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Statewide Greenhouse Gas Emissions Level: 1990 Baseline and 2020 Business As Usual Projection

Regulatory Authority: MGL Chapter 21N, Section 3

July 1, 2009

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:

- Establishment of statewide GHG emissions limits,
- Implementation of a plan 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, *"… determine the statewide greenhouse gas emissions level in calendar year 1990 and reasonably project what the emissions level will be in calendar year 2020 if no measures are imposed to lower emissions other than those formally adopted and implemented as of January 1, 2009. This projection shall hereafter be referred to as the projected 2020 business as usual level."* [MGL chapter 21N, section 3, subsection (a)]

Section 14 of the GWSA further requires that the 1990 Baseline and 2020 Business as Usual (BAU) Projection be established by July 1, 2009.

The GWSA also calls upon the Executive Office of Energy and Environmental Affairs (EOEEA), in consultation with other state agencies and the public, to set an economy-wide GHG reduction target for Massachusetts of between 10 and 25% below 1990 levels by 2020, with targets for each decade after that, culminating in at least an 80% reduction by 2050. The 2020 target must be set by January 1, 2011, and must be accompanied by an economy-wide plan to achieve that target. The 1990 emissions baseline will be the baseline against which Massachusetts' future GHG emissions reductions targets will be planned and measured.

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[1] See http://www.mass.gov/legis/laws/seslaw08/sl080298.htm

[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).

MassDEP solicited public comment on the 1990 Baseline and the 2020 BAU Projection, held six public meetings across the state in April and May 2009 to discuss the methodology and proposed 1990 Baseline and 2020 BAU Projection, and held a public hearing on May 19, 2009. Public comments were accepted until June 1, 2009.

This document presents the revised 1990 Baseline and the 2020BAU Projection. A summary of public comments received and responses to those comments accompanies this 1990 Baseline and 2020 BAU Projection.

The Department recognizes that the science and practice of determining GHG emissions is changing rapidly and that Massachusetts, being at the cutting edge of this work, should avail itself of advancements in the science to the extent possible. Therefore, MassDEP will reevaluate the 1990 Baseline as needed (e.g., significant new data becomes available). If amendment is necessary, a full public review process will be used.

- Part 1 of this document describes the 1990 Baseline;
- Part 2 describes the Massachusetts 2020 BAU Projection; and
- Part 3 describes the sources of GHG emissions, data sources, and methodology used to determine the Massachusetts 1990 Baseline and the 2020 BAU Projection.

Part 1: Massachusetts 1990 GHG Emissions Baseline

What is the purpose of the 1990 Baseline? The GWSA calls for the Commonwealth to adopt GHG emissions limits for 2020, 2030, 2040, and 2050 expressed in terms of percent reductions relative to emissions in the year 1990. The emissions baseline presented here will provide the emissions level or baseline against which these future limits will be set and against which progress in achieving reductions will be measured.

Using the data sources and methodology described in Part 3, MassDEP estimates that economy-wide GHG emissions in 1990 were 94 million metric tons of CO_2e ($MMTCO_2e$).

Table 1 below shows a breakdown of the 1990 Baseline GHG emission data by economic sector. The spreadsheet in Appendix I contains the calculations upon which the tables in Part 1 and 3 and the figures in Part 2 are based.

Table 1: 1990 Baseline ($MMTCO_2e$)

Energy Total	**89.8**
CO_2 from Fossil Fuel Combustion	83.9
Residential CO_2	15.0
Commercial CO_2	8.4
Industrial CO_2	6.0
Transportation CO_2	28.9
Electric Generation CO_2	25.6
Electricity Imports CO_2, CH_4, N_2O	2.0
Other Gases Total	3.8
Stationary Combustion	0.4
Electric Power	0.1
Other	0.3
Mobile Combustion	1.5
Natural Gas and Oil Systems	1.9
Industrial Processes	**0.7**
Agriculture	**0.4**
Waste	**3.6**
Gross Emissions	**94.4**

