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Final 2006-2008
Massachusetts Greenhouse Gas Emissions Inventory

Regulatory Authority:
MGL Chapter 21N, Section 2

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Introduction

In response to overwhelming scientific evidence that climate change is occurring as a result of human-created emissions of greenhouse gases (GHGs), and that these changes pose significant threats to public health and the environment, and because Massachusetts can seize significant economic benefits by moving to a clean energy economy, the Massachusetts Global Warming Solutions Act (GWSA)[1] was signed into law in August of 2008. The major requirements of this statute include:

- Adoption of statewide GHG emissions limits for 2020, 2030, and 2040 that will maximize the ability of the Commonwealth to meet the 2050 limit of at least 80% below 1990 emissions, as set by the Act,
- Implementation of plans to achieve these statewide GHG emissions limits, and
- Requirements for the mandatory reporting of GHG emissions by larger GHG emitting sources and retail sellers of electricity in the Commonwealth.

GHGs accumulate in the atmosphere and trap heat that would otherwise be radiated back into space. This "greenhouse effect" is the primary cause of global climate change. There are a number of gases that are considered GHGs. The most prevalent greenhouse gas is carbon dioxide (CO_2), which is emitted when fuels are burned. Methane (CH_4), nitrous oxide (N_2O) and several other compounds primarily used as refrigerants are also GHGs of concern due to their potential to contribute to climate change.[2]

The GWSA established the Climate Protection and Green Economy Act in Massachusetts General Law, which requires the Massachusetts Department of Environmental Protection (MassDEP) to, among other actions, "… *triennially publish a state greenhouse gas emissions inventory that includes comprehensive estimates of the quantity of greenhouse gas emissions in the commonwealth for the last 3 years in which the data is available.*" [MGL chapter 21N, section 2, subsection (c)]

Section 13 of the GWSA further states, "*The first inventory required pursuant to subsection (c) of said section 2 of said chapter 21N shall be published not later than December 31, 2010.*" A preliminary GHG inventory for 2006, 2007 and 2008 was published by the required deadline. The Department used a similar approach to that used to develop the "Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection,"[3] published on July 1, 2009, with the estimates for many sectors based on EPA's State GHG Inventory Tool (SGIT).[4] The version of SGIT that was available for the preliminary GHG inventory for 2006, 2007 and 2008 contained complete data only through 2007; however, the Department was able to develop 2008 emissions for many sectors, accounting for approximately 92% of 2008 data. MassDEP

[1] See http://www.malegislature.gov/Laws/SessionLaws/Acts/2008/Chapter298

[2] Not all GHGs have the same heat-trapping capacity. For example, one ton of methane is equivalent to greater than 20 tons of CO_2 with respect to their heat trapping potentials. To account for these differences, a standard relating the heat trapping potential of each GHG to an equivalent quantity of CO_2 over a given time horizon, has been developed. Emissions shown in this document utilize this standard, and are expressed in units of million metric tons of carbon dioxide equivalent (CO_2e).

[3] See http://www.mass.gov/dep/air/climate/gwsa_docs.htm#implement

[4] See http://www.epa.gov/statelocalclimate/resources/tool.html

used the early 2012 version of EPA's SGIT to complete this final GHG inventory for 2006, 2007 and 2008.

This document describes the inventory. Appendix A describes any differences between the sources of GHG emissions, data sources and the methodologies used to determine the preliminary and the final 2006, 2007 and 2008 inventory. Appendix B is a spreadsheet containing data upon which this final inventory is based.

Massachusetts Final 2006, 2007 and 2008 GHG Emissions Inventory

Table 1 below shows final non-biogenic GHG emissions data for 2006, 2007 and 2008 by economic sector. Table 2 below shows final biogenic[5] CO_2 emissions data for 2006, 2007 and 2008 from biomass combustion, forest sequestration and land use change. Any revisions to data sources or methodologies used to calculate the final inventory are described in Appendix A below. The spreadsheet in Appendix B contains the data upon which Tables 1 and 2 are based.

