2010 RI Greenhouse Gas Emissions Inventory

Background/Overview:

In June 2012, the Rhode Island Department of Environmental Management (RIDEM) contracted with Northeast States for Coordinated Air Use Management (NESCAUM) to develop a 2010 Greenhouse Gas Emissions Inventory for the State of Rhode Island. The project was broken down into three components or tasks.

Task 1: Compare and evaluate the methodologies used by the NESCAUM states (CT, MA, ME, NH, NJ, NY, RI and VT) to prepare Greenhouse Gas (GHG) emissions inventories. It was determined that the Northeast states utilize the US Environmental Protection Agency's (EPA) State Inventory Tool (SIT) to complete their statewide inventories for greenhouse gases. The SIT is an interactive spreadsheet model which relies on national data and assumptions but allows the user to replace default data with state-specific data. The idea being that with more state specific data entered into the model, the resulting emissions numbers will be more accurate. NESCAUM was also charged with determining whether to rely on the default data or recommend more credible or robust state specific data. The SIT also has Projection Tool which allows users to create a simple forecast of emissions through 2030 based on historical emissions and future estimates including energy consumption, population, and economic factors. Click on Task 1 link for full report.

Task 2: NESCAUM used the SIT and the Projection Tool to prepare the 1990 (baseline year) and 2010 inventories using the default data set or the recommended data set as determined in Task 1. In addition, a 2020 Business As Usual (BAU) projection was also completed. Refer to Task 2 link for complete inventory results.

Task 3: Identify and quantify GHG emissions from the major sources in Rhode Island. Individual sources with actual GHG emissions greater than or equal to 5000 tons/year CO2 equivalent emissions were catalogued and ranked according to total sum of C02 equivalent emissions. See the Task 3 link to view listing of facilities.

Summary of Findings:

The following are some of the highlights of the 2010 Emissions Inventory. For additional detail and a comprehensive overview of all the sectors inventoried, refer to the Task 2 link.

Using 1990 as the baseline year, total emissions, not including carbon fixing from land use and forestry, were approximately 10.74 million metric tons (MMT) of carbon dioxide equivalent (CO2e). Highway vehicles (41%) represented the largest single source sector for GHG emissions in 1990.

In 2010, total emissions, not including carbon fixing from land use changes and forestry were approximately 12.25 MMT CO2e. Similar to 1990, highway vehicles accounted for the highest single source sector for GHG emissions with approximately 3.70 MMT Co2e of emissions and representing 30% of the total emissions. It should be noted that the largest change in emissions between 1990 and 2010 was in the electric power generation sector. The emissions from power plants increased from 0.79 MMT CO2e to 3.17 MMT CO2e. The reason for this increase can be attributed to the fact that four out of the five power plants in Rhode Island began operating after 1990. Currently, the largest single source of GHG emissions in RI is from the Entergy power plant, a 550-megawatt combined-cycle natural gas-fired facility located in Johnston which emitted approximately 1,151,868 MT CO2e in 2010.

A BAU GHG emissions projection was calculated for 2020 and the GHG emissions totaled 12.63 MMT CO2e. As in 1990 and 2010, the transportation sector, specifically, highway vehicles, is estimated to be the largest source contributor with 29.8 percent. A close second with 29.1 percent of the projected emissions is electric power generation which is part of the energy sector.

RI Greenhouse Gas Emission Reduction Targets:

On July 2, 2014, Governor Chafee signed the Resilient Rhode Island Act (http://webserver.rilin.state.ri.us/BillText/BillText14/HouseText14/H7904A.pdf). This legislation set specific short-term and long-term greenhouse gas reduction goals. These mandated targets require greenhouse gas emissions to be reduced below 1990 levels as follows:

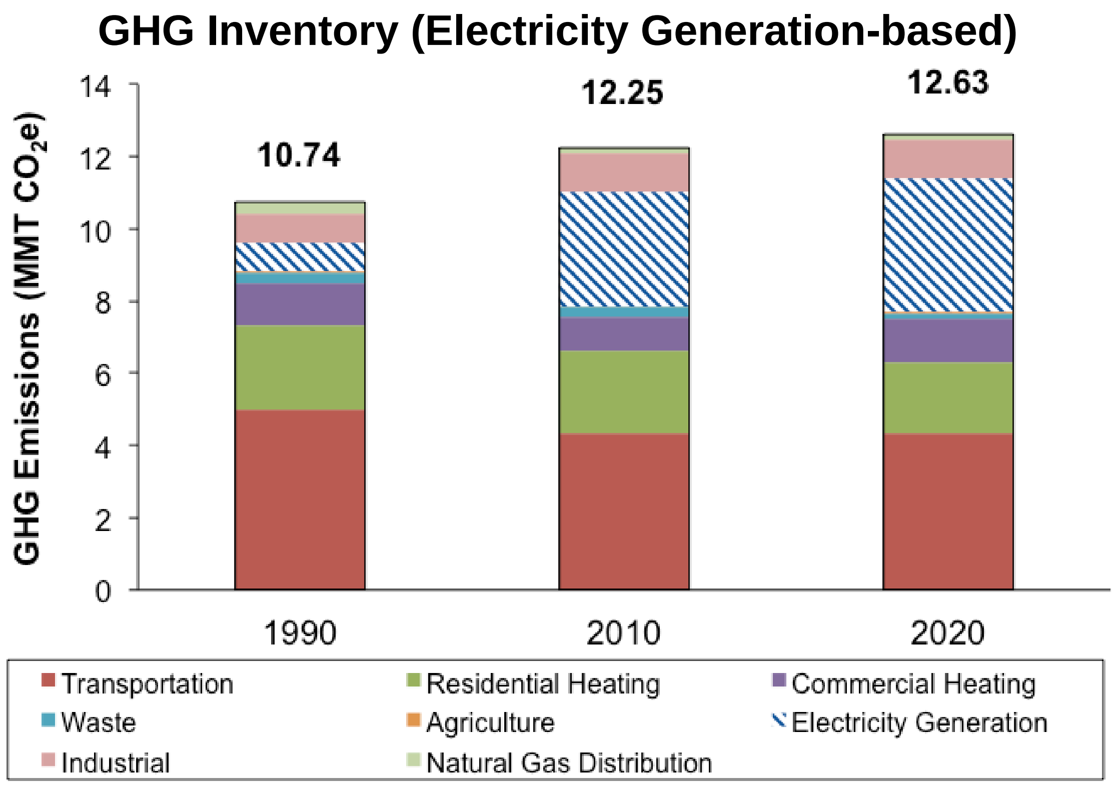
10% by 2020
45% by 2035
80% by 2050

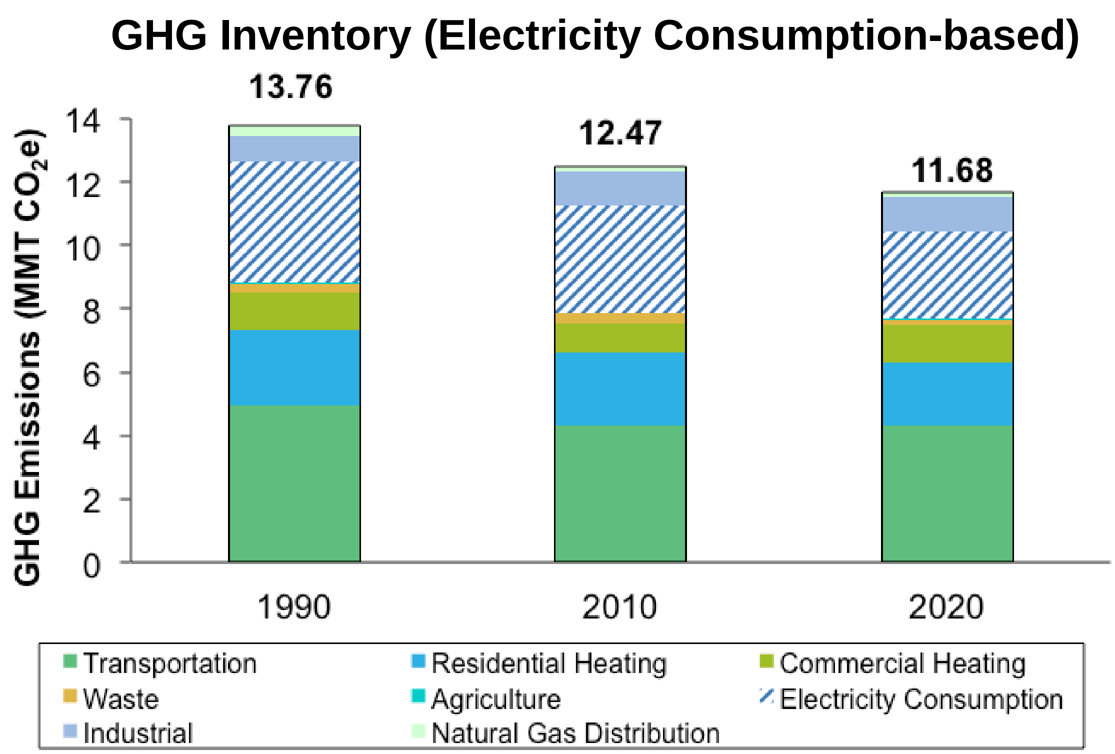
As stated in the Summary of Findings, electric power generation is a significant source of greenhouse gas emissions in Rhode Island. Based on electricity generation emissions inventoried, Rhode Island did not meet its 2010 emissions reduction goal and is not expected to meet its 2020 goal. Refer to RI GHG Emissions – Two Perspectives table below. However, if emissions are calculated based on electricity consumed as opposed to electricity generated, Rhode Island meets the 2010 goal and is expected to meet the 2020 target. These two different perspectives/approaches, generation vs. consumption, are significant to Rhode Island because our State may be a net electricity exporter. In 1990, Rhode Island consumed far more power (electricity) than it generated. However, in 2010, the State consumed nearly the same amount of power that Rhode Island power plants generated. The most recent data from 2011 & 2012 indicate that Rhode Island is generating more electricity than we are consuming. As such, the electric consumption-based approach may more accurately reflect our energy sector greenhouse gas emissions. The GHG Inventory bar graphs below illustrate the difference between Electricity Generation-based emissions and Electricity Consumption-based emissions.

Rhode Island GHG Emissions – Two Perspectives

GHG Emissions/Goals*	**Electricity Generation-based (MMT CO2e)**	**Electricity Consumption-based (MMT CO2e)**
1990 GHG Emissions (Baseline)	10.74	13.76
2010 Goal (Reduce to 1990)	10.74	13.76
2010 GHG Emissions	12.25	12.47
2020 Goal (10% below 1990)	9.67	12.38
2020 GHG Emissions	12.63	11.68

* As outlined in the 2001 New England Governors/Eastern Canadian Premiers Climate Change Action Plan 2001 and the Rhode Island Greenhouse Gas Action Plan 2002.





On March 20, 2014, NESCAUM presented the 2010 Rhode Island Greenhouse Gas Inventory to the Rhode Island Executive Climate Change Council (renamed in 2014 to RI Executive Climate Change Coordinating Council-EC4). Refer to the NESCAUM inventory link for the complete power point presentation.

Task 1 -

Overview of State Greenhouse Gas (GHG) Inventories and Recommendations for Rhode Island Inventory Development

The following provides background and recommendations for the development of a statewide GHG inventory for Rhode Island. Section 1 summarizes information compiled about state inventories for the NESCAUM states and for California, and provides recommendations to the Rhode Island Department of Environmental Management (RI DEM) on developing a regionally-consistent GHG inventory. Section 2 provides further detail on options and recommendations for inventory development by sector, including potential improvements to high-level inventories using state-specific data. At the end of this memorandum, two summary tables provide an overview of state GHG inventories in the surveyed states (Table 1) and data sources for developing a Rhode Island GHG inventory (Table 2).

1. GHG Inventories in the NESCAUM States and California

NESCAUM contacted the environmental departments in NESCAUM member states and California to catalogue how these states develop their GHG inventories and projections. Each of these states updates or plans to update an inventory on a regular basis. Several states reported developing an inventory in response to a state mandate to track progress against a climate goal. Each state has developed a projection or set of projections that may serve as a business-as-usual scenario, although some states have not yet publicly released their projections. Table 1, included at the end of this memorandum, provides a detailed summary of relevant GHG inventory information for these states.

The Northeast states rely on the US Environmental Protection Agency's (EPA) *State Inventory Tool* (SIT) to develop statewide inventories for greenhouse gases,[1] and California has developed its own tool for conducting its emissions inventory. Both SIT and California's tool rely on some national data and assumptions downscaled to the state-level but allow the user to replace default data where more credible or robust data are available. Data are entered into SIT at the state level, but the inventory may be supplemented with facility or source level data outside of the framework of the tool. For example, California and Massachusetts include facility-based data from their mandatory reporting programs in their GHG emissions inventories.