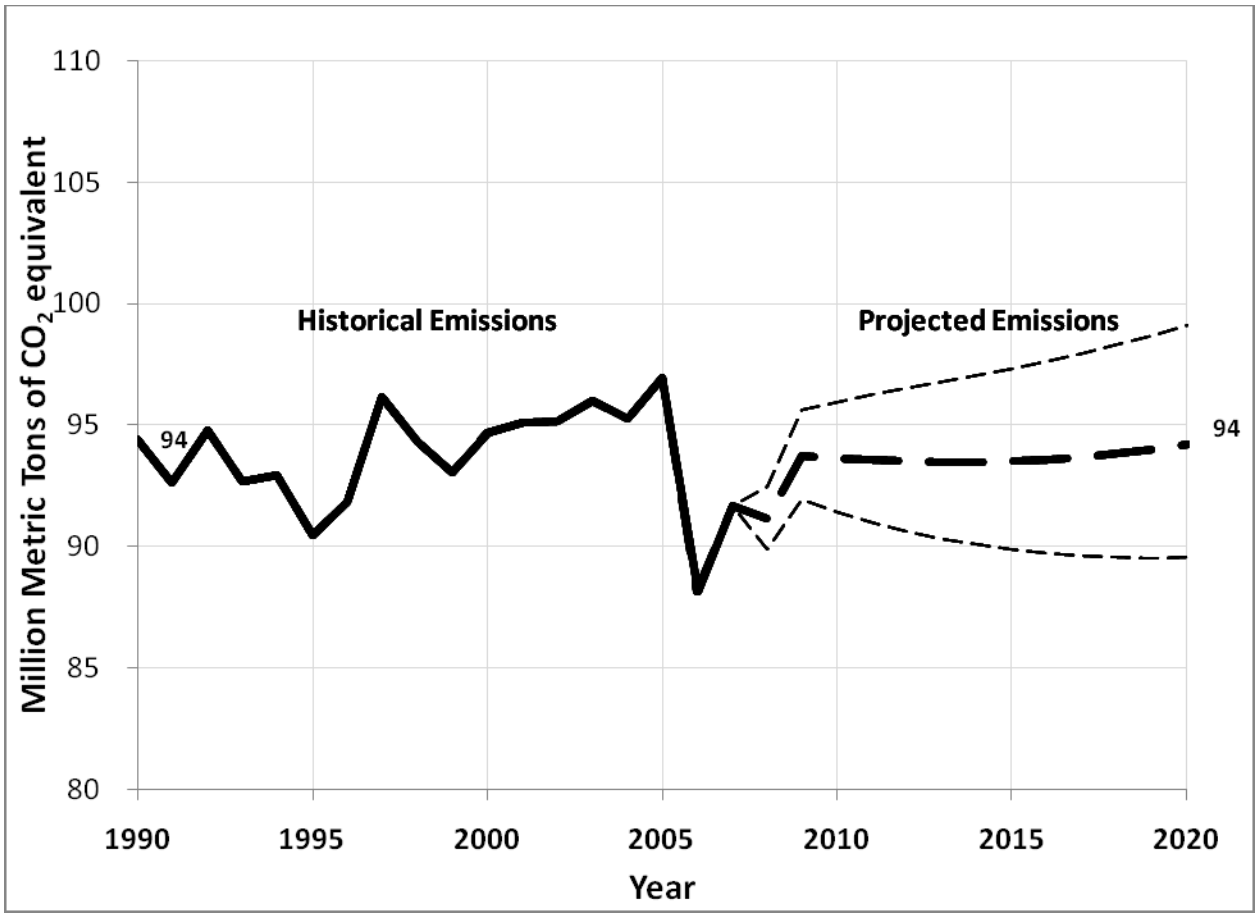
Note: due to rounding to 1 decimal place, the energy total of 89.8 appears higher than a simple sum of the sectors shown in table 1 (89.7), and for the same reason, the Gross Emissions total of 94.4 appears lower than the sum of the bolded numbers (94.5). Given the relative accuracy of these data, the Department rounded 94.4 million metric tons to 94, rather than incorporating a 3rd significant digit.

Part 2: Massachusetts 2020 Business as Usual (BAU) GHG Emissions Projection

What is the purpose of the 2020 BAU Projection? This projection will allow MassDEP and stakeholders to illustrate the magnitude of GHG reductions necessary to achieve the limit set for 2020 (10-25% below the 1990 Baseline). It provides a context to understand the emissions reductions achieved by implementing measures to reduce GHGs compared to what emissions would be if such measures were not implemented, i.e., Business As Usual.