[5] Biogenic Greenhouse Gas Emissions means emissions of CO_2 that result from the combustion of biogenic (plant or animal) material, excluding fossil fuels. Biogenic emissions include CO_2 emissions from combustion of biomass, biofuels, landfill gas and the organic portion of municipal solid waste.

Table 1: Non-Biogenic GHG Emissions, Million Metric Tons of Carbon Dioxide Equivalents ($MMTCO_2e$)

	2006	2007	2008
Energy Total	**79.5**	**82.9**	**80.1**
CO_2 from Fossil Fuel Combustion	76.5	80.0	77.4
Residential CO_2	12.8	13.5	14.2
Commercial CO_2	5.0	5.3	5.7
Industrial CO_2	4.5	4.4	4.1
Transportation CO_2	33.0	33.5	33.6
Electric Generation CO_2	21.2	23.3	19.8
Electricity Imports CO_2, CH_4, N_2O	2.9	2.6	3.0
Other Gases Total	3.0	2.9	2.8
Stationary Combustion	0.2	0.2	0.2
Electric Power	0.1	0.1	0.1
Other	0.2	0.2	0.2
Mobile Combustion	1.0	0.9	0.8
Natural Gas and Oil Systems	1.8	1.8	1.8
Industrial Processes	**3.1**	**3.1**	**3.2**
Agriculture	**0.3**	**0.3**	**0.3**
Waste	**2.3**	**2.3**	**2.4**
Gross Emissions	**88.1**	**91.1**	**89.0**

Note: due to rounding to 1 decimal place, some totals appear higher or lower than the simple sum of the sectors.

Table 2: Biogenic GHG Emissions ($MMTCO_2e$)

	2006	2007	2008
Energy Total	**4.3**	**4.6**	**4.6**
CO_2 from Biomass Combustion Total	3.8	4.1	3.9
Residential CO_2	0.3	0.4	0.4
Commercial CO_2	0.2	0.2	0.1
Industrial CO_2	0.3	0.3	0.3
Transportation CO_2	1.1	1.4	1.2
Electric Generation CO_2	1.9	1.8	2.0
Electricity Imports CO_2	0.5	0.5	0.7
Forest Sequestration	**-10.3**	**-10.6**	**-10.8**
Land Use Change Emissions	**1.1**	**0.9**	**0.6**
Net Biogenic CO_2 Emissions	**-4.8**	**-5.0**	**-5.6**

Note: due to rounding to 1 decimal place, some totals appear higher or lower than the simple sum of the sectors.
To the extent that biomass harvested due to land use change in Massachusetts is also combusted in Massachusetts, such emissions are double-reported in Table 2 in Combustion and Land Use Change emissions.

Appendix A. GHG Emission Sources, Data Sources and Methodology

This section describes the sources of GHG emissions, the information available, and the methodology that the Department used to develop the preliminary GHG inventory for 2006-2008, including differences between the draft and final GHG inventories for 2006-2008.

1. Sources of GHG Emissions

Combustion of Fossil Fuels: The biggest contribution to CO_2 emissions comes from burning fossil fuels for heat, transportation and electricity generation. Fossil fuel combustion also generates CH_4 and N_2O. Residential, Commercial, Industrial, Transportation and Electric Generation are the sectors in which fossil fuels are combusted.

Industrial Processes: The United States (US) Environmental Protection Agency (EPA) has identified 14 specific United States industrial processes that emit significant quantities of GHGs: Cement Production, Lime Manufacture, Limestone and Dolomite Use, Soda Ash Manufacture and Consumption, Iron and Steel Production, Ammonia Manufacture, Urea Consumption, Nitric Acid Production, Adipic Acid Production, Aluminum Production, Hydrochlorofluorocarbon (HCFC)-22 Production, Consumption of Substitutes for Ozone-Depleting Substances (ODS), Semiconductor Manufacture, Electric Power Transmission and Distribution, and Magnesium Production and Processing.

The industrial processes conducted in Massachusetts include Lime Manufacture, Limestone and Dolomite Use, Soda Ash Consumption, Urea Consumption, Consumption of Substitutes for ODS, Semiconductor Manufacture, and Electric Power Transmission and Distribution.