In part due to its consistent use across the region, NESCAUM recommends using SIT to develop Rhode Island's inventory. SIT offers a long-standing platform for inventory development and is updated regularly to include new data and assumptions. Functionality, past improvements, and limitations are well-documented in accompanying user's guides.[2] Much of the information in this memorandum is sourced from these user's guides and modules. SIT is also an appropriate

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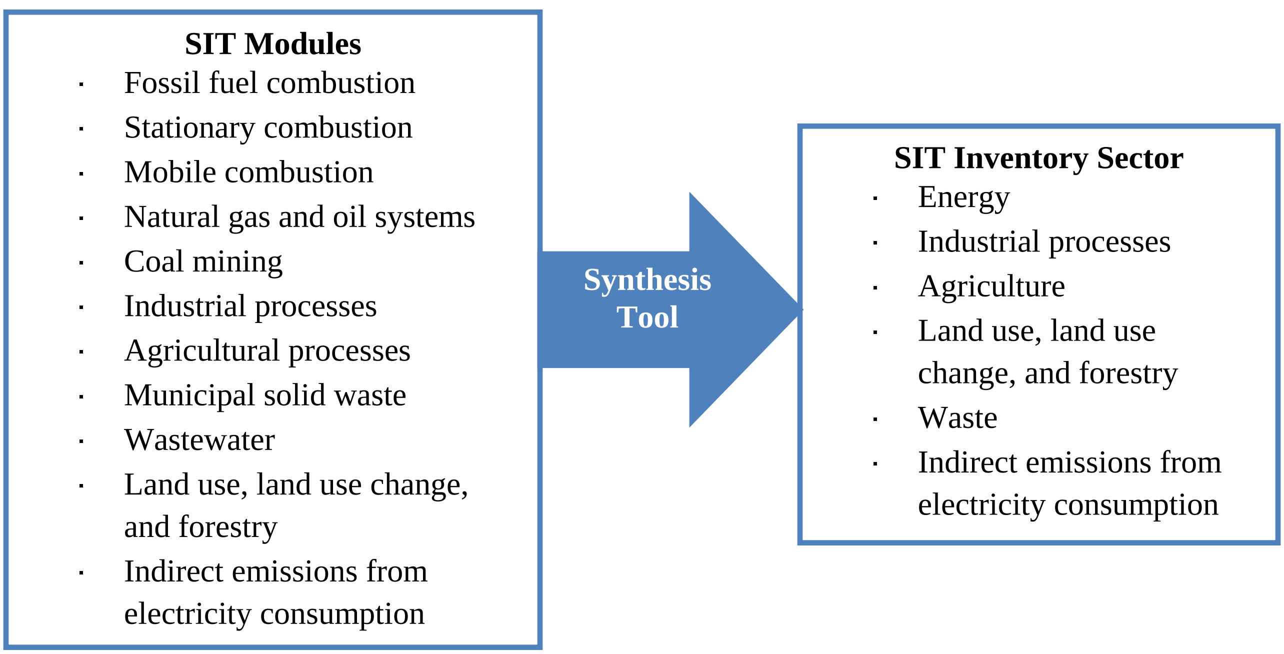
[1] In the past, states relied on SIT's predecessor, the Emissions Inventory Improvement Program (EIIP).
[2] To access documentation supporting the State Inventory Tool, go to: http://www.epa.gov/statelocalclimate/resources/tool.html.

choice because it is ready-to-use with default data and allows for the use of supplemental source-level data, enhancements to aggregated data, and improvement of tool assumptions.

SIT Methodology

SIT is a series of 11 Excel workbooks, or modules, representing all sectors responsible for generating emissions. Users have the option to rely on either default or user-supplied data, conversion factors, and other assumptions, or a hybrid approach (i.e., selecting a mix of default and user-supplied values). In each module, GHG emissions are generally estimated as a function of activity data (e.g., fuel consumption) and emission factors. Emissions estimates from the modules are then combined using another Excel workbook, the Synthesis Tool. Results may be filtered by sector or type of GHG. **Figure 1** below provides an overview of SIT data modules, where data are input, and the sectors included in the final inventory. Data and assumptions are entered into each SIT module; the modules are aggregated using the Synthesis Tool, and the emissions inventory is provided by sector.

Figure 1. Overview of SIT



The following section provides an overview of each SIT input category.[3] Detailed information about the data and assumption sources for each input category are included in Table 2 at the end of this memorandum.

Carbon Dioxide from Fossil Fuel Combustion (CO_2FFC): The CO_2FFC module calculates carbon dioxide (CO_2) emissions from fuel combustion at stationary sources and CO_2 emission from mobile source fuel combustion. This module incorporates CO_2

[3] The coal mining module is not described in this section or in the remainder of the document as coal mining is not a historical or anticipated activity in Rhode Island.

emissions from coal, natural gas, and petroleum products (e.g., distillate fuel, motor gasoline, and aviation fuel). Using default settings, the tool calculates emissions using energy consumption data from State Energy Consumption, Price, and Expenditure Estimates (SEDS) published by the Energy Information Administration (EIA).[4]

Stationary Combustion: The Stationary Combustion module calculates methane (CH_4) and nitrous oxide (N_2O) emissions from combustion of coal, natural gas, petroleum, and wood at stationary sources. Default data for this module are from SEDS (EIA 2012).

Mobile Combustion: The Mobile Combustion module calculates CH_4 and N_2O emissions from five highway vehicle classes (cars, light trucks, heavy trucks, buses, and motorcycles), three types of aviation fuels (kerosene, naphtha, and gasoline); three types of marine fuels (residual oil, diesel, and gasoline); three types of locomotive fuel (residual oil, diesel, and coal); and three categories of land-based non-road equipment (farm, construction, and other). The module may also be used to calculate CO_2 emissions from mobile sources, which are otherwise included in the CO_2FFC module. Default data for this module come from the Federal Highway Administration (FHWA)[5] and EPA's *Inventory of Greenhouse Gas Emissions and Sinks: 1990-2010*.[6]

Industrial Processes: The Industrial Processes module estimates CO_2, N_2O, hydrofluorocarbon (HFC), perfluorocarbon (PFC), and sulfur hexafluoride (SF_6) emissions from the manufacture and/or use of cement, lime, limestone and dolomite, soda ash, iron and steel, ammonia, nitric acid, adipic acid, aluminum, HCFC-22, substitutes for ozone-depleting substances, semiconductors, and magnesium. This module also calculates non-CO_2 emissions from electric power transmission and distribution. Default data and assumptions for this module come from a wide-range of industry trade group and analysis sources.

Natural Gas and Oil Systems: The Natural Gas and Oil Systems module estimates CH_4 and CO_2 emissions from the production, transmission, venting and flaring, and distribution of natural gas and the production, refining, and transport of petroleum. Default data are provided for some aspects of these systems, but additional data are required to complete an inventory of emissions in this sector.

[4] EIA. 2012. State Energy Data 2010 Consumption. Energy Information Administration, U.S. Department of Energy. DOE/EIA-0214(2010). Available online at http://www.eia.doe.gov/emeu/states/_seds.html.
[5] FHWA. 2012. Highway Statistics 2010. Federal Highway Administration, U.S. Department of Transportation. Tables VM-1 and VM-2. Available online at http://www.fhwa.dot.gov/policy/ohpi/hss/index.htm.
[6] EPA. 2012. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010. Office of Atmospheric Programs, US Environmental Protection Agency. EPA 430-R-12-001. Available online at http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

Agricultural processes: The Agriculture module calculates CH_4 and N_2O emissions from enteric fermentation, manure management, soil, rice cultivation, and residue burning. Default data come from the *Inventory of GHG Emissions and Sinks* (EPA 2012).

Municipal Solid Waste: The Municipal Solid Waste module calculates CH_4 emissions from decomposition of waste when landfilling and CO_2 and N_2O emissions from combustion of municipal solid waste (MSW). SIT does not consider CO_2 emitted as biogas or from combusting CH_4 at flares as an anthropogenic greenhouse gas emission. Emissions from biogenic sources of waste (e.g., yard trimmings, food waste, and paper) are also not considered to be anthropogenic emissions in SIT. Default data for this module are from the US Census Bureau's State Population Datasets,[7] the *Inventory of GHG Emissions and Sinks* (EPA 2012), EPA's analysis of MSW in the US,[8] and the Annual Nationwide Survey of Garbage in America conducted by BioCycle.[9]

Wastewater: The Wastewater module calculates CH_4 and N_2O emissions from municipal and industrial wastewater treatment. Default data for this module are from the *Inventory of GHG Emissions* (EPA 2012) and State Population Datasets (Census 2012).

Land Use, Land Use Change, and Forestry (LULUCF): The LULUCF module calculates net greenhouse gas emissions for the land use sector considering forest carbon flux, urban trees, carbon storage in landfilled yard trimmings, agricultural soil liming, N_2O from settlement soils, and non-CO_2 from forest fires. A more detailed description of this sector is provided in Section 2 of this memorandum. Default data for this module come from a range of sources, as listed in Table 2 at the end of this memorandum.

Indirect Emissions from Electricity Consumption: Indirect emissions from electricity consumption are the emissions that occur at an electric power generator when the end-user purchases power (e.g., the power plant emissions associated with turning on a light at an office). Designation of direct and indirect emissions is used to avoid double-counting and to properly track emissions reductions. A power plant may install cleaner technology or begin providing renewable energy, but at the same time a family or business may switch to more efficient lighting sources, choose to reduce their appliance usage, or better insulate their home (assuming electric heating/cooling). Default data for electricity consumption are available from SEDS (EIA 2012); emission factors are from eGRID.[10] Indirect emissions are reported separately from other emissions to avoid double-counting.

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[7] US Census. 2012. State Population Datasets. Available online at http://www.census.gov/.
[8] EPA. 2011. Municipal Solid Waste in the United States: 2010 Facts and Figures. Available online at http://www.epa.gov/epawaste/nonhaz/municipal/msw99.htm.
[9] BioCycle. 2010. The State of Garbage in America: Annual Nationwide Survey.
[10] EPA. 2008 and 2011. Emissions and Generation Resource Integrated Databases for 2007 and 2011 (eGRID2007, eGRID2010). Available online at http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html.

Common Methodologies Across States

The Northeast states use SIT to develop their state inventories and replace default data for certain sectors with improved data and assumptions. California uses its own tool to develop state inventories. To date, many of these updates have supplemented data in the electric power generation sector using data from state-mandated reports from Title V facilities. However, some states have begun to improve other sector inventories with state-specific data. For example, New Hampshire had the University of New Hampshire-based Carbon Solutions New England perform an analysis of the state's forestry sector, and New York updated its on-road vehicle emissions by substituting EIA fuel use data with vehicle travel data from the New York State Department of Transportation and fuel economy data from FHWA.

Emissions Projections

The Northeast states and California reported projecting their emissions inventory to at least 2020, with some states projecting to 2030 or 2050. Emissions projections may be done by simply using factors to represent population growth and economic indicators, or both. Emissions projections may be enhanced by considering influences on each sector, for example, considering improvement in the fuel economy of motor vehicles or increased investment in renewable energy and energy efficiency.

SIT is accompanied by the Projection Tool, which allows users to import historical emissions data and generate estimates for future years based on these data and on population and gross domestic product (GDP) forecasts. The Projection Tool allows the user to enhance the projections by modifying population and/or GDP forecasts or by overriding projections for certain sectors with analyses performed outside the tool.

Recommendations for Rhode Island

NESCAUM provides the following recommendations for Rhode Island's inventory of historical GHG emissions and projection of future emissions, respectively:

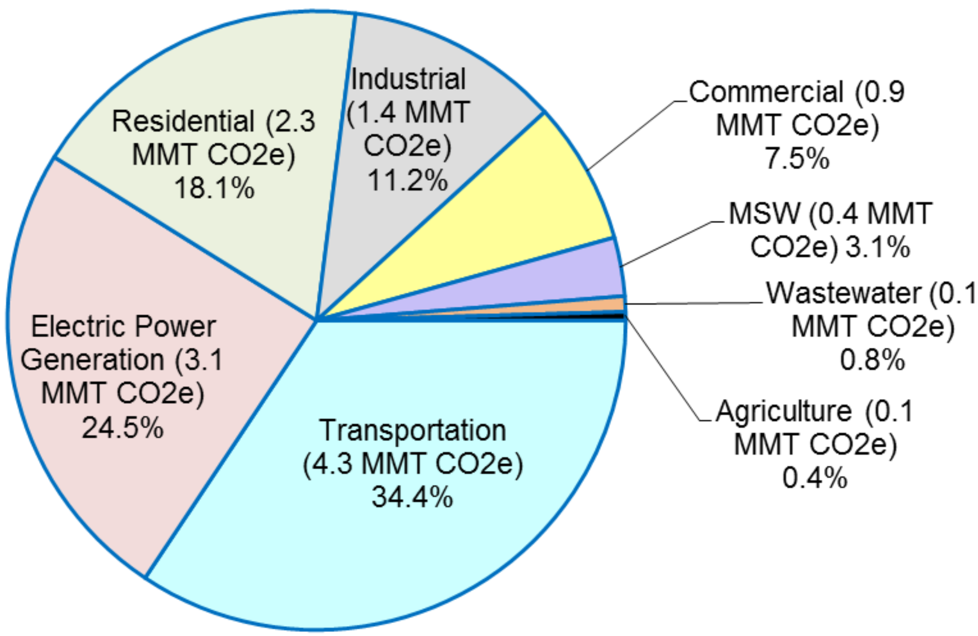
- **Inventory of Historical GHG Emissions:** Use SIT and its default data set as the basis for Rhode Island's initial GHG emissions inventory, and augment or replace default data with available state-specific or reported data where available. Continue to update the inventory over time with reported data as they become available.

- **2020 GHG Emissions Projection:** Use the SIT's Projection Tool as the platform for the emissions forecast, but replace projections for those sectors where additional data and information are available. For example, Rhode Island's planned investments of system benefit charges and RGGI funds in energy efficiency can be used to revise the SIT's estimates of future electricity demand. This approach would also allow for more meaningful analysis and tracking of Rhode Island's progress towards climate goals.

2. Options and Recommendations for Rhode Island's Greenhouse Gas Inventory

For an initial snapshot of the state's GHG emissions, NESCAUM performed an analysis of Rhode Island's 2010 GHG emissions using SIT, selecting only default values (hereafter, the "default run"). NESCAUM estimated Rhode Island's GHG emissions for the combined electric power generation,[11] residential, commercial, industrial, and transportation sectors to be approximately 12.0 million metric tons (MMT) carbon dioxide equivalent (CO_2e).[12] A combined additional ~0.6 MMT CO_2e are emitted from the MSW, wastewater, and agricultural sectors. The land use and forestry sector served as a "sink" for CO_2, removing 1.3 MMT CO_2e from the atmosphere. **Figure 2** below provides a breakdown of the emissions by sector.[13] For simplicity, we have excluded GHG sinks (i.e., land use) from this summary.[14]

Figure 2. 2010 Rhode Island Greenhouse Gas Emissions



Source: SIT Default Run, 2013.

[11] SIT uses the terminology "electric utilities sector" to reference emissions from the generation of electricity. To more accurately represent the source of emissions from this sector, we use the term electric power generation sector.
[12] CO_2e is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential relative to that of CO_2.
[13] The International Panel on Climate Change and EPA define a sink as "any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas or aerosol from the atmosphere."
[14] SIT considers agriculture outside of the LULUCF sector, although some aspects of agriculture, such as agricultural soil liming and N_2O emissions from settlement soils, are captured in the LULUCF sector.