The 2020 BAU Projection has been developed by extrapolating from historical emissions trends. The projection, which estimates 2020 BAU emissions at 94 $MMTCO_2e$, is labeled Projected Emissions and is represented as the heavy dashed line on Figure 1. This projection is based on a straightforward extrapolation of historical data rather than on a complex model that attempts to predict what the future holds. Also shown on Figure 1, the lightly dashed lines reflect a reasonable range of uncertainty in emissions given the variability inherent in GHG drivers such as economic activity and fuel prices. These ranges are based on historical variability (50% confidence that expected emissions lie between the two lightly dashed lines) rather than on an analysis of factors that might drive emissions higher or lower than the historical trend line, and by how much.

Figure 1: Massachusetts Baseline and Business as Usual (BAU) Projection of GHG emissions 1990-2020

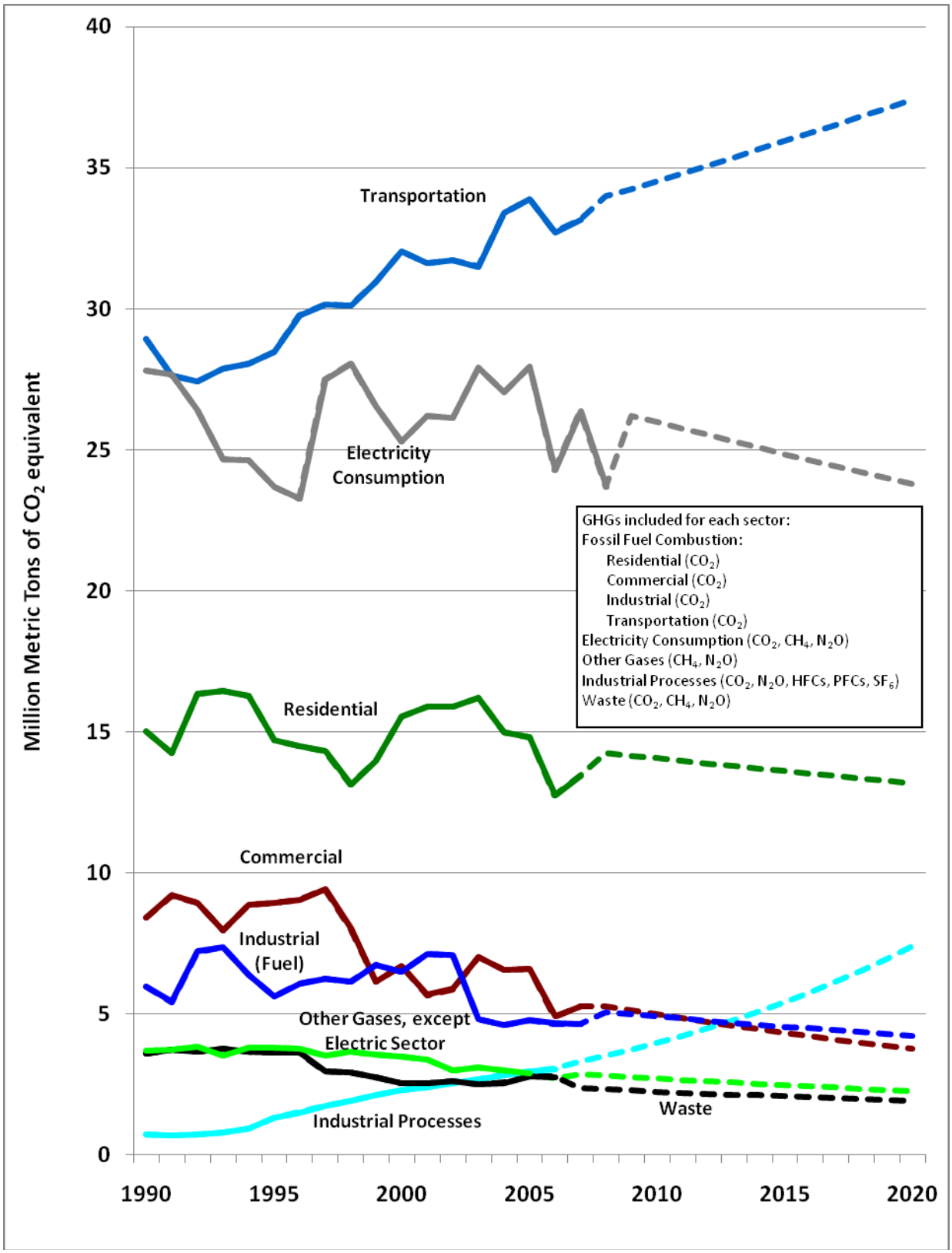


There are some changes in Massachusetts policy that were adopted, though not implemented, prior to January 1, 2009 that are not reflected in this projection. For example, the Regional Greenhouse Gas Initiative (RGGI), the 2007 revised Federal Corporate Average Fuel Economy (CAFE) vehicle efficiency standard, and the Federal Renewable Fuel Standard (RFS) will each result in emissions reductions. However, the extent to which such programs will specifically reduce emissions in Massachusetts is not known, since the programs are federal or regional in scope. Also, since some of the programs were not implemented by January 1, 2009, there are no actual data yet on which to base projected emissions. Although not included here, these programs will be factored into setting the 2020 emissions limit and developing the plan to achieve that limit.

