. However, the consulting team has identified substantial potential for increasing the quantity of low- or zero-carbon electric energy in the Commonwealth by increasing imports of hydroelectric and wind power from Canada. Our judgment is that it would be technically and economically feasible to double the projected imports of power into New England, primarily from Quebec but also possibly from other Canadian provinces. This would displace the consumption of electricity from carbon-intensive generation (the fuel for which all comes from outside Massachusetts), leading to an overall estimated reduction in emissions of 2.7$MMtCO_2e$ per year associated with the state's electricity use.

Finally, the consulting team estimates that new combined heat and power (CHP) installations could be implemented in the state at existing industrial sites, producing approximately 1,800 gigawatt-hours (GWh) of electric energy per year. The consulting team estimates that the overall impact of using this highly efficient approach to electricity generation would be to replace existing generation with more efficient energy resources, resulting in 0.3 million metric tons per year of avoided CO_2e emissions.

In total, the consulting team projects that the potential for cost-effective reductions in electricity sector emissions—associated with electric efficiency improvements in residential and commercial buildings and the industrial sector, increased imports of carbon-free power from Canada, and full utilization of cost-effective CHP at industrial sites—is **5.2 MMtCO_2e of avoided GHG emissions per year.**

Case Study—High-Efficiency Commercial Buildings

The Commonwealth's electric and gas utilities provide financial incentives for commercial developers to construct buildings that are at least 20 percent more energy efficient than the building code requires. One example is the Fidelity Bank building in Leominster, which is expected to use 31 percent less energy than a standard office building of the same size. Upgrades included high-efficiency lighting, advanced lighting controls, additional insulation, high-performance windows, and advanced HVAC (heating, ventilating, and air conditioning) systems. These upgrades added $101,000 to the cost of the building, while yielding $28,000 in annual energy savings, for a payback of less than four years. In addition, National Grid covered two-thirds of the cost with $67,000 in rebates, allowing the building owners to recover their investment in just over one year.

Source:
http://www.nationalgridus.com/non_html/shared_FidelityTrifoldBrochure.pdf

3.3 Residential and Commercial Buildings Sector Emissions Reduction Potential

Existing technologies for enhancing the energy efficiency of buildings, such as improved insulation and heating systems, integrated HVAC (heating, ventilation and air conditioning) systems, and improved lighting and appliances, create significant potential for cost-effective GHG emissions reductions. Implementing these technologies throughout the Commonwealth could lower GHG emissions, save consumers money, and lead to better performing, more comfortable residences and commercial buildings. To assess the potential for deploying existing building energy efficiency technologies in Massachusetts, the consulting team used the following approach:

- First, we reviewed several energy-efficiency potential studies recently performed for states near Massachusetts (Connecticut, New Hampshire, and New York) and the nation as a whole.[8] Averaging these studies provided an estimate of the potential for cost-effective reductions in electricity and natural gas use in Massachusetts buildings (residential and commercial).
- Next, we estimated the potential for cost-effective reductions in oil and liquefied petroleum gas (LPG) use based on the natural gas potential. Basing the estimate on the natural gas potential seems reasonable because oil, LPG, and natural gas are used for similar purposes in Massachusetts buildings, and similar energy efficiency technologies (e.g., improved insulation) apply to all three fuels. The estimate was adjusted for the age, efficiency of heating systems, and energy intensity of oil and LPG-heated buildings in comparison to natural gas-heated buildings, as well as expected differences in the future prices of oil, LPG, and natural gas. On average, the potential for efficiency savings per housing unit is greater for oil-heated than gas-heated buildings, because oil-heated homes tend to be older and have less efficient technology in place.
- We then subtracted projected energy-use reductions related to the implementation of existing policies (including revised residential building codes) from the electricity, natural gas, oil, and LPG potentials, and we converted the net potentials into GHG savings using appropriate emissions factors.
- Finally, we increased the net potential GHG emissions reductions related to heating-oil use to account for the advent of the regional LCFS, described in section 3.1. The LCFS is primarily directed at transportation fuels, but it may also be applied to heating oil, seeing that transportation diesel is very similar to heating oil in composition.

Table 2 shows the results calculated for 2020.