Rhode Island GHG Emissions Inventory

The following discussion provides descriptions of how the GHG emissions estimate for individual sectors is developed within the framework of SIT, and presents options and recommendations for alternative data and assumptions where possible. The wastewater and agricultural sectors are not included because they each represent less than one percent of the overall inventory.

Electric Power Generation

Electric power generation contributes a significant percentage of the GHG emissions in Rhode Island in the form of CO_2, N_2O, and CH_4. NESCAUM's default run of SIT for 2010 indicates that the electric power generation sector emits about 3.1 MMT CO_2e, or about 24 percent of GHG emissions in Rhode Island.

In SIT, the methods to calculate GHG emissions for the electric power and industrial sectors largely follow those steps described in the Emission Inventory Improvement Program (EIIP) volume VIII guidance (2004), with updates from the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (EPA 2012) and the 2006 Intergovernmental Panel on Climate Change (IPCC) *Guidelines for National Greenhouse Gas Inventories*.[15] Default fuel consumption data for the electric power sector have been taken from SEDS (EIA 2012). Additional data from EIA and EPA are used to calculate combustion emissions of CO_2, CH_4, and N_2O. These data include heat and carbon contents of various fuels, fuel combustion efficiency, the fraction of stored carbon when fossil fuels are employed for non-energy uses in the industrial sector (e.g., asphalt usage in highway construction), and N_2O and CH_4 emission factors.

Methodologies and default data assumptions to calculate GHG emissions for the electric power generation sector are described below:

> **CO_2FFC Module:** CO_2 emissions from fossil fuel combustion are calculated from fuel consumption by fuel type and sector (on an energy basis), carbon content coefficients per fuel type, percentage of carbon oxidized during combustion, and, in the case of non-energy industrial fossil fuel usage, the amount of carbon stored in products. Default data are based on information obtained from EIA (2012), EPA (2012), and IPCC (2006).
>
> **Stationary Source Module:** CH_4 and N_2O emissions from fossil fuel and wood combustion are calculated in the stationary combustion module from consumption data by fuel type and sector, global warming potential of CH_4 and N_2O, and emission factors by fuel type and sector.

[15] IPCC. 2006. Guidelines for National Greenhouse Gas Inventories. Institute for Global Environmental Strategies. Available online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/.

CH_4 and N_2O emission factors vary based on a number of factors, including fuel type and size, vintage, maintenance, operation, and/or control of the combustion technology. Default data for CH_4 and N_2O emission factors were based on the *Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). The eGRID 2012 database (see EPA 2008, 2011) now includes these emissions at the facility-level.

<u>Recommendations for Rhode Island</u>

NESCAUM recommends that state-specific data be added to the CO_2FFC and Stationary Source modules to improve the electric utility emissions inventory for Rhode Island. Data collected from Title V facilities under Rhode Island's reporting requirement will provide improved information to disaggregate GHG emissions for large sources. For smaller sources, NESCAUM is currently working with RI DEM to identify additional data available from non-Title V facility permit applications.

NESCAUM recommends including as much state-collected data as possible from Title V reports that are already imported into accessible databases and supplementing these data, where possible, with additional sources that might provide a more state-specific analysis. For example, power plants that are subject to Clean Air Act's Acid Rain provisions report annual CO_2 emissions at the facility-level through EPA's Emissions Tracking System/Continuous Emissions Monitoring (ETS/CEM) requirements. In addition, the eGRID database contains this same information for discrete years as well as estimated emissions for smaller units, cogeneration units, and non-utility sources not subject to ETS/CEM reporting. The most recent version, eGRID2012 (EPA 2013), now also includes estimates of CH_4 and N_2O emissions at the facility level for 2009. NESCAUM recommends reviewing available data from ETS/CEM for 2010 and eGRID for 2009, with appropriate adjustments to 2010, to identify all potential facility-level sources and then working with RI DEM to identify additional data sources that have been collected by the state.

Transportation Sector

Transportation emissions comprise the largest sector share of Rhode Island's GHG emissions, with approximately 4.3 MMT CO_2e in annual emissions, representing about 34 percent of total GHG emissions in the state. Transportation GHG emissions result mainly from the combustion of fossil fuels, with a relatively small contribution due to leakage from mobile air conditioning systems. Gasoline and No. 2 distillate (diesel) fuel comprise most of the energy consumed in the sector. Specific GHGs attributable to transportation sources include CO_2, CH_4, N_2O, and HFCs.

Accounting for GHG emissions from mobile sources generally requires three steps: 1) characterizing the existing vehicle fleet; 2) identifying the activity associated with each vehicle class (e.g., vehicle miles travelled [VMT], engine hours, or fuel consumption); and 3) applying emission factors for each pollutant. Emission factors are typically defined in grams per unit of fuel consumed, and are published in Annex 3 of the *Inventory of U.S. GHG Emissions and Sinks*

(EPA 2012). Fleet characterization and activity data collection methods will vary with source category as described below.

SIT pulls emissions data from the Mobile Sources sector and the CO_2FFC modules. However, the user may select the Mobile Source module to calculate CO_2 emissions so that state-specific mobile sources data, rather than fuel consumption data, are used to calculate all transportation GHG emissions.

Highway Vehicles: Detailed characterizations exist for highway fleets in the form of vehicle registration databases maintained by state motor vehicle departments. Activity data are monitored by each state's Department of Transportation for reporting to FHWA. Future-year fleet characteristics and GHG emissions for highway vehicles can be projected using the VISION-NE model, which calculates fleet penetration rates, energy use, and emissions based on annual rates of fleet turnover and VMT growth.

Combustion emissions are calculated based on fuel consumption, which in turn is a function of the distributions of age, vehicle type, and emission control technology across the state's vehicle fleet. Hydrofluorocarbon (HFC) emissions from mobile air conditioning systems are less well understood, though the California Air Resources Board (CARB) and NESCAUM have each conducted preliminary research toward improving emission projections from cooling systems. At present, the best available data for HFC emissions are national estimates that can be apportioned to individual states according to fleet size.

Construction and Farm Equipment: Detailed fleet inventory data are not readily available for non-road land-based equipment, as these vehicles are not registered with any state authority. EPA's NONROAD model contains state-level estimates of fleet characterization data and can generate fuel consumption estimates by equipment type for construction, farm, and other types of nonroad land-based engines. NONROAD's default population data are based on years 1996-2000, and the model can extrapolate population estimates for any year between 1970 and 2050. Emissions of CO_2, CH_4 and N_2O can be calculated based on fuel consumption using emission factors from *Inventory of U.S. GHG Emissions and Sinks* (EPA 2012).

Locomotives: EPA developed emissions and fleet inventory data for marine and locomotive engines at the national level as part of its regulatory impact analysis (RIA) for the 2008 marine/locomotive emissions rule. The RIA includes annual projections for years 2002 through 2040. Emissions of CO_2, CH_4, and N_2O can be calculated using emissions factors from *Inventory of U.S. GHG Emissions and Sinks* (EPA 2012).

Marine Vessels and Aviation: Energy consumption for marine vessels and aviation fuels is tracked at the state level by FHWA and EIA, respectively. Emission factors for CO_2, CH_4, and N_2O are published in *Inventory of U.S. GHG Emissions and Sinks* (EPA 2012).

Recommendations for Rhode Island

NESCAUM recommends using EPA's Motor Vehicle Emissions Simulator (MOVES) model in conjunction with county-specific databases of vehicle fleets and annual miles traveled for highway vehicles. Rhode Island DEM staff recently worked with EPA to update the MOVES input databases to reflect year 2011.

Future-year projections of highway vehicle emissions can be generated using the VISION-NE fleet turnover model. This model will generate detailed fleet characterizations based on rates provided by the user for VMT growth and penetration or estimates of specific advanced vehicle technologies. NESCAUM can use this modeling tool to compare the effects of policy incentives for certain vehicle types.

For non-highway vehicles, SIT estimates future energy demand based primarily on sector-specific growth rates from the Annual Energy Outlook. NESCAUM can compare the effects of modified growth rates or improved emission factors in future scenario years to determine the overall impact of using sector-specific growth rates. NESCAUM also suggests using data from the *T.F. Green Airport 2010 Air Emissions and Greenhouse Gas Inventory*[16] in place of default data from SEDS. Since T.F. Green Airport accounts for approximately 99 percent of annual passenger activity in Rhode Island, it is a reasonable surrogate for annual aircraft activity in the state. The 2011 Green Airport GHG inventory will provide additional information about trends in airport activities for projection to the 2020 future year.

Industrial Sector

Industrial processes emit CO_2 and N_2O, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). NESCAUM's default run of SIT indicates that about 11 percent of Rhode Island's emissions may come from industrial processes.

The industrial sector emissions are calculated from the CO_2FFC, Stationary Sources, Natural Gas and Oil Systems, and Industrial Processes modules. The data requirements, sources, and methodologies employed in the SIT for the industrial sectors are described below and represent a basis for a regionally-consistent GHG inventory. This description is followed by recommended data improvements to further disaggregate the inventory and represent GHG emissions at the facility level.

> **CO_2 from Fossil Fuel Combustion:** CO_2 emissions from fossil fuel combustion are calculated from fuel consumption by fuel type and sector (on an energy basis), carbon content coefficients per fuel type, percentage of carbon oxidized during combustion, and, in the case of non-energy industrial fossil fuel usage, the amount of carbon stored in products. Default data are based on information obtained from the EIA, EPA, and IPCC.

[16] RI Airport Corporation. 2011. T.F. Green Airport 2010 Air Emissions and Greenhouse Gas Inventory.

CH_4 and N_2O from Stationary Combustion: CH_4 and N_2O emissions from fossil fuel and wood combustion are calculated from consumption data by fuel type and sector (including non-energy consumption by fuel type for the industrial sector), global warming potential of CH_4 and N_2O, and emission factors by fuel type and sector.

CH_4 and N_2O emission factors vary based on a number of factors, including fuel type and the size, vintage, maintenance, operation, and control of the combustion technology. Default data for CH_4 and N_2O emission factors were based on the IPCC guidelines for National Greenhouse Gas Inventories. EPA's eGRID 2007 now includes these emissions at the facility-level in its database.

Natural Gas and Oil Processes: The industrial sector includes estimates of emissions from natural gas transmission and distribution, with the majority coming from distribution activities. These emissions are due to leaks, fugitive emissions, meters, pressure regulator failure, and mishaps. Data on miles of pipeline for transmission and distribution of natural gas can be taken from the US Department of Transportation's Office of Pipeline Safety, and this is the primary data used to estimate emissions from these processes.

Industrial Processes: The US Geological Survey (USGS) mineral yearbooks are used to estimate minerals activities. Emissions from other industrial processes like semiconductor manufacturing, SF_6 usage in electrical transmission and distribution equipment, and HFC/PFC usage are estimated from ratios of state to national population/economic data in conjunction with national emissions levels.

Recommendations for Rhode Island

NESCAUM recommends supplementing default SIT data with state-specific data where possible. Information may be available from Title V reporting and permits submitted to Rhode Island DEM. Where data supplied to the state is not available, it may be possible to access additional sources to improve SIT defaults. Industrial facilities with boilers which are subject to the Clean Air Act's acid rain provisions and report CO_2 emissions at the facility level through EPA's Emissions Tracking System/Continuous Emissions Monitoring (ETS/CEM) requirements. In addition, EPA's eGRID database contains this same information as well as estimated emissions for some non-utility sources not subject to EPA's ETS/CEM reporting. eGRID also includes estimates of CH_4 and N_2O emissions at the facility level.

EPA's Online Tracking Information System (OTIS) and Air Facility System (AFS) may reveal additional sources of data on industrial emissions. NESCAUM recommends reviewing unit-level CO_2 emissions ETS/CEM data from EPA's Clean Air Markets Division (CAMD) database, which covers generators and boilers in the Acid Rain Program, to supplement the existing EIA data.

Residential and Commercial Sectors

NESCAUM's default run of SIT indicates that the residential sector emits about 18 percent and the commercial sector emits about 7 percent of Rhode Island's GHG emissions, respectively. The residential and commercial sectors emit CO_2 and N_2O from the combustion of fossil fuels for non-electric space heating and cooling and water heating and CH_4 emissions from the inefficient combustion of wood. SIT's default assumes that biomass has net-zero carbon emission and therefore does not capture point CO_2 emissions from the combustion of wood. The amount of energy dedicated to space heating and air conditioning is closely related to geographic location and physical characteristics of the unit, such as the thermal envelope and furnace efficiency.

Emissions data are pulled from the CO_2FFC and Stationary Source modules, but do not include emissions from electricity, which are included in the electric power generation sector. Electricity use for heating and cooling, lighting, and appliances in residences and businesses may be assigned to the residential and commercial sectors as indirect emissions, but are not included in the residential and commercial sector analysis in order to avoid double-counting. Indirect emissions are included as a separate line item in SIT inventories; this information is important when tracking progress on certain energy efficiency and weatherization initiatives.

State-specific data enhancements and disaggregation of the data could make the inventory more meaningful and robust in order to allow for the tracking of weatherization, energy efficiency, and renewable energy. The three main areas that require data input specific to the residential and commercial sectors are:

> **Energy Use Data:** SIT uses default energy consumption data from SEDS (EIA 2012). SEDS data come from surveys of suppliers and marketers of energy sources and end users of energy. End use surveys include the Residential Energy Consumption Survey and the Commercial Building Energy Consumption Survey. End use surveys provide states with the percentage of total energy consumed by each of the sectors.
>
> **Carbon Content in Fuels:** SIT uses values from the *Inventory of U.S. GHG Emissions and Sinks* (EPA 2012) as the default carbon contents for most fuels.
>
> **Combustion Efficiencies:** SIT assumes that the percent of carbon oxidized is 100 percent during combustion of petroleum, coal, and natural gas. This default assumption may be exchanged for higher level data.