MassDEP and the EOEEA agencies intend to use the 2020 BAU Projection to provide context for upcoming discussions on the 2020 GHG reduction target and the strategies that will be included in the plan to reach that limit.

Figure 2 provides a breakdown of 1990 Baseline and 2020 BAU Projection by major sector. These data demonstrate how the sectors comprising the overall Massachusetts inventory may be projected to 2020. However, the caveats noted above, along with the caveats about data quality in Part 3, also apply to each sector.

Figure 2: Massachusetts Baseline and BAU Projection of GHG emissions 1990-2020 by sector



Part 3: GHG Emission Sources, Data Sources and Methodology

The goals for emissions reductions in GHGs established by the GWSA are framed as percent reductions from 1990 levels. Establishing a baseline level of 1990 emissions is critical for the Commonwealth's ability to measure progress toward meeting the goals of the statute. This section describes the sources of GHG emissions, the information available upon which to base the 1990 estimate, and the methodology that MassDEP has used to develop a 1990 Baseline and a 2020 BAU Projection.

1. Sources of GHG emissions:

Combustion of Fossil Fuels: GHGs are emitted by all sectors of our economy. 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, 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. Please note that not all of these industrial processes are conducted in Massachusetts.

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 (e.g., rice cultivation).

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 Massachusetts 1990 Baseline and 2020 BAU Projection:

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 starting with 1990 and ending with a year that varies by sector, ranging from 2005 to 2008, depending on the availability of data for each sector. Therefore, the SGIT was the basis for both the 1990 Baseline and the historical data from which the 2020 BAU Projection was extrapolated. 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 to calculate the electricity sector emissions from fuel combustion; SGIT draws this data from the US Department of Energy's Energy Information Administration (EIA). MassDEP used SGIT's 1990 estimates of GHG emissions from fossil fuel electrical generation and other sectors to derive the 1990 Baseline for Massachusetts.

The most current EPA SGIT data was used to modify the 2020 BAU Projection. In April and May 2009, EIA released updates[3] of the data from which 1990-2007 CO_2, CH_4 and N_2O emissions from fossil fuel combustion for all sectors (except transportation sector CH_4 and N_2O, which are calculated using SGIT default data) were calculated using the EPA SGIT in the 1990 Baseline and 2020 BAU Projection. In November 2008, EIA released the data from which 1990-2006 CH_4 and N_2O emissions from biomass combustion for all sectors (except transportation sector CH_4 and N_2O which are calculated using SGIT default data) were calculated using the EPA SGIT in the 1990 Baseline and 2020 BAU Projection. In addition, the Department calculated 2008 CO_2, CH_4 and N_2O emissions from electric sector fossil fuel combustion using the same methodology, as the needed raw data are now available.[4] Preliminary 2006 SGIT estimates for Mobile Combustion (CH_4 and N_2O only), Industrial Processes, Agriculture[5] and Waste[6] sectors were also incorporated in the 2020 BAU Projection.

As no default EPA SGIT data exist for the length of natural gas transmission and distribution pipelines (used to estimate emissions for the natural gas transmission and distribution sector), state specific data were entered.[7]

The EPA SGIT data set 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

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[3] See http://www.eia.doe.gov/emeu/states/_seds_updates.html.
Petroleum and fuel ethanol "Data for all years including revisions for earlier years (Btu)" was released 4/10/09; Natural gas "Data for all years including revisions for earlier years (Consumption)" was released 4/17/09; and Coal and coal coke "Data for all years including revisions for earlier years (Consumption)" was released 5/8/09.

[4] See http://www.eia.doe.gov/cneaf/electricity/epm/epm_ex_bkis.html for Electric Power Monthly data.