[8] Efficiency Vermont: www.efficiencyvermont.com/pages/Business/HVAC/Lighting/LED/; "Real Prospects for Energy Efficiency in the United States, America's Energy Future Energy Efficiency Technologies Subcommittee," pg. 56, National Academy of Sciences, National Academy of Engineering, National Research Council, 2009: http://www.nap.edu/catalog/12621.html; "Connecticut Electric Residential, Commercial, and Industrial Energy-Efficiency Potential Study," KEMA, 2009a; "Connecticut Electric Residential, Commercial, and Industrial Energy-Efficiency Potential Study," KEMA, 2009b. "Assessment of All Available Cost-Effective Electric and Gas Savings Energy Efficiency and CHP," MA EEAC Consultants, 2009; "Vermont Electric Energy Efficiency Potential Study." For the Vermont Department of Public Service, by GDS Associates, 2007; "Additional Opportunities for Energy Efficiency in New Hampshire," GDS Associates, 2009; "Natural Gas Energy Efficiency Resource Development Potential In New York: Final Report." For the New York Energy Research and Development Authority, by Optimal Energy, Inc. (OEI) et al., 2006.

Table 2. Potential in 2020 for Cost-Effective GHG Emissions Reductions in the Residential and Commercial Buildings Sector

	Energy Source	Potential for Cost-Effective GHG Emissions Reductions ($MMtCO_2e$)
Residential	Natural Gas	0.29
	Distillate Oil	1.50
	LPG	0.06
Commercial	Natural Gas	0.23
	Residual Oil	0.09
	Distillate Oil	0.47

Table 2 does not include reductions related to electricity use, as these are reported in Section 3.2. Considering only fuels combusted on site in residential and commercial buildings, our projection of the potential for cost-effective GHG emissions reductions in 2020 is **2.6 million metric tons of avoided CO_2e per year.**

3.4 Industrial Sector Emissions Reduction Potential

Within the industrial sector, most of the opportunities for cost-effective GHG emissions reductions lie in two areas:

- Reduction in energy consumption through increased efficiency in producing power and doing work (not including electricity consumption and CHP [see Section 3.2]).
- Decline in the direct release of high-global warming potential (GWP) gases from industrial processes: primarily refrigerants used in industrial applications and sulfur hexafluoride (SF_6) used in the semiconductor industry and electrical power systems (EPS).

Industrial Energy Consumption. The consulting team reviewed potential information sources and prior studies to identify and quantify cost-effective opportunities for reducing fossil energy-based emissions in the Massachusetts industrial sector. We concluded that data from DOE's Industrial Assessment Center (IAC) program provide the most applicable and useful information readily available on the quantity and economics of energy efficiency and GHG reduction opportunities in this sector. Although the IAC audit database is not a random sample and does not span all business size categories, it has three key attributes: 1) the scope of the dataset's coverage of Massachusetts facilities, 2) its focus on identifying and assessing energy-efficiency opportunities, and 3) its reporting of key economic information on energy-efficiency opportunities. Only not-yet-implemented emissions reduction opportunities were examined. Based on these data, an economic analysis was performed to ensure that the annual value of energy savings for a given opportunity would exceed the annualized cost of implementation. These findings were then extrapolated based on the IAC dataset to represent the broader Massachusetts industrial sector.

***Case Study*—Coca-Cola Cuts GHG Emissions from Refrigerants in Vending Machines**

A fast-growing source of GHG emissions in Massachusetts is leakage of the chemicals used as refrigerants, often hydrofluorocarbons (HFCs). These chemicals have more than 1,000 times the global warming impact per pound of the most common GHG, carbon dioxide. Coca-Cola began reducing these emissions in 2002 by replacing HFCs in its soda vending machines. Today Coke has over 120,000 HFC-free machines in operation.