Recommendations for Rhode Island

Potential enhancements and disaggregation of these data categories could be achieved by incorporating existing data from the Rhode Island Department of Environmental Management and the Public Utility Commission. Data from the US Census Bureau, including County

Business Patterns, and other consumer surveys should be compared to SEDS data to gauge consistency and potential for data improvements or disaggregation to the census tract or county level. Rhode Island could use the Census Bureau's American Community Survey (ACS) to identify residential areas within the state that have high concentrations of oil furnaces, as well as obtain community-scale breakdowns of other types of fuels used for residential space heating (e.g., electric). This type of information could be used to better target programs promoting cleaner fuels and energy efficiency measures for residential space heating.

Additional data might be available from residential and commercial realtor associations, insulation manufacturers and installers, trade associations (e.g., American Society of Heating, Refrigerating, and Air-Conditioning Engineers), electric utilities, and energy service companies (ESCOS).

Land Use, Land Use Change, and Forestry Sector

EPA has updated the LULUCF module in SIT with recent activity data, a new source category of N_2O emissions from settlement soils, and methods for estimating emission factors for urban trees, landfilled yard trimmings, and food scraps. Land use and forests in 2010 represented a net "sink" for GHG in Rhode Island. The categories of land use change and forestry that accounted for the most significant changes include forest carbon, soil organic carbon, and landfilled yard waste. Other categories of LULUCF included in the EPA SIT estimates—agricultural soil liming, non-CO_2 emissions from forest fires, and N_2O emissions from settlement soils—are estimated to have negligible impact on Rhode Island's LULUCF GHG inventory. The LULUCF categories covered by SIT that might affect Rhode Island's GHG inventory include:

Forest carbon flux: SIT estimates changes in forest carbon using data from the US Forest Service's *Carbon Calculation Tool* for years between 1990 and 2010. SIT also estimates forest carbon for years outside of the 1990-2010 range using state wood harvesting records from the Forest Service.

Urban trees: SIT estimates carbon storage in urban trees by multiplying the percent of urban area covered by trees by a carbon sequestration factor. Newly available data describing urban areas from the 2000 US Census were used to update historical estimates (1991 to 1999) and to extrapolate estimates for subsequent years (2001 to 2009).

Carbon Stored in Landfilled Yard Trimmings: SIT calculates the carbon flux for landfilled yard trimmings and food scraps, consisting of carbon stored in dry grass, branches, food scraps and other wastes, and calculated on a mass balance basis to account for the contribution of CH_4 emissions from decomposition of organic matter as well as carbon stored.

Recommendations for Rhode Island

NESCAUM recommends working with Rhode Island forestry and resource officials to determine availability of relevant state-level data and other enhancements to SIT assumptions, if resources allow. Under Task 2 of this project, NESCAUM can investigate the availability of additional state-level data from RI DEM or other state agencies that may be used to improve upon the estimates provided by the default data in the LULUCF module. For example, while the occurrence of large, catastrophic forest fires is highly unlikely in Rhode Island, records from the National Interagency Fire Center, which maintains state-level records from 2002 to present, indicate that an average of 100 to 200 acres of forest fires per year is typical in the state. It is unclear whether the available data will be of sufficient quality for inclusion, and significant future changes in this sector's emissions are unlikely, so these refinements may be of lower priority than others.

Municipal Solid Waste Sector

Municipal solid waste includes waste from residences and businesses in Rhode Island and waste imported from residences and businesses in other states. In this sector, we will also consider waste from non-hazardous industrial landfills. NESCAUM's default run of SIT indicates that about 3.1 percent of Rhode Island's emissions may come from landfilling and combustion of solid waste.

SIT estimates emissions of CH_4 from landfilling of MSW, and CO_2 and N_2O emissions from the combustion of MSW. SIT estimates default disposal data by downscaling national waste disposal data based on historical state population from state population data (Census 2012). SIT defaults assume the end destination for MSW using BioCycle's *State of Garbage in America: Annual Nationwide Survey* (BioCycle 2010), an assessment conducted by BioCycle in collaboration with Columbia University.

SIT inventories do not include emissions from landfilling or combusting biogenic waste, such as food waste and yard trimmings, so it is necessary to characterize the waste. Characterization of MSW is also important in determining the composition of the waste and the rate at which it decays. SIT relies on the national waste characterization in *Municipal Solid Waste in the United States: 2010 Facts and Figures* [17] to categorize MSW.

In order to estimate the annual emissions released by Rhode Island landfills, estimates are needed for the amount of biogas, which is a mix of methane and carbon dioxide, and the portion of biogas captured and flared, which converts methane in the biogas to carbon dioxide. SIT calculates the amount of biogas produced using assumptions of the rate of aerobic and anaerobic

[17] U.S. EPA. (2011). *Municipal Solid Waste in the United States: 2010 Facts and Figures*. Available at: http://www.epa.gov/epawaste/nonhaz/municipal/msw99.htm.

digestion in typical landfills and uses data from the EPA Landfill Methane and Outreach Program (LMOP) to estimate the amount of biogas flared.[18]

Recommendations for Rhode Island

NESCAUM recommends working with RI DEM Division of Waste to identify improved sources of the amount of waste disposed in Rhode Island's landfills and combusted at in-state waste-to-energy facilities. If such sources are not accessible, NESCAUM suggests working with RI DEM to compare the differences in data derived by downscaling national data and the data contained in the BioCycle survey and determine the appropriate source of data. NESCAUM will also coordinate with the Northeast Waste Management Officials' Association (NEWMOA) to incorporate available data, if any, and review publications such as the NEWMOA report on the interstate flow of MSW.[19]

In order to better characterize the waste, NESCAUM recommends reviewing waste characterizations performed in other nearby areas, such as Vermont, Pennsylvania, and New York City. The characterizations might be a better proxy for Rhode Island waste than the national characterization.

[18] U.S. EPA. (2012). *Landfill Gas-to-Energy Project Database 2011*. Landfill Methane and Outreach Program. Available at: http://www.epa.gov/lmop/index.html.
[19] Northeast Waste Management Officials' Association (NEWMOA). (2013). Municipal Solid Waste (MSW) Interstate Flow in 2010. Available at: http://www.newmoa.org/solidwaste/MSW2010DatatReportFinalJan2013.pdf.

Table 1. Summary of Selected State GHG Inventories

State	Status	Purpose	GHGs	Sectors	Timeframe	Methods used	Link
Connecticut	Inventory developed by NESCAUM in 2009	Inventory required by Global Warming Solutions Act; inventory/ forecast used to track GHG reduction goals	Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6)	Sector-level reporting: - electric generation - transportation - residential - commercial - industrial - industrial processes - agriculture - high global warming potential (GWP) Some estimates of forest carbon flux and carbon stocks	Base year: 1990 Inventory covers 1990-2007 BAU forecast for 2020	EPA SIT with state-specific data	http://www.ct.gov/deep/cwp/view.asp?a=4423&q=521742&deepNav_GID=2121#inventory
Maine	Inventory developed in 2006	Inventory required every two years beginning in 2006 by Maine's Act to Provide Leadership in Addressing the Threat of Climate Change	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	Sector-level reporting - electric generation and consumption - transportation - residential - commercial - industrial - industrial processes - agriculture - waste	Base year: 1990 Annual point source inventory; biannual SIT inventory Projections made with SIT but not reported/used at this time	EPA SIT with state-specific data, including point-source data from the Maine Air Inventory Reporting System; facilities choose which emission factors to use	

State	Status	Purpose	GHGs	Sectors	Timeframe	Methods used	Link
Massachusetts	Inventory developed by NESCAUM in 2004; updated annually by MassDEP to include mandatory reporting of GHGs beginning in 2010	Inventory required by Global Warming Solutions Act; inventory/ forecast used to track GHG reduction goals	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	Sector-level reporting - agriculture - electric generation and consumption - transportation - residential - commercial - industrial - industrial processes - agriculture - waste Some estimates of forest carbon flux	Base year: 1990 Inventory covers 1990-2009 2010 inventory update underway BAU forecast for 2020	EPA SIT with state-specific data and adjustment for imported electricity, including mandatory GHG emissions reporting from Title V facilities, facilities that emit greater than 5000 tpy CO_2e, retail sellers of electricity	http://www.mass.gov/eea/agencies/massdep/air/climate/greenhouse-gas-ghg-emissions-in-massachusetts.html
New Hampshire	Inventory updated through 2010 by NHDES, with forestry analysis performed in 2008 by Carbon Solutions NE England	Inventory used to track progress on the NH Climate Action Plan (CAP)	CO_2, CH_4, N_2O, HFCs, PFCs	Sector-level reporting - electric generation and consumption - transportation - residential - commercial - industrial - agriculture - waste - forestry	Base year: 1990 Inventory covers 1990-2010 Projections made in 2008 based on 1990-2005 data for years 2012, 2025, and 2050	EIA SEDS and EPA SIT with electric sector emissions from RGGI CO_2 Allowance Tracking System (RGGI COATS) Forestry wedge analysis done by UNH-based Carbon Solutions New England in 2008	

State	Status	Purpose	GHGs	Sectors	Timeframe	Methods used	Link
New Jersey	Inventory and forecast created by CCS; update annually	Inventory required by Global Warming Response Act; used to set and track long-term reduction targets	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	Sector-level reporting - transportation - electricity generation - residential - industrial - commercial - high GWPs - industrial non-fuel - waste management - land clearing - terrestrial carbon sequestration	Base year: 1990 Inventory covers 1990, 2005-2009 BAU forecast for 2020 developed in 2008	EPA SIT with state-specific data	http://www.nj.gov/dep/sage/ce-ggi.html
New York	Inventory and forecast developed by NYS DEC in 2008; currently being updated for 2011	Inventory for use in NYS Energy plan	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6	Sector-level reporting - electric generation and consumption - transportation - residential - commercial - industrial - industrial processes - agriculture - waste	Base year: 2005 Forecasts through 2030	EPA SIT with current data from EIA and NYSERDA's Patterns and Trends Now calculate on-road fuel consumption/ emissions using VMT (from NYS DOT) and fuel economy (from Federal Highway Administration) instead of from EIA fuel use data	

State	Status	Purpose	GHGs	Sectors	Timeframe	Methods used	Link
Vermont	Inventory and forecasts developed by consultant in 2007; inventory updated annually by ANR	Inventory used to track GHG reduction goals; forecast used for planning purposes	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6; original inventory estimated black carbon	Sector-level reporting - electric generation – transportation - residential - commercial - industrial - industrial processes - agriculture Some estimates of forest carbon flux and carbon stocks	Base year: 1990 Inventory covers 1990, 1995, 2000, 2005, 2008-2010; 2011 inventory underway forecast for 2030 included in 2007 report	EPA SIT with state-specific data	http://www.anr.state.vt.us/anr/climatechange/Vermont_Emissions.html
California	Inventory and forecast developed by CARB; inventory updated with annual mandatory reporting data	Mandatory reporting data foundation of CA cap and trade regulation	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, nitrogen triflouride	Sector-level reporting - transportation - electric power - commercial and residential - industrial - recycling and waste - high GWP - agriculture - forestry	Base year: 1990 Inventory covers 2000-2010; 2011 inventory underway BAU forecast for 2020	CARB developed top-down inventory tool; updates inventory with facility-based mandatory reporting data	http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_scopingplan_00-10_2013-02-19.pdf

Table 2. Summary of Data Inputs to State Inventory Tool (SIT)

Input Category	Source Data Component	SIT Default	Data Upgrade	Links
Fuel Combustion *GHG emissions from fuel combustion at stationary sources and CO_2 emissions from mobile source fuel combustion* SIT modules: - CO_2 from Fossil Fuel Combustion - Stationary Combustion	Fossil fuel energy consumption by fuel type and sector	State Energy Data 2010 Consumption (SEDS; EIA 2012)	- Utility Commission/ utility data - EPA MRR - NEEP's EMV REED database - EPA fuel information for major/minor sources - EPA OTIS - AFS Compliance Tracking Systems - RI Airport Corporation 2011, 2012	- http://www.ripuc.org/ - http://www.epa.gov/ghgreporting - http://www.neep.org/emv/about-the-emv-forum/reed/index - http://www.epa.gov/compliance/data/systems/multimedia/aboutotis.html
	Wood consumption by sector	2010 SEDS (EIA 2012)		
	Fossil fuel non-energy consumption (industrial sector)	2010 SEDS (EIA 2012)	- EPA fuel information for major/minor sources - EPA OTIS - AFS Compliance Tracking Systems	
	Carbon content coefficients	EPA's Inventory of GHG Emissions (EPA 2012)	- EPA MRR - State Title V documentation	http://www.epa.gov/ghgreporting/
	Carbon stored in products	National default values for storage factors from US inventory		
	Percentage of carbon oxidized during combustion	Assumed to be 100 percent for petroleum, coal, natural gas, and LPG based on guidance from IPCC (2006)	- EPA MRR - State Title V documentation	http://www.epa.gov/ghgreporting/
	Non-energy consumption by fuel type for the industrial sector	2010 SEDS (EIA 2012)		
	Emission factors by fuel type and sector	2006 Guidelines for National GHG Inventories (IPCC 2006)		
Mobile Combustion	Emission factors for each vehicle control technology	EPA's Inventory of GHG Emissions (EPA 2012)		
	Annual state total VMT for highway vehicles	2010 Highway Statistics (FHWA 2012)	RI DOT RI/EPA 2011 MOVES	

Input Category	Source Data Component	SIT Default	Data Upgrade	Links
Mobile Combustion (continued) *GHG emissions from mobile combustion* SIT module: Mobile Combustion	Annual VMT for each vehicle model year	EPA's Inventory of GHG Emissions (EPA 2012)	RI DOT RI/EPA 2011 MOVES	
	Age distribution of vehicles	EPA's Inventory of GHG Emissions (EPA 2012)	RI DOT RI/EPA 2011 MOVES	
	Percent vehicles with controls, by control type	EPA's Inventory of GHG Emissions (EPA 2012)		
	Energy contents for aviation fuels	2010 Annual Energy Review (EIA 2011)		
	Density factors for marine, locomotive, and other non-highway fuels	- 2010 Annual Energy Review (EIA 2011) - US GHG Emissions and Sinks (EPA 2012)		
	Emission factors for aviation, marine, locomotive, and other non-highway fuels, and alternative fuel for vehicles	- EPA's Inventory of GHG Emissions (EPA 2012) - Revised 1996 Guidelines for National GHG Inventories (IPCC/UNEP/OECD/IEA 1997)	RI DOT Intermodal Transport Division	http://www.dot.ri.gov/intermodal/index.asp
	Aviation, marine, locomotive, alternative vehicle fuels, and other non-highway fuel consumption	- 2010 SEDS (EIA 2012) - 2010 Highway Statistics (FHWA 2012) - 2010 Fuel Oil and Kerosene Sales (EIA 2011)	RI Airport Corporation 2011, 2012	
	Annual state total VMT for alternative fuel vehicles	EPA's Inventory of GHG Emissions (EPA 2012)		
Industrial Processes	Industry-specific emission factors			
	Industry-specific production data	- Various in-state sources - US Geological Survey	Title V and other RI air quality permit applications	