[5] With the exception of updated quantities of alfalfa produced in 2003-2008 from U. S. Department of Agriculture, National Agricultural Statistics Service at http://www.nass.usda.gov/Statistics_by_State/Massachusetts/index.asp

[6] With the exception of Massachusetts-specific quantities of solid waste land filled and combusted.

[7] See the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration "Distribution, Transmission, and Liquid Annual Data" at http://phmsa.dot.gov/pipeline/library/data-stats

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 1990-1992 and 2001-2006, and use of limestone for 1990-1993;
- **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 and limestone, due to the absence of data on these activities in Massachusetts, these activities are not included in either the 1990 Baseline or the 2020 BAU Projection. For lime and limestone, 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,[8] 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. ISO-NE generation data is not available prior to 2000, however, so EIA generation data for each New England state is used for 1990-1999[9]. Data on electricity imported to New England from the adjacent New York, New Brunswick and Quebec control areas are only available from ISO-NE beginning with 2000, so 1990-1999 megawatt hours and associated emissions were estimated based on other data from ISO-New England and EIA.

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.

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[8] 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."

[9] EIA generation (at http://www.eia.doe.gov/cneaf/electricity/epa/generation_state.xls) and EPA SGIT electric sector GHG emissions (as updated using the most recent EIA data described in footnote 3) include the entire state of Maine, while ISO-NE load (at http://www.iso-ne.com/trans/celt/fsct_detail/2009/_isone_2009_forecast_data_rev2.xls tab 8 column I) for Maine does not include the part of Maine supplied by the Northern Maine Independent System Administrator (NMISA). Northern Maine load and generation data were obtained from NMISA for 2000-2008; the 2000-2008 average was used to estimate 1990-1999 NMISA generation as a portion of Maine's total generation, to pro-rate Maine's SGIT electric sector GHG emissions.

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. The strategies chosen to reduce GHG emissions as part of the Commonwealth's 2020 (and beyond) plans will benefit from recognizing the inherent regional nature of the New England electric grid, as the effectiveness of GHG reduction strategies may vary based on whether or not it is assumed that all electricity generated in-state is consumed in-state.

The 1990 Baseline and 2020 BAU Projection present emissions associated with electricity consumption using an approach that more directly accounts for emissions associated with electricity generated in Massachusetts, while an alternative regional approach is discussed further below and documented in the accompanying Appendix I spreadsheet. The 1990 Baseline and 2020 BAU Projection approach assume 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 1990 Baseline includes a share of the emissions associated with each electricity-exporting state's exported electricity, as calculated from the EPA SGIT estimate of each state's CO_2, CH_4 and N_2O emissions from fossil fuel and CH_4 and N_2O emissions from biomass combustion for electricity generation. Similarly, the 1990 Baseline apportions to Massachusetts a percentage of the megawatt hours of losses (and associated emissions) due to pumped hydro[10] and of the net annual imports into the ISO-NE grid from the New York, New Brunswick and Quebec grids.[11] New York emissions are based on the EPA SGIT estimate of New York's CO_2, CH_4 and N_2O emissions from fossil fuel and CH_4 and N_2O emissions from biomass combustion for electricity generation.[12] Emissions from the Canadian Provinces were calculated using Environment

[10] The megawatt hours of losses associated with pumped hydro were found in NEPOOL and ISO-NE Annual Reports at http://www.iso-ne.com/aboutiso/fin/annl_reports/1990/ for 1990 to 1999 and at http://www.iso-ne.com/nwsiss/grid_mkts/enrgy_srcs/index-p1.html, with corrections from ISO-NE, for 2000-2008. 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.

[11] The megawatt hours associated with net imports to New England from New York, New Brunswick and Quebec in 1990 to 1999 were set equal to pumping (see footnote 10) plus the ISO-NE load (at http://www.iso-ne.com/trans/celt/fsct_detail/2009/isone_2009_forecast_data_rev.xls tab 8 column I) minus adjusted EIA generation (from http://www.eia.doe.gov/cneaf/electricity/epa/generation_state.xls).

[12] New York GHG emissions are based on New York SGIT CO_2, CH_4 and N_2O emissions from fossil fuel and CH_4 and N_2O emissions from biomass combustion for electric generation (at http://www.epa.gov/climatechange/emissions/downloads/CO2FFC_2005.pdf, as updated using the most recent EIA data described in footnote 3) for 1990-2007, and using the same methodology for 2008.