Agriculture: The US EPA has identified several agricultural processes that are important GHG sources across the country: enteric fermentation (fermentation in the intestines of certain animals such as cows and sheep), manure management, management of plant residues retained in soil, legume cultivation, agricultural fertilizer use, rice cultivation, and burning agricultural residues. As with the industrial sources identified above, some of these activities are not found in Massachusetts or are at such *de minimis* levels that their contribution to GHGs in the Commonwealth is negligible, if any (specifically, rice cultivation and agricultural residue burning are the two processes that do not occur in Massachusetts).

Waste Management: The US EPA has identified several waste management activities that produce significant GHG emissions: municipal solid waste combustion, landfill methane generation, and wastewater disposal and treatment. All of these are found in Massachusetts.

2. Data Sources and Methodology for Developing the Final Inventory

State and federal air pollution control programs have traditionally estimated air emissions of a wide variety of pollutants by applying pollutant-specific emission factors to measures of activities conducted by industrial sectors. The US EPA has developed a State GHG Inventory Tool (SGIT) which employs this methodology to estimate GHG emissions from sectors of concern in each state, based on the activities in key sectors in the state's economy. Gases

included in the inventory are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulfur hexafluoride (SF_6).

The SGIT was used to estimate emissions from 2006 to 2008. This section discusses data issues related to the SGIT.

The SGIT default data set provides a basis for estimating and reporting annual GHG emissions by sector. For example, one large sector is CO_2 emissions from fossil fuel electrical generation plants in Massachusetts. The EPA SGIT methodology uses Massachusetts electric generator fuel use data (the data is taken from the US Department of Energy's Energy Information Administration (EIA)) to calculate the electricity sector emissions from fuel combustion. The Department used SGIT's estimates of GHG emissions from fossil fuel electrical generation and other sectors to derive the final inventory for Massachusetts.

Each year, by the end of June, EIA releases updates[6] of the data that SGIT uses to calculate CO_2, CH_4 and N_2O emissions from fossil fuel and biomass combustion (except transportation sector CH_4 and N_2O, which SGIT calculates from other default data). This final 2006-2008 inventory used the June 2011 EIA data update. The preliminary 2006-2008 inventory was missing 2008 emissions for Mobile Combustion (CH_4 and N_2O only) and Industrial Processes, and had incomplete 2008 emissions for Agricultural and Waste, while this final 2006-2008 inventory includes all sectors.

The Department made the following methodology changes from the preliminary to the final 2006-2008 inventory for CH_4 and N_2O emissions from ethanol, landfill gas, and municipal solid waste.

- In the preliminary inventory, emissions from the combustion of ethanol in the Commercial and Industrial sectors were missing.
    - In this final inventory they are now included on a new inventory spreadsheet tab based on EIA[6] data.
- In the preliminary inventory, the CH_4 emissions from the combustion of the non-biomass portion of municipal solid waste were omitted and N_2O emissions from the combustion of the biomass portion of municipal solid waste were double-counted.
    - In this final inventory, the CH_4 and N_2O emissions from the combustion of all municipal solid waste are now calculated in the SGIT Solid Waste module.
    - In this final inventory, the CH_4 and N_2O emissions from the combustion of landfill gas to generate electricity are now calculated on a new inventory spreadsheet tab based on EIA[7] data, allowing fuel-specific CH_4 and N_2O emission factors to be used for landfill gas.

As no default EPA SGIT data exist for the length of natural gas transmission and distribution pipelines and the number of customer service meters (used to estimate emissions for the natural gas transmission and distribution sector), state specific data were entered.[8]

[6] See the State Energy Data System (SEDS) at http://www.eia.doe.gov/emeu/states/_seds.html
[7] EIA Form 923 at http://www.eia.gov/cneaf/electricity/page/eia906_920.html
[8] See the US Department of Transportation Pipeline and Hazardous Materials Safety Administration "Distribution, Transmission, and Liquid Annual Data" at http://phmsa.dot.gov/pipeline/library/data-stats.