Input Category	Source Data Component	SIT Default	Data Upgrade	Links
Industrial Processes (continued) *GHG emissions from various industrial processes* SIT module: IP	Industry-specific consumption data	(USGS) reports - US Census current industrial reports - Directory of Chemical Producers (SRI 2000) - Chemical Manufacturers Association - Alliance for Responsible CFC Policy - Grant Thorton Consulting - EPA's Inventory of GHG Emissions (EPA 2012) - 2010 Electric Power Annual Report (EIA 2011) - 2010 Commercial Fertilizers (AAPFCO 2012) - EPA GHG Reporting Program, 2010 Download Data (EPA 2013)		
	Industry-specific pollutant control efficiency	Various sources		
Natural Gas distribution *GHG emissions from leakage and flaring of natural gas* SIT module: Natural gas and oil systems	Miles of distribution iron, unprotected and protected steel, and plastic natural gas pipeline	No default data	US Department of Transportation Office of Pipeline Safety (OPS)	http://ops.dot.gov/stats.htm
	Number of unprotected and protected steel and total natural gas services	No default data	US DOT OPS	http://ops.dot.gov/stats.htm
	Emission factors for natural gas pipeline and services	Methane emissions from the natural gas industry (Gas Research Institute (GRI) and EPA 1996)		
Agricultural processes **Agricultural**	Enteric fermentation emission factors	EPA's Inventory of GHG Emissions (EPA 2012)	- State agriculture department - State fertilizer control official	
	Animal population numbers			
	Typical animal mass			

Input Category	Source Data Component	SIT Default	Data Upgrade	Links
processes (continued) *GHG emissions from agricultural processes, including fertilizer* SIT module: Agriculture	Volatile solids in manure production rate	EPA's Inventory of GHG Emissions (EPA 2012)	- State agriculture department - State fertilizer control official	
	Maximum potential manure methane emissions			
	Kjeldahl Nitrogen Excreted			
	Crop residue dry matter fraction			
	Fraction crop residue applied			
	Nitrogen content of crop residue			
	Crop production			
	Fertilizer utilization			
	Seasonal methane emission factor for rice production			
	Area of rice harvested			
	Ratio of crop residue to total crop			
	Fraction of crop residue burned			
	Crop burning efficiency			
	Crop combustion efficiency			
	Crop carbon content			
Municipal Solid Waste (MSW) *Landfilling and combustion of MSW* SIT module: Solid Waste	Amount of MSW landfilled in state	National waste disposal data (EPA 2011)	- State specific disposal information (1960-present) - State specific disposal information (1990-present) and national per capita landfilling rates	http://www.dem.ri.gov/programs/benviron/waste/
	Annual state population	State's population (US Census 2012)		
	Flared methane	EPA's Inventory of GHG Emissions (EPA 2011)		
	Fraction of MSW landfill methane emissions from industrial sources	2010 Municipal Solid Waste in the US (EPA 2011)	EPA Landfill Methane Outreach Program landfill characteristics	http://www.epa.gov/lmop/

Input Category	Source Data Component	SIT Default	Data Upgrade	Links
MSW (continued)	Landfill oxidation factor	Annual Nationwide Survey of Garbage in America (BioCycle 2010)		
	Fraction of plastics, synthetic rubbers, and synthetic fibers in MSW stream, by type Fraction of plastics, synthetic rubbers, and synthetic fibers in MSW stream, by type (continued)	2010 Municipal Solid Waste in the US (EPA 2011)	- BioCycle, State of Garbage in America - Northeast state waste characterization studies, e.g., PA, VT, NYC	- http://www.biocycle.net/images/art/1010/bc101016_s.pdf - https://www.dep.state.pa.us/dep/deputate/airwaste/wm/recycle/Waste_Comp/Study.htm - http://www.nyc.gov/html/nycwasteless/html/resources/wcs.shtml - http://www.anr.state.vt.us/dec/wastediv/solid/pubs/VT%20WASTE%20COMP.pdf
	Total MSW combustion	2010 Municipal Solid Waste in the US (EPA 2011)	BioCycle, State of Garbage in America	- http://www.biocycle.net/images/art/1010/bc101016_s.pdf
Wastewater *Treatment of municipal and industrial wastewater* SIT module: Wastewater	Per capita 5-day biological oxygen demand (BOD_5)	EPA's Inventory of GHG Emissions (EPA 2012)		
	Fraction of wastewater BOD_5 anaerobically digested	EPA's Inventory of GHG Emissions (EPA 2012)		
	Digestion emission factor for BOD_5	EPA's Inventory of GHG Emissions (EPA 2012)		
	State population	State's population (US Census 2012)	RI Office of Water Resources –real data on wastewater processing volumes	- http://www.dem.ri.gov/programs/benviron/water/licenses/wwoper/
	Emission(?) factor for non-consumption nitrogen	EPA's Inventory of GHG Emissions (EPA 2012)		
	Fraction of population on with sewer service	EPA's Inventory of GHG Emissions (EPA 2012)	RI Office of Water Resources	http://www.dem.ri.gov/programs/benviron/water/licenses/wwoper/
	Direct wastewater treatment plant N_2O emissions	EPA's Inventory of GHG Emissions (EPA 2012)		
	Biosolids N_2O emission factor	EPA's Inventory of GHG Emissions (EPA 2012)		
	Fraction of N in biosolids protein	EPA's Inventory of GHG Emissions (EPA 2012)		
Wastewater	Protein content in biosolids	EPA's Inventory of GHG Emissions (EPA 2012)		

Input Category	Source Data Component	SIT Default	Data Upgrade	Links
(continued)	Fraction biosolids used as fertilizer	EPA's Inventory of GHG Emissions (EPA 2012)		
	Industrial wastewater outflow, by industry	EPA's Inventory of GHG Emissions (EPA 2012)		
	Industrial wastewater organic content (COD), by industry	EPA's Inventory of GHG Emissions (EPA 2012)		
	Fraction COD anaerobically degraded in industrial wastewater, by industry	EPA's Inventory of GHG Emissions (EPA 2012)		
	Industrial food and pulp/paper product processed, by industry	N/A for Rhode Island		
	Industrial wastewater emission factor, by industry	EPA's Inventory of GHG Emissions (EPA 2012)		
Land Use, Land Use Change, and Forestry *Land use related emissions of GHGs* SIT module: Land Use, Land Use Change, and Forestry (LULUCF) **Land Use, Land Use Change, and**	Carbon emitted from or sequestered in aboveground biomass, belowground biomass, dead wood, litter, soil organic carbon, wood products and landfills	MSW in the US (EPA 2011)		
	Emission factors for agricultural liming and urea fertilization	IPCC 2006		
	Total limestone and urea applied	USGS 2011		
	Sequestration factor for urban trees	Nowak and Crane 2002		
	Urban area	Nowak et al. 2005		
	Percent urban tree cover	Dwyer et al. 2000		
	Direct N_2O emission factor for managed (non-agricultural) soils	IPCC 2006		
	Total synthetic fertilizer applied to settlements	- TVA 1991-1994 - AAPFCO 2011		

Input Category	Source Data Component	SIT Default	Data Upgrade	Links
Forestry (continued)	Emission factors for CH_4 and N_2O emitted from burning forest and savanna	IPCC 2006		
	Combustion efficiency of different vegetation types	IPCC 2006	US Federal Wildland Fire Management	- http://www.fs.fed.us/fire/ - http://fire.org
	Average biomass density	- Smith et al. 2001 - EPA 2012	- Situation and Incident Status Summaries (National Interagency Coordination Center [NICC]) - US Forest Service - Bureau of Land Management (BLM) - RI Natural Resources Division	http://www.nifc.gov/
	Area burned	No default data		
Indirect emissions from electricity consumption *Indirect GHG emissions from electricity consumption* SIT module: Electricity Consumption	Electricity consumption by sector	2010 SEDS (EIA 2012)		
	Percent electricity consumption by end-use equipment	- Residential Energy Consumption Survey (EIA 2008a) - Commercial Building Energy Consumption Survey (EIA 2008b) - National Transit Database (FTA 2007) - Manufacturing Energy Consumption Survey (EIA 2009)	- RI EE and Resource Management Council - Utility/ ESCO data - EPA fuel information for major/minor sources - EPA OTIS - AFS Compliance Tracking Systems Energy Efficiency -Synapse documentation on accounting for EE - REED EMV Forum - LBNL: Utility EE programs	- http://www.rieermc.ri.gov/ - http://www.epa.gov/compliance/data/systems/multimedia/aboutotis.html - http://www.synapse-energy.com/Downloads/SynapseReport.2012-07.NHPC.EE-Program-Screening.12-040.pdf - http://neep.org/emv-forum/ - http://emp.lbl.gov/sites/all/files/lbnl-5803e.pdf
	Electricity emission factors	- Year 2005 and 2007 Emissions & Generation - Resource Integrated Database (eGRID) subregion values	- Utilities - ISO-NE emission reports	http://www.iso-ne.com/genrtion_resrcs/reports/emission/
	Transmission loss factors			

Task 1 continued -

Recommendations for Use of Alternative Data in the Rhode Island Greenhouse Gas (GHG) Inventories

The following serves two purposes. First, it describes and presents summary results and recommendations from data collected from facility emissions records provided by RI DEM. Second, it describes suggested replacement data and alternative methodologies for defaults to the Environmental Protection Agency's (EPA's) State Inventory Tool (SIT),[1] which will be used to develop Rhode Island's greenhouse gas (GHG) inventories for selected years. These two topics are presented in separate sections below. This document is an extension of information presented in Table 2 of the earlier June 7, 2013 memorandum submitted for Task 1 of this project. This memorandum also follows up on a number of issues discussed with RI DEM in response to earlier drafts of this memorandum.

1. Facility emission records

Facilities report emissions and fuel use to RI DEM on an annual basis. In July 2013, NESCAUM personnel visited RI DEM headquarters in Providence, Rhode Island to review hard-copy records submitted by facilities for the year 1990, or up to 1995 where 1990 records did not exist. NESCAUM extracted the following types of information from the records: state facility number, Standard Industrial Classification (SIC code), boiler number, boiler size, fuel type, fuel quantity, fuel units, and record year.

NESCAUM and RI DEM compiled paper records maintained by RI DEM into spreadsheets. Unreasonable data and duplicate entries were removed. All entries with nonsensical fuel units or facility numbers were also removed. Some facilities did not report in 1990 but did report in a subsequent year over the 1991 to 1995 period; in those cases, the subsequent year closest to 1990 was selected, per direction from RI DEM. In some cases, when facilities reported having different types of fuel used or different boiler numbers over multiple years, the additional boilers were included even if they were from later years. Table 1 presents a summary of record years from which data entries were selected for this analysis. These data reflect the post-quality controlled results. Hereafter, we refer to these data collectively as 1990-era data. NESCAUM reviewed 1990 and 1993 facility-reported emissions data sent by RI DEM and determined that for facilities reporting in both years, values were largely consistent. This evaluation provided a measure of confidence in the accuracy of RI DEM data.

Table 1. Summary of facility data record submissions year selected in the analysis

[1] To access documentation supporting the State Inventory Tool, visit: http://www.epa.gov/statelocalclimate/resources/tool.html.

Year	Records
1990	143 (13%)
1991	48 (4%)
1992	714 (63%)
1993	141 (12%)
1994	86 (8%)
1995	2 (<1%)
Total	1,134 (100%)

NESCAUM calculated results by SIC code for 1990-era data and compared these to default data for stationary source fuel combustion based on Energy Information Administration (EIA) estimates.[2] A summary of post-processed results of the 1990-era data is presented in Table 2.

To compare these results with estimates derived from EIA data (i.e., the SIT defaults), NESCAUM made a number of assumptions:

- Sources using approximately 683 billion British thermal units (Btu) in fuel (approximately half natural gas and half residual fuel oil) did not have SIC codes. Table 2 lists these as "Unknown," and we assumed these to be sources in the industrial sector for comparing to EIA data, which had higher industrial emission estimates than in the RI records.
- We excluded fuel usage in the natural gas, residential, and sewage sectors from comparison to avoid double-counting. (These sectors are included in SIT elsewhere.)
- Though most facilities reported quantities of individual fuels used when multiple fuels were used in the same boiler, several reported using "mixtures" of fuel oil and natural gas without indicating the ratio of fuels. For these cases, we assumed that fuel use reported in cubic feet was natural gas and fuel use reported in gallons was fuel oil. One facility accounting for a very small fraction of total fuel mixtures use reported in units of MMBtu; we assume that this was fuel oil.
- Because SIT does not have an entry for No. 4 fuel oil, we assigned this fuel use partially (40 percent) to distillate fuel use and partially (60 percent) to residual fuel use by volume, per RI DEM.
- We used fuel energy content values from EPA AP-42.

Table 2. Summary of post-processed results of 1990-era fuel consumption reporting from stationary sources in Rhode Island

Sector/Fuel Type	**Fuel Use (Million Btu)**	**Relative Contribution**
Commercial	**5,639,908**	**30%**
Distillate Fuel	147,421	
Mixture - Residual Fuel/Natural	308,392	

[2] See SIT documentation.