Canada's National Inventory Report.[13]

An alternative electricity consumption emissions approach 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 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 ElecImport tab of Appendix I. This approach and resulting emissions will be considered as the 2020 emission reduction target and plan are developed.

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

Despite the lack of annual historical 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 the data available for the biomass sector are sufficient, and their magnitude is significant enough that it is important to track going forward. For the purposes of compliance with the 2020 limit (i.e. a reduction between 10 and 25%), the Department will use gross emissions numbers as the primary point of reference. This is due to several factors, including that biomass emissions are double-reported when biomass harvested as a result of land use change in Massachusetts is also combusted in Massachusetts, that carbon sinks are only included for forestry, and that annual forest sink data points for many years are based on interpolated rather than measured data.

Table 2: 1990 Biomass Biogenic CO_2 Emissions, Forest Sequestration and Land Use Change Emissions ($MMTCO_2e$)

CO_2 from Biomass Combustion Total	**4.9**
Residential CO_2	1.7
Commercial CO_2	0.2
Industrial CO_2	0.7
Transportation CO_2	--
Electric Generation CO_2	2.3
Forest Sequestration	**-8.6**
Land Use Change Emissions	**2.2**
Net Biogenic CO_2 Emissions	**-1.5**

Note: 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.

[13] The 1990-2006 New Brunswick and Quebec GHG emissions are based on the National Inventory Report by Environment Canada (at http://www.ec.gc.ca/pdb/ghg/inventory_report/2006_report/ta9_5_eng.cfm and http://www.ec.gc.ca/pdb/ghg/inventory_report/2006_report/ta9_6_eng.cfm).

Biogenic CO_2 emissions result from burning biomass, including: biofuels such as ethanol; wood- and paper-fired electric generation; and, the biomass component of 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, the 1990 Baseline and 2020 BAU Projection use 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 and Figure 1 do not indicate quantities of CO_2 released during combustion of biomass.[14] However, the 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]

Including biogenic CO_2 emissions in this report in Table 2 and in Appendix I provides a mechanism for considering the use of biomass and biofuels in choosing strategies to meet the 2020 and longer term goals of GWSA. Recently, there has been increased interest in bioenergy, including biomass heat and electricity generation and transportation biofuels such as ethanol and biodiesel.

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 1990 Baseline and 2020 BAU Projection spreadsheet in Appendix I. 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 1985, 1999 and 2005. 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).

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[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 on November 28, 2008 released the data from which 1990-2006 CO_2 emissions from biomass combustion for all sectors (except transportation) were calculated using the EPA SGIT. Transportation sector biomass ethanol CO_2 emissions were calculated using the EPA SGIT based on the EIA data update described in footnote 3.

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 course of the long-term carbon cycle. In order to take account of these emissions, the 1990 Baseline and 2020 BAU Projection 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.

5. Other Methodological Issues:

Several potentially significant sources of GHGs are not included in the Massachusetts historical baseline and BAU projections 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 (see Weber and Matthews[16]), there is still great uncertainty in such estimates. Further analysis is needed in this area; therefore, embodied emissions were not included in the 1990 Baseline or 2020 BAU Projection.
- 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 capped landfills, asphalt in roads and a portion of construction materials in permanent buildings. These emissions are also not included in the 1990 Baseline or the 2020 BAU projection.

[16] "Embodied Environmental Emissions in U.S. International Trade," 1997-2004," Christopher L. Weber and H. Scott Matthews, Environmental Science & Technology, 2007; "CO2 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.

6. Methodological Issues with the 2020 BAU Projection:

Technology change will inevitably affect future GHG emissions, with potentially dramatic results. The effects of technology change have not been explicitly modeled, though past changes are implicitly reflected in the historical emissions numbers. While it may be unrealistic to project increases in GHG emissions given the proliferation of GHG mitigation technologies today, it is on the other hand important not to assume that the pace of technological innovation will change significantly and/or will necessarily result in significantly lower emissions.

Another approach to a BAU projection would be to base it on the projections of CO_2 emissions from fossil fuel combustion in the U.S. Department of Energy's Energy Information Administration (EIA) Annual Energy Outlook (AEO). The AEO projects U.S. energy demand and the resulting CO_2 emissions to 2020. However, the AEO provides only regional and national emissions projections, which complicates the development of a Massachusetts-specific projection. MassDEP believes that, in light of the recent volatility in fuel prices and the economic business cycle, it is more prudent to rely on the statistical projection of historic data used in this BAU projection rather than to presume to predict economic dynamics with any precision.