The EPA SGIT does not provide data for certain categories of activities in Massachusetts. This is typically the case where categories of activities, such as oil refining, do not occur in the state, or where they occur at such *de minimis* levels (such as rice cultivation) that their emissions are negligible as a sector. For other categories of activities, the activity occurs in Massachusetts, but EPA SGIT does not contain complete data (e.g., lime and limestone production for certain years). The activities that may or do occur in Massachusetts for which EPA SGIT does not contain data include the following:

- **Industrial Processes:** Production of lime for 2006-2008;
- **Agriculture:** Retention of plant residues in soil, legume cultivation, rice cultivation, and agricultural residue burning; and
- **Wastewater**: Production of industrial wastewater from fruit, vegetable, red meat, and poultry processing, pulp and paper manufacturing; and use of bio-solids as fertilizer versus other disposal methods.

Except for lime, these activities are not included in the preliminary inventory due to the absence of data on these activities in Massachusetts. For lime, the available SGIT emissions were extrapolated to the years listed above, using a linear least-squares trend line. The GHG emissions from the remaining activities are believed to be relatively small sources of emissions.

3. Estimating CO_2 Emissions from Imported Electricity Generation

It is important to recognize that 20-25% of the Commonwealth's electricity is imported from power plants located in other states and in Canada. In order to account for the net electricity imports into Massachusetts from other New England states and import areas, as required by statute,[9] Massachusetts-specific generation and load data were utilized to develop an imported emissions estimate. The New England Independent System Operator (ISO-NE), which manages the New England electricity grid, maintains generation and load megawatt hour data for each New England state. Data on electricity imported to New England from the adjacent New York, New Brunswick and Quebec control areas are also available from ISO-NE.

There are a variety of methods that can be used to estimate the emissions due to Massachusetts' consumption of electricity, including emissions associated with electricity generated out-of-state. MassDEP believes it is appropriate to consider GHG emissions associated with electricity consumption in regional and more state-specific contexts, since, due to the linked, regional nature of the New England electric grid, electricity generated in a state is not necessarily consumed in that state, even if that state is a net importer of electricity.

Table 1 of this preliminary inventory presents emissions associated with electricity consumption using an approach that more directly accounts for emissions associated with electricity generated

[9] From GWSA, ""Statewide greenhouse gas emissions", the total annual emissions of greenhouse gases in the commonwealth, including all emissions of greenhouse gases from the generation of electricity delivered to and consumed in the commonwealth, accounting for transmission and distribution line losses, whether the electricity is generated in the commonwealth or imported; provided, however, that statewide greenhouse gas emissions shall be expressed in tons of carbon dioxide equivalents."

in Massachusetts, while an alternative regional approach is discussed further below. The approach used in Table 1 assumes that all electricity generated in Massachusetts is used in Massachusetts. Thus, electric sector emissions in this approach are based on emissions from Massachusetts power plants plus a portion of emissions from power plants in the other New England states that generate more electricity than they use in a given year and in the adjacent control areas (New York, New Brunswick, Quebec) in years that New England received net imports of electricity from those control areas.

Under this approach, emissions due to Massachusetts' consumption of imported electricity were determined by apportioning to Massachusetts a share of any excess generation (and associated emissions) from each New England state that generates more electricity than it uses. Thus, the inventory includes a share of the emissions associated with each electricity-exporting state's exported electricity, as calculated[10] from EIA fuel heat content data (which is also the basis of EPA's SGIT estimate of each state's CO_2, CH_4 and N_2O emissions from fossil fuel combustion and CH_4 and N_2O emissions from biomass combustion). Similarly, the inventory apportions to Massachusetts a percentage of the megawatt hours of losses (and associated emissions) due to pumped hydro and of the net annual imports into the ISO-NE grid from the New York, New Brunswick and Quebec grids.[11] Emissions from the Canadian Provinces were calculated using Environment Canada's National Inventory Report.[12]