Sector/Fuel Type	**Fuel Use (Million Btu)**	**Relative Contribution**
Gas		
Residual Fuel	*192,062*	
Natural Gas	*116,330*	
Natural Gas	1,437,823	
No. 4 Fuel	1,002,131	
Distillate Fuel	*384,379*	
Residual Fuel	*617,752*	
Propane	3,583	
Residual Fuel	2,740,558	
Electric Power	**3,893,951**	**21%**
Distillate Fuel	88,356	
Mixture - Distillate Fuel/Natural Gas	82	
Distillate Fuel	*82*	
Natural Gas	30,511	
Residual Fuel	3,775,002	
Industrial	**8,186,909**	**44%**
Distillate Fuel	768,051	
Kerosene	385	
Liquid Propane Gas	11,774	
Mixture - Distillate Fuel/Natural Gas	98	
Distillate Fuel	*98*	
Mixture - Residual Fuel/Natural Gas	460,599	
Natural Gas	*460,599*	
Natural Gas	4,094,359	
No. 4 Fuel	396,649	
Distillate Fuel	*152,139*	
Residual Fuel	*244,510*	
Propane	1,104	
Residual Fuel	2,453,439	
Waste Oil	450	
Natural Gas	**93,464**	**1%**
Natural Gas	93,464	
Residential	**16,200**	**<1%**
Residual Fuel	16,200	
Sewage	**7,214**	**<1%**
Distillate Fuel	5,334	
Natural Gas	1,880	
Unknown	**683,108**	**4%**
Distillate Fuel	17,061	
Mixture - Residual Fuel/Natural Gas	13,884	
Natural Gas	*13,884*	

Sector/Fuel Type	**Fuel Use (Million Btu)**	**Relative Contribution**
Natural Gas	309,379	
No. 4 Fuel	40,699	
Distillate Fuel	*15,611*	
Residual Fuel	*25,088*	
Propane	2,144	
Residual Fuel	300,221	

RI DEM supplied NESCAUM with fuel use data for small stationary sources for 2011 and for major sources (i.e., sources with Title V permits) for 2010. As a reasonableness check for the 2010 RI DEM major source records, NESCAUM compared carbon dioxide equivalent (CO_2e) emission estimates derived from the RI DEM records against data from the EPA greenhouse gas mandatory reporting rule (MRR)[3] for those specific facilities (Table 3). Most of the facilities' 2010 CO_2e emissions as reported to the MRR are within a few percent of results derived from fuel use reported to RI DEM. All major source facilities reported nearly identical (within 7 percent) emissions to EPA and RI DEM. These results indicate that values reported to RI DEM are largely in line with values reported to EPA. NESCAUM assumed that 2011 data for small sources adequately represented fuel use in 2010 based on conversations with RI DEM. We used EPA AP-42 energy content values to convert fuel use to energy use. No additional assumptions were necessary.

Table 3. Comparison of EPA and RI DEM carbon dioxide equivalent (CO_2e) emissions data for 2010 at major sources in Rhode Island

	CO_2e (MT/yr)		**Relative**
Facility	**EPA MRR**	**RI DEM**	**Difference**[c]
Brown University Main Campus	31,070	30,120	-3%
Burrillville	30,853	30,447	-1%
FPLE Rhode Island State Energy LP	1,178,660	1,160,630	-2%
Manchester Street	873,409	812,672	-7%
Ocean State Power (I & II)[a]	668,753	699,109	+5%
Pawtucket Power Associates LP	25,457	24,820	-3%
RI Hospital	49,518	49,968	+1%
Rhode Island Resource Recovery Corp.[b]	-	-	-
Toray Plastics America Inc.	55,864	55,855	0%
Tiverton Power	437,909	435,622	-1%
US Navy Newport Naval Station	26,775	26,908	0%

Notes:

a. Values for emissions from Ocean State Power units I and II are combined.

[3] EPA Greenhouse Gas Reporting Program, GHG Data Publication Tool, Facility Level Information on GreenHouse gases Tool (FLIGHT). Available at http://www.epa.gov/ghgreporting/.

b. Rhode Island Resource Recovery Corp. (the firm operating the Central Landfill) was excluded from this comparison because landfill emissions are covered under a different module in SIT.
c. Values rounded to the nearest whole percent.

Table 4. Comparison of facility fuel use records and EIA estimates for 1990 and 2010 energy use in Rhode Island, for commercial, electric power, and industrial sectors, by fuel type (billion Btu)

	1990		**2010**	
Sector/Fuel Type	**EIA**	**RI DEM**	**EIA**	**RI DEM**
Commercial Coal	101		-	
Commercial Distillate Fuel	4,657	147	4,148	262
Commercial Kerosene	9		3	
Commercial Liquid Petroleum Gas (LPG)	416	4	322	1
Commercial Motor Gasoline	203		48	
Commercial Natural Gas	8,288	1,438	10,698	4,329
Commercial Residual Fuel	3,754	**4,044**	479	**396**
Commercial Wood	331		99	
Electric Power Distillate Fuel	108	88	132	**124**
Electric Power Natural Gas	9,339	31	57,871	**59,487**
Electric Power Residual Fuel	2,136	**3,775**	-	
Industrial Asphalt and Road Oil	10,843		7,247	
Industrial Coal	3		-	
Industrial Distillate Fuel	1,624	785	891	192
Industrial Kerosene	82	0	-	
Industrial LPG	557	15	259	79
Industrial Lubricants	384		308	
Industrial Motor Gasoline	182		857	
Industrial Natural Gas	4,498	**4,404**	8,218	2,627
Industrial Residual Fuel	2,846	**3,662**	659	**600**
Industrial Special Naphthas	306		53	
Industrial Waxes	-		49	
Industrial Wood	-		56	
Industrial Other Coal	3		-	

A comparison of the RI DEM summary data and EIA 1990-era and 2010 data is presented in Table 4. Results show that natural gas use in the commercial sector was largely missing from the RI DEM records in 1990 and 2010, and from the electric power sector in 1990. RI DEM and EIA data show reasonable agreement for the 1990-era data for residual oil in the commercial, electric generating, and industrial sectors; and for natural gas in the industrial sector. For the 2010 data comparison, RI DEM and EIA data are in reasonable agreement for residual fuel in the commercial and industrial sectors, and for natural gas and distillate fuel in the electric generating sector. After consultation with RI DEM, we selected RI DEM data for these entries as being more accurate because they represent data already reviewed by the agency. Entries in Table 4 for which RI DEM data were selected for replacement over EIA defaults are presented in bold. For all other entries, we assumed that RI DEM records were incomplete and relied on default EIA data.

Differences between the EIA data and RI DEM data suggest that certain sectors and fuel types are well captured through state reporting requirements, while other sector fuel use, particularly non-electric generating sector natural gas, is not being reported to the state.

2. Proposed data substitutions

NESCAUM has identified and evaluated state-specific data sources for use in place of default inputs for development of the Rhode Island GHG inventories. This section compares the default and proposed substitute data, and provides a rationale for selecting the substitution data for use in the Rhode Island GHG inventories. Each proposed data substitution or alternative methodology is presented in the subsections below, organized by input category. Default data inputs for which no substitution or alternative methodology is offered are not addressed.

Fuel combustion
GHG emissions from fuel combustion at stationary sources and CO2 emissions from mobile source fuel combustion

- Fossil fuel energy consumption by fuel type and sector, non-energy consumption

  NESCAUM recommends replacement of default EIA estimates of fuel consumption for some stationary sectors, per section 1 of this memorandum, with facility-reported fuel use for the 1990 and 2010 inventory years.

  For 2020 emissions estimates, NESCAUM will rely on the analysis prepared recently by Environment Northeast (ENE)[4] over other available data sources. We prefer the ENE analysis because it incorporates state policies, regional cooperative agreements, and is otherwise consistent with the EIA projections on which the default SIT analysis is based. Other possible sources include EIA projections (the default SIT option); a March 2013 analysis by ICF International using the IPM model for the final Regional Greenhouse Gas Initiative (RGGI) corresponding to a region-wide cap of power sector CO_2e emissions of 91 million tons; and an analysis performed by Navigant in support of the Rhode Island State Energy Plan,[5] hereafter "the Navigant report."

[4] ENE. 2013. Rhode Island State Energy Plan Business-as-Usual Forecast. Varun Kumar & Jamie Howland. Submitted to the Rhode Island Office of Energy Resources. October 2013. Available at http://www.energy.ri.gov/energyplan/index.php.
[5] Navigant. 2013. Rhode Island State Energy Plan Scenario Modeling, Executive Summary & Results. September 24, 2013. Burlington, Massachusetts. Available at http://www.energy.ri.gov/documents/energyplan/Navigant_RISEP_Scenario_Modeling_Executive_Summary_Results.pdf. Note that the authors of this report emphasize that it should not be relied upon as an accurate data source.

- **EIA projections.** We prefer ENE analysis over default EIA projections because it is consistent with the EIA projections and offers additional refinements based on state and regional policies that are otherwise absent from the EIA projections. Specifically, ENE's business-as-usual (BAU) forecast was based on the EIA's Annual Energy Outlook 2013 Early Release (AEO 2013ER) reference case and was adjusted to include impacts of increases in energy efficiency resulting from the Rhode Island Comprehensive Energy Conservation, Efficiency and Affordability Act, and impacts from changes to the RGGI cap.

- **ICF analysis.** The ICF International analysis was performed on behalf of RGGI and relied on the Integrated Planning Model (IPM). Though IPM is an industry standard for analysis of power markets, and EIA does examine ICF projections produced using the IPM model for their Annual Energy Outlook (AEO), the analysis is not wholly consistent with EIA methodology. We prefer the ENE analysis over the ICF analysis because it is consistent with EIA projections adjusted to account for the RGGI results and state measures, as described above.

- **Navigant report.** The Navigant report describes modeling of three long-term policy scenarios (evaluating policies to promote energy security, economics, and sustainability) compared against a business as usual (BAU) scenario. The Navigant report indicates that overall energy generation in Rhode Island will decrease slightly from 2013 to 2020, especially between 2015 and 2018, in the BAU scenario. According to the Navigant report, energy generation in Rhode Island in 2020 will not be significantly different in the BAU scenario compared to the other policy scenarios. This comparison suggests that the energy generation profile in 2020 for the state is unlikely to be significantly affected by even aggressive implementation of policies to address state priorities. Navigant warns against relying on its report and indicates that it was prepared "solely for the purposes set forth in the report and may not be used for any other purpose." As such, we prefer the ENE analysis as its results are more broadly applicable.

Transportation sector onroad motor vehicle fuel consumption will be based on estimates from EPA's MOVES model.[6] NESCAUM created input databases for the inventory years (i.e., 1990, 2010, and 2020) based on databases prepared by RI DEM and EPA for the 2011 National Emissions Inventory (NEI),[7] and ran default simulations for 2011 and the inventory years to determine baseline fleet and vehicle activity (measured in vehicle-miles-traveled [VMT]) growth factors. We applied these factors to the 2011 databases to estimate fleet population and VMT demand for the inventory years. For remaining

[6] EPA Motor Vehicle Emission Simulator (MOVES), version 2010b. Available at http://www.epa.gov/otaq/models/moves/index.htm.

[7] RI DEM, "Rhode Island MOVES CDM Preparation for 2011 NEI", January 4, 2013. Prepared by Karen Slattery (RI DEM) and Ron Marcaccio (RI DEM), with assistance from Alexis Zubrow (EPA). EPA estimated real world fleet economy based on projections of manufacturers compliance strategies using numerous compliance options and flexibility mechanisms in the CAFE rule. These projections were published in the Notice of Proposed Rulemaking rather than in the CAFE rule itself. Since 2011, EPA has updated these projections and the newer values are largely similar (but not identical) to the values used in this analysis.

database requirements, e.g., default fuel formulation and age distribution characteristics, we used MOVES default information for 1990 and 2020 model years.

We post-processed MOVES outputs for 2020 to reflect the 2017-2025 Corporate Average Fuel Economy (CAFE) standards. We post-processed the results by disaggregating the energy demand results by model year, and adjusting the 2017-2020 model year energy demand for light-duty vehicles based on the fuel economy factors included in Table I-2 of EPA's Notice of Proposed Rulemaking (NPRM) for the CAFE standards.[8] Changes in the EPA methodology for fuel economy factors between the NPRM and final rule were minor, and we believe that changes will not significantly affect the results. We adjusted energy demand for all fuels based on the ratio of low heating value (LHV) to high heating value (HHV) to account for the differing treatment of heating value in the MOVES outputs (LHV) vs. SIT inputs (HHV). Table 5 presents the default (EIA) and suggested replacement (MOVES) data for the transportation sector fuel combustion.

MOVES results for natural gas used in transportation are based on national average estimates, whereas EIA has state-specific estimates that include losses from compressor stations. NESCAUM prefers the EIA data over MOVES outputs because EIA has more state level detail and includes both highway and non-highway transportation fuel consumption, while MOVES only accounts for highway transportation fuel consumption.

For gasoline and ethanol, NESCAUM recommends using MOVES outputs. For diesel, we prefer the EIA estimates over the MOVES estimates because diesel fuel is consumed in both highway and non-highway transportation.

NESCAUM recommendations are indicated with bold font in Table 5.

Table 5. Comparison of EIA and MOVES estimates for transportation energy use in Rhode Island, by fuel type (billion Btu)

	1990		**2010**		**2020**	
Sector/Fuel Type	**EIA**	**MOVES**	**EIA**	**MOVES**	**EIA**	**MOVES**
Transportation Distillate Fuel	**6,723**	3,759	**9,591**	5,731	**10,244**	7,297
Transportation Ethanol	0	0	4,523	**3,300**	-	3,170
Transportation Motor Gasoline	45,658	**40,397**	43,608	**43,747**	46,647	**42,022**
Transportation Natural Gas	**129**	0	**1,602**	2	**1,456**	2

Note: Values for 2020 EIA are based on projections derived by NESCAUM from historic EIA values.

Ø Aviation fuel consumption

[8] 75 FR 229. Environmental Protection Agency and Department of Transportation, National Highway Transportation Safety Administration. Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Proposed Rule. November 30, 2010. Available at: http://www.nhtsa.gov/fuel-economy. The final rule contained a range of fuel economy factors, and the central value of the range is, in most cases, approximately equal to the value given in the NPRM.