Source: http://www.forbes.com/2010/03/11/greenhouse-gases-refrigerants-technology-ecotech-coca-cola.html

Industrial Processes. Emissions reduction opportunities were examined for the most significant industrial process sources in the 1990 baseline inventory and 2020 existing policies case projection: chemicals that are being increasingly used as substitutes for ozone-depleting substances (ODS) (various sectors) and SF_6 from semiconductor manufacturing and EPS. Potential emissions reductions were based on values presented in a 2006 study prepared for EPA, which included a schedule of mitigation options for each sector and estimates of the cost of abatement per ton of CO_2e reduced.[9] For example, for refrigerants, almost all of the potential reductions—achieved through minimizing leakage and substitution of other chemicals—can be accomplished at costs below $15/ton of CO_2e. We also found that of the 30-percent potential reduction in emissions from refrigerants, about two-thirds could be accomplished while yielding net cost savings to the businesses involved. The remaining one-third would involve net costs on the order of one hundredth of one percent (0.01%) of overall business operating costs. This approach implicitly assumes that Massachusetts' baseline profile of high-GWP gas emissions and mitigation opportunities is reasonably similar to the national profile.

Summary of Potential for Cost-Effective GHG Emissions Reductions in the Industrial Sector. A summary of the estimated industrial-sector GHG emissions reduction opportunities is presented in Table 3. As noted above, emissions reduction potential related to CHP growth and electric efficiency in the industrial sector is described in Section 3.2.

As Table 3 shows, the total cost-effective potential for reducing GHG emissions from the Massachusetts industrial sector, including energy-based reductions (but excluding electric energy and CHP opportunities) and process-based opportunities associated with ODS substitutes and SF_6 reductions, is **2.1 million metric tons of avoided CO_2e emissions per year.**

[9] "Global Mitigation of Non-CO_2 Greenhouse Gases," EPA Report 430-R-06-005, U.S. Environmental Protection Agency, 2006.

Table 3. Potential in 2020 for Cost-Effective GHG Emissions Reductions in the Industrial Sector

Type of GHG Emissions Reduction Opportunity	Potential for Cost-Effective GHG Emissions Reductions ($MMtCO_2e$)
Energy-Based Reduction Opportunities (excluding electricity and CHP):	
Coal	0.02
Petroleum	0.06
Natural Gas	0.17
Process-Based Reduction Opportunities:	
ODS Substitutes:	
Cooling	1.39
Aerosols	0.07
Foams	0.02
Solvents	0.03
Semiconductor Manufacturing	0.21
Electrical Power Systems	0.14

3.5 Solid Waste Sector Emissions Reduction Potential

Solid waste is generated by residences and businesses across Massachusetts. Diverting high-carbon-content materials, such as plastics, from the waste stream can reduce emissions released after materials are discarded. These diverted materials can then be recycled into other products. In this report, we have not examined all potential strategies for reducing emissions from solid waste but have focused solely on plastics. Diverting plastics from the waste stream will result in materials with a lower carbon content being combusted at Massachusetts' municipal waste combustors, reducing emissions of CO_2. Looking only at in-state emissions reductions, the reduction potential from diverting a portion of plastics from solid waste disposal in 2020 was conservatively estimated by the Massachusetts Department of Environmental Protection at **0.3 million metric tons of avoided CO_2e emissions per year.**

3.6 Other Sectors

Several sectors were not included in this report's analysis of GHG reduction potential, either because their total emissions are relatively small or because we lack sufficient data to make reliable estimates of the historical figures and to project emissions into the future. Included in this category are biogenic CO_2 emissions, which were not part of the state's 1990 baseline published in July 2009, but were shown in a separate table. Biogenic emissions and carbon sinks result from burning biomass; from sequestration of CO_2 by trees in the Commonwealth, both in forests and other locations; and from changes in sequestration due to land-use change. Also not addressed in this report is reduction potential related to agriculture, wastewater treatment, and natural gas and oil distribution systems.

4.0 CONCLUSION

Massachusetts' Global Warming Solutions Act of 2008 establishes the Commonwealth's commitment to reducing GHG emissions. It requires that the Secretary of Energy and Environmental Affairs establish a target reduction of 10 percent to 25 percent below 1990 emissions by 2020 and a reduction of 80 percent by 2050. The present report, in combination with the February report, shows that the state's existing policies (along with federal policies and prospective state policies whose development is well underway) will bring the state most of the way toward a 25-percent reduction in 2020. Further, this report shows that the cost-effective potential for further GHG reductions in 2020 is well above the 25-percent maximum target specified by the Act. Achieving a large proportion of this reduction potential will not only help address the threat of climate change but also yield large savings in energy and transportation costs to businesses and households.