Massachusetts also considers electric sector emissions in a broader regional context, due to the linked nature of the New England electric grid, in which demand for electricity in one state influences electricity generation in other states. An alternative electricity consumption emissions approach, documented in Appendix B, involves first determining the fraction of New England electricity (in MWh) that is consumed in Massachusetts. Massachusetts is then assumed to be responsible for that same fraction of the GHGs emitted while generating that electricity. Thus, electric sector emissions in this approach are based on the total New England GHG emissions from electricity generation plus GHG emissions associated with electricity imported from the adjacent control areas (New York, New Brunswick, Quebec) in years that New England received

[10] The GHG emissions from each state are calculated in retail seller spreadsheets for 2006, 2007 and 2008. Note that the 2008 spreadsheet was created to enable retail sellers of electricity to report GHG emissions under 310 CMR 7.71(9) "Reporting Requirements for Retail Sellers of Electricity." The 2006 and 2007 spreadsheets were created for the purpose of this inventory. All 3 spreadsheets use the methodology that went out to public comment in summer 2010 and that was finalized in December 2010, see http://www.mass.gov/dep/air/climate/reporting.htm#forms for the spreadsheets and a document detailing the methodology.

[11] The megawatt hours of imports and of losses associated with pumped hydro were found in ISO-NE "Net Energy and Peak Load by Source" report at http://www.iso-ne.com/markets/hstdata/rpts/net_eng_peak_load_sorc/index.html. The megawatt hours of losses associated with pumped hydro were apportioned to each New England state according to that state's fraction of total New England load.

[12] The New Brunswick and Quebec GHG emissions are based on the National Inventory Report by Environment Canada *National Inventory Report 1990–2008: Greenhouse Gas Sources and Sinks in Canada*, Environment Canada, April 15, 2010 at http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/5270.php. See Table A13-5 "Electricity Generation and GHG Emission Details for New Brunswick" and Table A13-6 "Electricity Generation and GHG Emission Details for Quebec") and *Table 127-0006 - Electricity generated from fuels, by electric utility thermal plants, annual (megawatt hour)*, Statistics Canada, CANSIM (database). http://cansim2.statcan.gc.ca/cgi-win/cnsmcgi.exe?Lang=E&CNSM-Fi=CII/CII_1-eng.htm (accessed: May 5, 2010).

net imports of electricity from those control areas; this total was multiplied by the ratio of Massachusetts to New England electricity consumption. This approach is documented on the far right of the emission factors tab of the retail seller spreadsheets for 2006, 2007 and 2008.

4. Biomass Biogenic CO_2 Emissions, Forest Sequestration and Land Use Change Emissions

Given the lack of annual data for biogenic sources and sinks, the Department has estimated biomass biogenic CO_2 emissions, forest sequestration and land use change emissions. Estimates of biomass combustion, forest sequestration and land use change are documented in Table 2. Despite the challenges in accurately calculating these data on an annual basis, it appears that other, non-annual, data available for the biomass sector are sufficient, and their magnitude is significant enough that it is important to track going forward. Some of the limitations associated with the data in Table 2 include: biomass emissions are double-reported when biomass harvested as a result of land use change in Massachusetts is also combusted in Massachusetts; carbon sinks are only included for forestry; and annual forest sink data points for years between forest surveys are based on interpolated rather than measured data.

Biogenic CO_2 emissions result from burning biomass, including: biofuels such as ethanol (used in vehicles and in the commercial and industrial sectors), wood and paper (largely combusted at residences and electric generation plants), landfill gas (combusted for electric generation[13]), and the biomass portion of municipal solid waste (combusted at waste-to-energy plants). In addition, emissions from land use change include the one-time release of previously sequestered soil carbon due to the soil disturbance involved. In presenting the biogenic CO_2 emissions associated with the combustion of biomass, this inventory uses the convention for biogenic sources adopted by the World Resources Institute, The Climate Registry, and others, which report biogenic CO_2 emissions separately from other GHG emissions. Hence, Table 1 does not indicate quantities of CO_2 released during combustion of biomass.[14] Estimates of CO_2 emissions due to biomass combustion are presented in Table 2 and were determined using EPA's SGIT with the most recent EIA data.[15] CO_2 emissions from Massachusetts' consumption of imported electricity generated from biomass combustion were determined using the methodology discussed above for imported electricity generation and are also included in Table 2.