NESCAUM recommends relying on information for aviation fuel use provided in the Rhode Island Airport Corporation (RIAC) annual environmental report[9] for 2010 aviation fuel use. T.F. Green Airport has experienced steady declines in passengers since 2005. Overall, 3,650,737 passengers flew from T.F. Green Airport in 2012, 36 percent lower than the 2005 ridership of 5,730,557 passengers.[10] Annual operations at the airport were 81,572 in 2010, well below the capacity level of 221,000 operations per year. A record of decision[11] allowing for expansion of the T.F. Green Airport indicates project completion to allow flights from the West Coast to depart and land by 2020. The document discusses efficiency improvements that will occur, but these improvements will almost certainly be accompanied by increases in aviation and jet fuel consumption. The northeast region overall will be increasing operations by 19 percent through 2030 over 2009 levels.[12] Interpolated through 2020, NESCAUM estimates a 9 percent increase in airport activity and associated aviation emissions between 2010 and 2020. We recommend scaling 2010 aviation and jet fuel by this percentage for the 2020 estimate.

Mobile combustion

GHG emissions from mobile combustion

- Vehicle activity (annual state total VMT for highway vehicles, annual VMT for each vehicle model year, age distribution of vehicles)

  NESCAUM recommends replacement of default data (Federal Highway Administration [FHWA][13] and EPA's Inventory of GHG Emissions[14]) for vehicle VMT with estimates consistent with the assumptions from the MOVES analysis for the sake of consistency.

- Emission factors for non-highway fuel consumption

  NESCAUM reviewed the Rhode Island "Transportation 2035" plan document[15] to identify information relevant to projecting emissions or transportation activity levels for 2020. Unfortunately, no firm activity level assumptions were readily available from this report. NESCAUM performed a run of EPA's NONROAD model for comparison against EIA defaults and found that results were not comparable. Therefore, we recommend using default non-aviation, non-highway fuel consumption values.

Natural gas distribution

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[9] RIAC. T.F. Green Airport 2010 Air Emissions and Greenhouse Gas Inventory. March 25, 2011.

[10] RIAC. Ridership data. Available at: http://www.pvdairport.com/corporate/ri-airport-corporation/passenger-numbers

[11] US Department of Transportation. Record of Decision. Airport Improvement Program. T.F. Green Airport, Warwick, Rhode Island. September 23, 2011. Available at: http://www.faa.gov/airports/environmental/records_decision/media/rod_pvd_20110923_text.pdf

[12] Federal Aviation Administration. Terminal Area Forecast Summary. Fiscal Years 2009-2030.

[13] FHWA. 2012. Highway Statistics 2010. Available at: http://www.fhwa.dot.gov/policyinformation/statistics/2010/.

[14] EPA. 2012. Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2010. Available at: http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html.

[15] Rhode Island Statewide Planning Program. Transportation 2035. Long Range Transportation Plan. State Guide Plan Element 611. Report #116. December 13, 2012. Available at: http://www.planning.ri.gov/documents/trans/LRTP%202035%20-%20Final.pdf

GHG emissions from leakage and flaring of natural gas

- Miles of distribution iron, unprotected steel and total natural gas services; number of unprotected and protected steel and total natural gas services

  NESCAUM recommends using data from US Department of Transportation (DOT) Pipeline & Hazardous Materials Safety Administration (PHMSA) reports for distribution and service level data.[16] NESCAUM recommends the use of steel and cast iron pipeline and service statistics available through the Office of Pipeline Safety. There are no data defaults for these inputs.

  For 2011, the Narragansett Electric Company reported net GHG emissions of 154,358 $MTCO_2e$. Per conversations with RI DEM, NESCAUM will select the emissions from FLIGHT for 2011 as representative of 2010 emissions rather than using the estimates from the SIT methodology.

Agricultural processes
GHG emissions from agricultural processes, including fertilizer

- Animal population numbers

  NESCAUM contacted the Rhode Island Agricultural Division regarding animal population estimates. The Agricultural Division recommended using information from the US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS). NASS survey data were retrieved for 2010 through 2013 and were projected forward to 2020 for the future year analysis. Agricultural census data were obtained for 1992 and 1997 and were used to extrapolate 1990 data. Where 1992 or 1997 data were unavailable, levels were assumed to have remained constant. If only 2002 data were available, those were used instead. Missing or withheld data from USDA were not filled and default values were used.

- Fertilizer utilization

  The Agricultural Division also supplied NESCAUM with estimates of annual fertilizer use for the 2012-2013 growing season.[17] The state does not keep records of historic year usage levels. NESCAUM recommends using these values in place of the default 2010 values from EPA's Inventory of GHG Emissions, and relying on default assumptions for 1990 and 2020 values.

  According to state records, about 773,000 tons of nitrogen fertilizer was applied to farms in the state in 2010, compared to the default value of 1,938,000 tons in SIT. The difference in these values scales to a change in total nitrous oxide emissions from fertilizers by 18 MT.

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[16] US DOT. Pipeline & Hazardous Materials Safety Administration. Rhode Island Incident and Mileage Overview. Available at: http://primis.phmsa.dot.gov/comm/reports/safety/RI_detail1.html.
[17] Rhode Island Agricultural Division. Total Fertilizer Summary. October 5, 2012.

Municipal solid waste (MSW)
Landfilling and combustion of MSW

- Amount of MSW landfilled in state

  State-specific values for landfilling in Rhode Island for 2010 are available from the Northeast Waste Management Officials' Association (NEWMOA) MSW Interstate Flow document, as provided by the RI DEM Office of Waste Management.[18] Data for waste disposal for 2004-2005 are available from the state's master waste plan.[19] Data for 2006-2010 are from the NEWMOA report. NESCAUM recommends projection for 2020 based on the recommended scenario from the master plan. Industrial landfilling is assumed to be 0 percent as it should be included in the state-reported values, which appear to be combined commercial and residential waste.

  Information about the new electricity generating facility at the Central Landfill will be taken from the environmental assessment[20] for the facility, which projects annual methane emission avoidance.

Land use, land use change, and forestry
Land use related emissions of GHGs

- Area burned

  There are no defaults available for area burned in forests. NESCAUM recommends using data available from the National Interagency Fire Center.[21] NESCAUM recommends using average annual fire statistics for all available years as a placeholder for fire activity in 1990 and 2020. Average annual area burned from 2002 through 2011 was approximately 121 acres. Forest fires in 2010 consumed only 23 acres, far below the annual average.

Indirect emissions from electricity consumption
GHG emissions resulting from electricity supplied to meet end-user electricity consumption

EPA provides a module to calculate GHG emissions resulting from the consumption of electricity by end-users. Such emissions actually occur at the electricity generator source (as described in the Fuel Combustion modules earlier), but result from the demand by end users. Because we are already accounting for emissions occurring instate by electricity generators, it would be double counting to simply add emissions resulting from end user electricity demand.

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[18] NEWMOA. Municipal Solid Waste (MSW) Interstate Flow in 2010. January 30, 2013.
[19] Rhode Island Resource Recovery Corporation. 2006. Rhode Island Comprehensive Solid Waste Management Plan. January 2006.
[20] National Energy Technology Laboratory. Final Environmental Assessment for the Rhode Island LFG GenCo LLC Combined Cycle Electricity Generation Plant Fueled by Landfill Gas, Johnston, Rhode Island. August 2010. US Department of Transportation. DOE/EA-1742.
[21] National Interagency Fire Center. Statistics. Available at http://www.nifc.gov/fireInfo/fireInfo_statistics.html. Historical data available from 1997 to present.

Furthermore, electricity supplied to meet instate demand is not always from instate sources. Instead, electricity for the New England region is managed by ISO-New England.

Emissions resulting from instate electricity demand will be provided as an attachment to the traditional electricity generation-based emissions inventory and will be caveated as for contextual analysis only. NESCAUM will explicitly warn against including this consumption-based inventory in the inventory total as doing so would be double counting. Including electricity consumption in state GHG inventories is relatively uncommon, except when the state is a net electricity importer. For net electricity exporting states like Rhode Island, some states split their emissions from electric generation into instate consumption and export portions. The electricity consumption approach will use consumption levels for the state for all years (1990, 2010, and 2020) from ENE (2013). After consultation with RI DEM, NESCAUM will assume consumption-based CO_2e emission factors that reflect the Rhode Island generation mix rather regional consumption factors, such as those used by ENE to estimate emissions. We have selected this approach because Rhode Island is a net electricity exporter, and though it is difficult to determine the source of electricity at the end user, it is reasonable to expect that much of the electricity consumed in state is also generated in state. Table 6 shows the emission rates that NESCAUM will use for the consumption-based approach described here. Based on this approach, NESCAUM will also be able to split Rhode Island electricity generation totals into instate and export portions.

In developing this memorandum, NESCAUM contacted Danny Musher of the Rhode Island Office of Energy Resources (OER) and Jamie Howland of Environment Northeast to discuss historic energy efficiency activities and planning and to ensure that our assumptions for 2020 projections are consistent with analysis being used to develop the Rhode Island State Energy Plan.

Table 6. Emission rates for consumption-based emissions inventory approach

Year	**Emission Rate (lb/MWh)**	**Source**
1990	1,307	Calculation using electricity sector emissions estimates from ENE 2013 and EIA electricity generation estimates
2010	959	2010 ISO-New England, Electric Generator Air Emissions Report, 2012, available at http://www.iso-ne.com/genrtion_resrcs/reports/emission/.
2020	943	Calculation using data from ICF 2013 and

Task 2 -

Greenhouse gas (GHG) Emission Inventories for Rhode Island for 1990, 2010, and 2020

The following describes statewide greenhouse gas emission inventories for 1990, 2010, and 2020 developed by NESCAUM for the Rhode Island Department of Environmental Management (RI DEM). These inventories represent a snapshot of the role that Rhode Island residents, industries, utilities, and other sectors play in contributing to Rhode Island's overall greenhouse gas (GHG) emissions. The inventories also provide insight into how emissions have changed over time and may change in the future, and which types of sources may present opportunities for further emissions reductions.

The following is organized as follows:

- **Section 1** provides background information about prior efforts to understand and mitigate Rhode Island's GHG emissions.
- **Sections 2, 3, and 4** present summary results and accompanying analysis for each of the three inventories, respectively.
- **Section 5** presents a summary of overall results and conclusions.

In addition, there are two attachments to this memorandum.

- **Attachment A** presents the methodology used in preparing this analysis.
- **Attachment B** presents the same overall GHG emissions levels reflected in this memorandum, but from an electricity consumption-based perspective rather than focusing on electricity generation alone.

1. Background

This memorandum follows up on prior efforts by the state to understand and address its role in contributing to climate change. In 2002, Rhode Island released its *Greenhouse Gas Action Plan*,[1] which catalogued priorities for reducing emissions based on the consensus of a group of stakeholders, convened by RI DEM, the Rhode Island State Energy Office, and the Governor's Office, and representing business, industry, citizen groups, environmental organizations, and state and federal governmental agencies. In the *Greenhouse Gas Action Plan*, the stakeholders agreed to set achievable goals for GHG emissions based on a 1990 baseline year. The stakeholders' goals are consistent with the *Climate Change Action Plan* agreed to by the New England Governors and Eastern Canadian Premiers,[2] of which Rhode Island is a participant. The *Climate Change Action Plan* set a goal to reduce regional GHG emissions to 1990 levels by 2010 and to 10 percent below 1990 levels by 2020.

NESCAUM generated the emissions inventories and projection using the State Inventory Tool (SIT) provided by the US Environmental Protection Agency (EPA). Many states, and all states in the Northeast region, including Rhode Island, have used SIT with state-specific inputs to develop state GHG inventories.[3] EPA created SIT to assist states in developing consistent and accurate assessments of their GHG emissions. SIT provides default values for many inputs, but EPA encourages users to override those values with state-validated inputs for a more refined inventory. NESCAUM has included alternative data wherever they are of sufficient quality to include in place of default data. In many cases, default data were the best information available with which to create the inventories; otherwise, we used alternative data sources, as recommended in our previous memoranda.[4] We present the data sources and methodologies that we used as inputs for the emissions inventories in detail in Attachment A.

SIT provides an overview of annual statewide GHG emissions beginning in 1990 through the year of latest data availability, as well as a projection tool with which to estimate emissions in future years. NESCAUM focused on developing inputs for the three years discussed above, not for annual emissions for all interim years.

[1] Rhode Island Greenhouse Gas (RI GHG) Stakeholder Process, Rhode Island Greenhouse Gas Action Plan, facilitated by Raab Associates, Ltd., July 2002. Available at http://righg.raabassociates.org/Articles/GHGPlanBody7-19-02FINAL.pdf.
[2] New England Governors/Eastern Canadian Premiers (NEG/ECP), Climate Change Action Plan, 2001. Available at http://www.negc.org/uploads/file/Reports/ClimateChangeAP%5B1%5D.pdf.
[3] NESCAUM, Memorandum, "Overview of State Greenhouse Gas (GHG) Inventories and Recommendations for Rhode Island Inventory Development," June 7, 2013, from Allison Guerette, Leiran Biton, and Michelle Manion, NESCAUM to Doug McVay and Karen Slattery, RI DEM.
[4] NESCAUM, Memorandum, "Recommendations for use of alternative data in the Rhode Island Greenhouse Gas (GHG) inventories," November 27, 2013, from Leiran Biton, NESCAUM to Doug McVay and Karen Slattery, RI DEM.

Table 1. Summary of 1990 Baseline Rhode Island GHG Emissions Inventory

Sector	**Emissions (MMT CO_2e)**	**Relative Contribution**
Energy	1.09	10.2%
Electric Power Generation	*0.79*	*7.3%*
Natural Gas Distribution	*0.30*	*2.8%*
Residential Heating	2.37	22.1%
Commercial Heating	1.15	10.7%
Transportation	4.97	46.3%
Aviation	*0.33*	*3.1%*
Highway Vehicles	*4.37*	*40.7%*
Nonroad Sources	*0.24*	*2.2%*
Lubricants	*0.03*	*0.3%*
Industrial	0.81	7.5%
Industrial Heating	*0.71*	*6.7%*
Industrial Processes	*0.09*	*0.9%*
Agriculture	0.04	0.4%
Waste	0.31	2.8%
Solid Waste	*0.23*	*2.1%*
Wastewater	*0.08*	*0.7%*
TOTAL	**10.74**	**100.0%**

Note: Values are rounded to the nearest 0.01 MMT CO_2e or 0.1 percent. This rounding accounts for discrepancies in subtotals and totals.