The Department made the following methodology changes from the preliminary to the final 2006-2008 Massachusetts GHG inventory for the biogenic CO_2 emissions from biomass fuel sources.

- In the preliminary inventory, the biogenic CO_2 emissions from the combustion of ethanol in the Commercial and Industrial sectors were missing.
    - In this final inventory they are now included on a new inventory spreadsheet tab based on EIA[6] data
- In the preliminary inventory, the biogenic CO_2 emissions from the combustion of wood,

[13] GHG emissions from flared landfill gas are not included in the inventory due to a lack of data.
[14] Note, CH_4 and N_2O emissions associated with biomass combustion are included in gross emissions in Table 1, as part of the Stationary Combustion category and Mobile Combustion categories. CO_2 emissions associated with biomass combustion are not included in Table 1.
[15] EIA released the data in June 2011 from which CO_2 emissions from biomass combustion for all sectors were calculated using the EPA SGIT.

landfill gas and the biomass portion of municipal solid waste were calculated in the SGIT CO_2 from Fossil Fuel Combustion (CO2FFC) module.

- In this final inventory, biogenic CO_2 emissions from the combustion of wood were calculated in the CO2FFC module. The biogenic CO_2 emissions from the combustion of the biomass portion of municipal solid waste and landfill gas for the generation of electricity were calculated on a new inventory spreadsheet tab based on EIA[16] data, allowing fuel-specific CO_2 emission factors to be used for each fuel type.

In addition, the value of forested lands as a carbon sequestration sink and the carbon released due to forest land lost annually to land use change are documented in the spreadsheet in Appendix B. While other land uses also sequester carbon, the Department focused on forests because those data are most readily available and forests account for the largest portion of naturally sequestered carbon.

While overall forest acreage in Massachusetts expanded greatly from a low point in the mid-1800s (the peak of our agricultural period) to the early 1950s, net forest coverage has begun to decline since then, principally due to the loss of forests to development of land for residential, commercial and industrial uses. At the same time, annual forest carbon sequestration is still increasing as the Commonwealth's relatively young forests mature. The Massachusetts Office of Geographic and Environmental Information (MassGIS) and the University of Massachusetts at Amherst have tracked land use via the interpretation of statewide aerial photography since the 1970s, most recently for photography taken in 2005 and 2008-9 (2008 photography covered the Boston metropolitan area and northeast Massachusetts; the remainder of the state was photographed in 2009). To interpolate between the years, MassGIS used building permit data from a statewide database that records all building permits.

To estimate the net growth of the forest, the Department relied on net growth measured by the United States Department of Agriculture Forest Service at 596 permanent Massachusetts forest plots (known as the Forest Inventory and Analysis (FIA)). The net growth is multiplied by the forest cover acreage to give net growth in tons per county, and converted to tons of CO_2 using a formula derived from chemical analysis of trees (approximately one-half of a tree weight is carbon).

In addition to this aboveground forest carbon storage, a significant amount of carbon can be stored below ground in coarse roots and in forest soils. Organic carbon accumulates in forest soils and can reach density levels nearly equal to that of above ground biomass of a mature forest stand. All exposed soils sequester carbon (at a rate determined by soil class, cover type, and disturbance regime), but only forest soil sequestration is included in Table 2. It should be noted that the inclusion of carbon sinks only from forestry represents a substantial but not complete set of carbon sinks in the state.

As land is developed, trees and vegetation (which sequester carbon) are replaced by buildings, roads, etc. These changes in land use lead to the one-time release of significant quantities of carbon previously locked up in natural ecosystem sinks, as the development disrupts the normal

[16] EIA Form 923 at http://www.eia.gov/cneaf/electricity/page/eia906_920.html

course of the long-term carbon cycle. In order to take account of these emissions, this inventory is using land use change data together with estimates of carbon stored in forests and soil to quantify the annual emissions due to land use change.

The Department corrected a mathematical error in the soil carbon sequestration rate (from 0.37 to 0.3 megagrams CO_2 per acre per year) from the preliminary to the final 2006-2008 Massachusetts GHG inventory.

5. Other Methodological Issues

Several potentially significant sources of GHGs are not included in the Massachusetts inventory due primarily to the difficulty in quantifying emissions in these sectors. These notably include GHG emissions and GHG sequestration from embodied emissions:

- Traditional emissions inventories (including the SGIT) and projections are based on the production of emissions in a geographic area. But emissions generated by the manufacture of products elsewhere and transportation of these products into Massachusetts (and thus "embodied" in these products) are potentially significant, and in the future could be tracked and projected as well. This adjustment becomes more important as manufacturing shifts from Massachusetts to other states and nations (some of which produce significantly more carbon emissions per unit of output than does the production of these goods in Massachusetts). From 1990 to 2005, net imports (imports minus exports) of manufactured products to Massachusetts rose from $9 billion to $25 billion (in constant $1997), becoming equivalent to 41% of our output of manufactured goods. While some academic studies have started to quantify embodied emissions,[17] there is still great uncertainty in such estimates. Further analysis is needed in this area; therefore, embodied emissions were not included in the inventory.
- On the other side of the equation, some embodied emissions are essentially sequestered when they are stored in landfills or used for the manufacture of long lifespan infrastructure. Some examples of sequestered fossil fuels include plastics in landfills, asphalt in roads and a portion of construction materials in permanent buildings. While EPA's SGIT does exclude the non-energy consumption of asphalt and road oil from reported emissions, the fate of most other materials consumed in Massachusetts is not addressed in the inventory.

6. Issues for the Next GHG Inventory

Technology changes, methodology changes, and data updates will inevitably affect future GHG emissions inventories. An example of a methodological improvement made for this inventory is calculation of emissions associated with electricity imported to Massachusetts, as detailed in footnote 11. The data for imported electricity in this inventory are developed using

[17] "Embodied Environmental Emissions in U.S. International Trade," 1997-2004," Christopher L. Weber and H. Scott Matthews, Environmental Science & Technology, 2007; "CO_2 Embodied in International Trade with Implications for Global Climate Policy," Glen P. Peters and Edgar G. Hertwich, Environmental Science and Technology, Vol. 42, No. 5, 2008; "Consumption-based accounting of CO_2 emissions," Steven J. Davis and Ken Caldeira, Proceedings of the National Academy of Sciences online, March 8, 2010, at http://www.pnas.org/content/early/2010/02/23/0906974107.full.pdf+html

methodologies for retail electricity seller GHG reporting; those methodologies are subject to revisions and improvements each year, seeking to use the best data and approaches available.

In addition, future inventories may include data submitted under 310 CMR 7.71, Massachusetts' "Reporting of Greenhouse Gas Emissions" rule. This rule requires Massachusetts sources that have an operating permit and/or that emit greater than 5,000 short tons of GHGs annually to report GHG emissions to the Massachusetts GHG registry. Note that reporting was limited to CO_2 for the first reporting year (2009 emissions), and the number of reporting facilities expanded beginning with 2010 emissions when facilities reported six GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6). The reporting rule emissions data will always represent a subset of the full Massachusetts inventory. The full GHG emissions inventory includes emissions from small stationary and mobile sources such as residential and commercial furnaces and personal vehicles, which are not reported individually to MassDEP due to their small size.

CO_2 emissions from facilities that report pursuant to 310 CMR 7.70, the "Massachusetts CO_2 Budget Trading Program" (which implements Massachusetts' participation in the Regional Greenhouse Gas Initiative (RGGI)), are also reported under the 7.71 reporting rule, as all RGGI facilities are operating permit facilities. RGGI facility reporting under 7.70 and 7.71 began in 2009, and each year's reported emissions represent a subset of total electric sector emissions.

MassDEP posts summaries online of the GHG emissions data reported under 310 CMR 7.71.[18]

[18] For example, see "MassDEP GHG Reporting Program Summary Report; Emissions Year 2009 (Carbon Dioxide Only)" at http://www.mass.gov/dep/air/climate/reporting.htm#registry.