2. 1990 Baseline GHG Emissions Inventory

According to Rhode Island's *Greenhouse Gas Action Plan*, 1990 represents the baseline year against which current and future progress may be measured.

Table 1 presents a summary of GHG emissions by source sector for the 1990 baseline year. The information is displayed graphically in Figure 1.

Highway vehicles (40.7 percent) represented the largest single source sector for GHG emissions in Rhode Island in 1990, followed by residential sources (22.1 percent). Transportation overall accounted for 46.3 percent of Rhode Island GHG emissions. The electricity generation and natural gas distribution sectors accounted for about 10.2 percent of total in-state emissions. Total emissions, not including carbon fixing from land use changes and forestry, were about 10.74 MMT CO_2e.

Carbon sequestration from land use changes, forest management, and related activities removed 0.57 MMT CO_2e from the atmosphere in 1990, mostly due to tree growth in forest and urban environments. We have not included these emissions reductions in the summary tables or figures, though they are presented in more comprehensive tables in Attachment A.

3. 2010 GHG Emissions Inventory

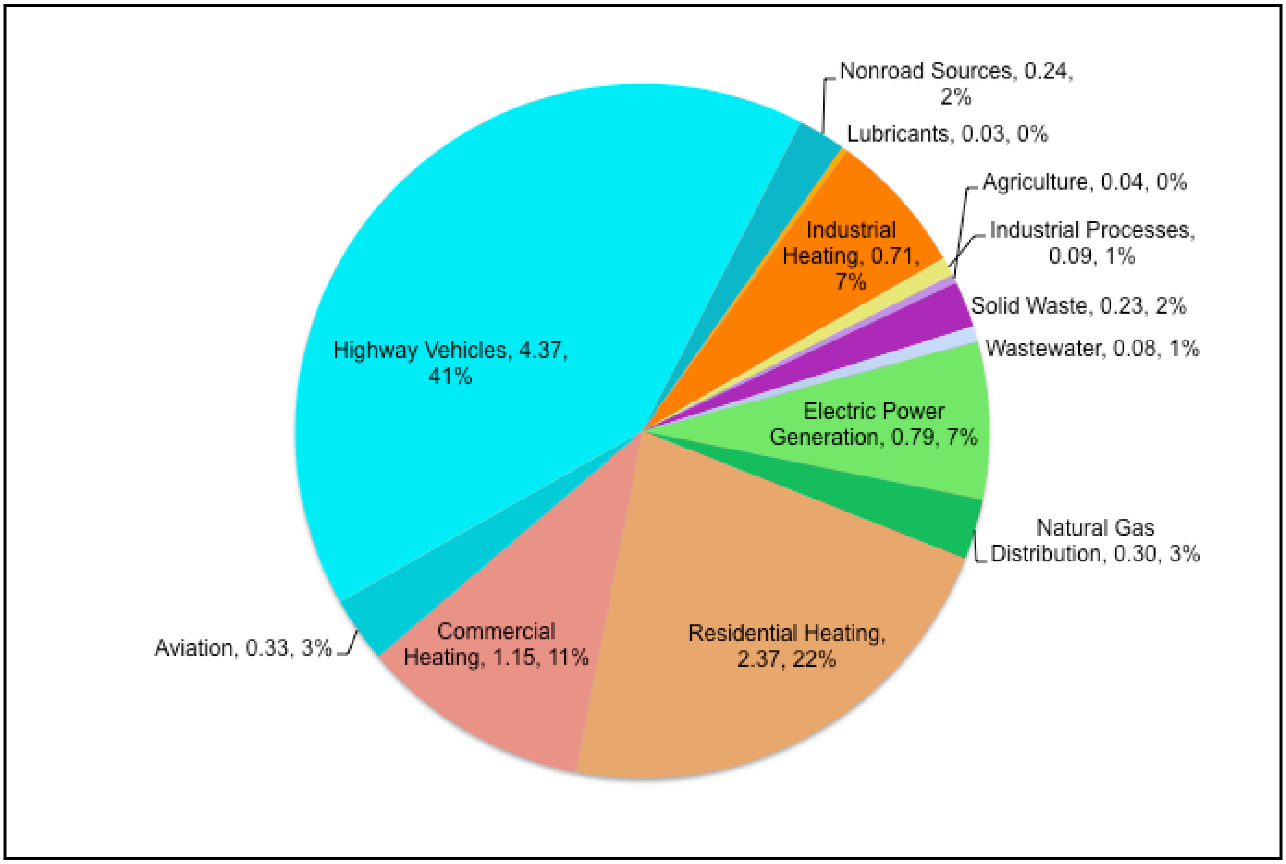
The year 2010 is the first significant milestone for assessing progress with regard to GHG emission reduction goals set forth in the Rhode Island *Greenhouse Gas Action Plan*. The goal for statewide GHG emissions in 2010 was to achieve 1990 level emissions (10.74 MMT CO_2e).

Table 2 presents a summary of GHG emissions by source sector for 2010. The information is displayed graphically in Figure 2.

As in 1990, transportation sources accounted for the largest portion of GHG emissions, 35.3 percent, of which 30.2 percent were from highway vehicles. Electric power generation contributed 25.8 percent, up from 7.3 percent in 1990. Combined, residential and commercial heating emissions accounted for 26.2 percent of total in-state emissions. Total emissions, not including carbon fixing from land use changes and forestry, were about 12.25 MMT CO_2e.

In 2010, land use changes, forest management, and related activities removed 1.34 MMT CO_2e from the atmosphere, primarily through forest and urban tree growth. As with 1990, these values

Figure 1. Summary of 1990 Rhode Island Greenhouse Gas (GHG) Emissions by Source Type (MMT CO_2e)



Note: Values are rounded to the nearest whole percentage point or nearest 0.01 MMT CO2e.

Table 2. Summary of 2010 Rhode Island Greenhouse Gas (GHG) Emissions Inventory

Sector	**Emissions (MMT CO_2e)**	**Relative Contribution**
Energy	3.32	27.1%
Electric Power Generation	*3.17*	*25.8%*
Natural Gas Distribution	*0.15*	*1.3%*
Residential Heating	2.28	18.6%
Commercial Heating	0.93	7.6%
Transportation	4.33	35.3%
Aviation	*0.27*	*2.2%*
Highway Vehicles	*3.70*	*30.2%*
Nonroad Sources	*0.33*	*2.7%*
Lubricants	*0.02*	*0.2%*
Industrial	1.07	8.7%
Industrial Heating	*0.64*	*5.2%*
Industrial Processes	*0.43*	*3.5%*
Agriculture	0.02	0.2%
Waste	0.30	2.4%
Solid Waste	*0.22*	*1.8%*
Wastewater	*0.08*	*0.6%*
TOTAL	**12.25**	**100.0%**

Note: Values are rounded to the nearest 0.01 MMT CO_2e or 0.1 percent. This rounding accounts for discrepancies in subtotals and totals.

are excluded from the summary table and figure, though they are presented in more comprehensive tables in Attachment A.

The largest change in emissions between 1990 and 2010 for any sector was the emissions increase of about 2.4 MMT CO_2e from electric power generation. This increase was primarily due to large combined cycle natural gas power plants that began operations since 1990. The following power plants were among the top GHG emitters in Rhode Island in 2010 according to RI DEM and EPA[5] records.

- The Rhode Island State Energy Center, a 550-megawatt facility operated by Entergy, began commercial operations in November 2002 and is currently the largest single source of GHG emissions in Rhode Island, emitting 1,178,660 MT CO_2e in 2010.

- The second largest single source of GHG emissions in the state, 450-megawatt Dominion Manchester Street Power Station in Providence, repowered in 1995, and emitted 873,409 MT CO_2e in 2010.

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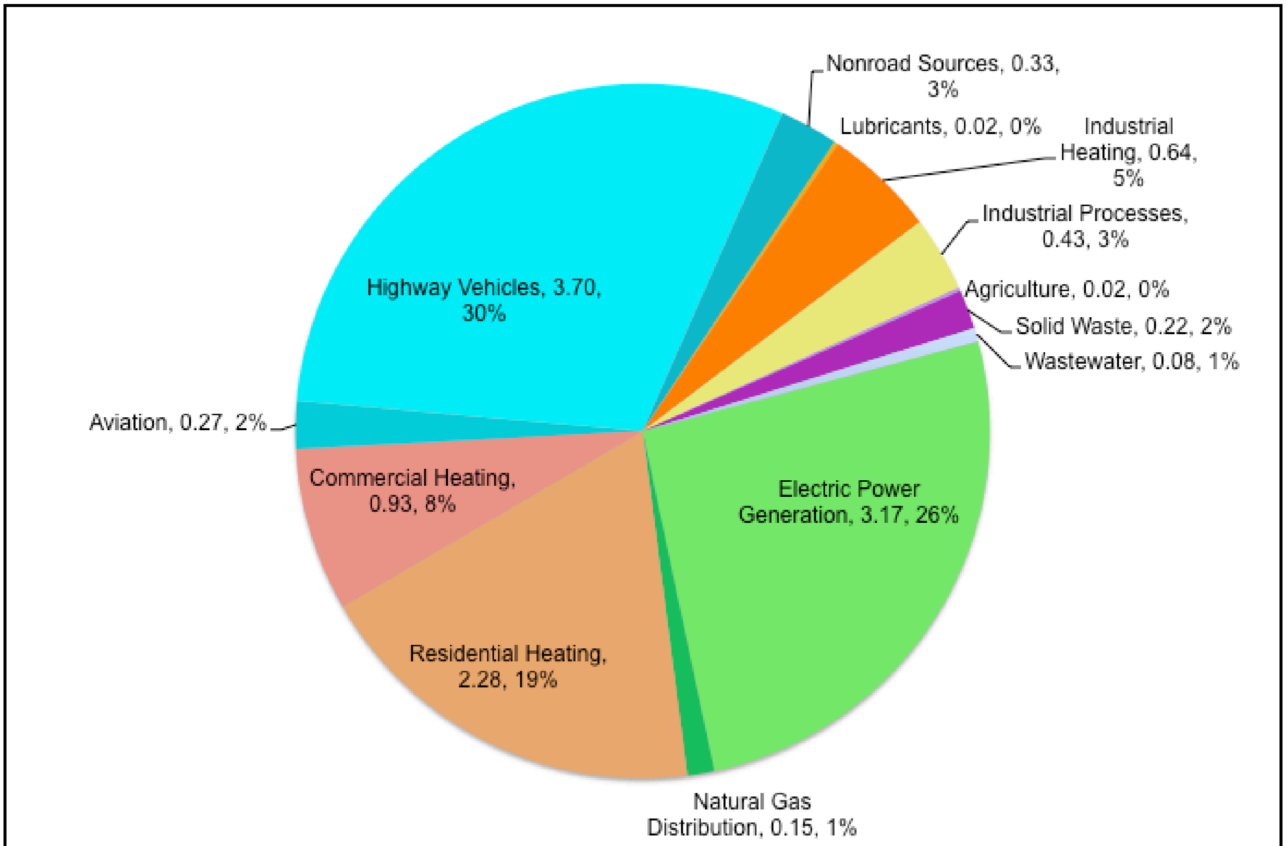
[5] EPA, 2012, Facility Level Information on GreenHouse gases Tool (FLIGHT) webpage, available at http://ghgdata.epa.gov/ghgp/main.do, accessed on September 20, 2013. Data filters for state (Rhode Island) and year (2010) for GHG emitters were used to narrow the data search.

- Tiverton Power began commercial power operations in 2000 for its 265-megawatt plant and emitted 437,909 MT CO_2e in 2010.
- Units at Ocean State Power in Burrillville generated a combined 668,753 MT CO_2e in 2010 at this 560-megawatt facility, which began operations between 1990 and 1991.

Modest reductions in emissions from other fuel combustion sectors (~19 percent for commercial heating, ~13 percent for transportation, ~11 percent for industrial heating, and ~4 for residential heating, totaling reductions of greater than 1.0 MMT CO_2e) were not sufficient in magnitude to compensate for the large growth in GHG emissions from the electric power generation sector since 1990 (2.38 MMT CO_2e, about a threefold increase). Paired with significant increases in emissions from industrial processes (0.34 MMT CO_2e), mostly from releases of substitutes for

Figure 2. Summary of 2010 Rhode Island Greenhouse Gas (GHG) Emissions by Source Type (MMT CO_2e)



Note: Values are rounded to the nearest whole percentage point or nearest 0.01 MMT CO_2e.

ozone depleting substances from a number of end-use applications,[6] Rhode Island's GHG emissions in 2010 were about 1.51 MMT CO_2e (14.0 percent) higher than in 1990.

4. 2020 Business-as-Usual GHG Emissions Projection

This section presents results from a 2020 growth projection based on current Rhode Island policy, agreements, and trends. The goal for statewide GHG emissions in 2020 is to achieve a 10 percent reduction below 1990 level emissions, or 9.67 MMT CO_2e.

Table 3. Summary of 2020 Rhode Island Business-as-Usual GHG Emissions Projection

Sector	**Emissions (MMT CO_2e)**	**Relative Contribution**
Energy	3.82	30.3%
Electric Power Generation	*3.67*	*29.1%*
Natural Gas Distribution	*0.15*	*1.2%*
Residential Heating	1.99	15.8%
Commercial Heating	1.19	9.4%
Transportation	4.32	34.2%
Aviation	*0.29*	*2.3%*
Highway Vehicles	*3.76*	*29.8%*
Nonroad Sources	*0.25*	*2.0%*
Lubricants	*0.02*	*0.1%*
Industrial	1.09	8.6%
Industrial Heating	*0.83*	*6.6%*
Industrial Processes	*0.26*	*2.1%*
Agriculture	0.05	0.4%
Waste	0.17	1.3%
Solid Waste	*0.08*	*0.7%*
Wastewater	*0.08*	*0.7%*
TOTAL	**12.63**	**100.0%**

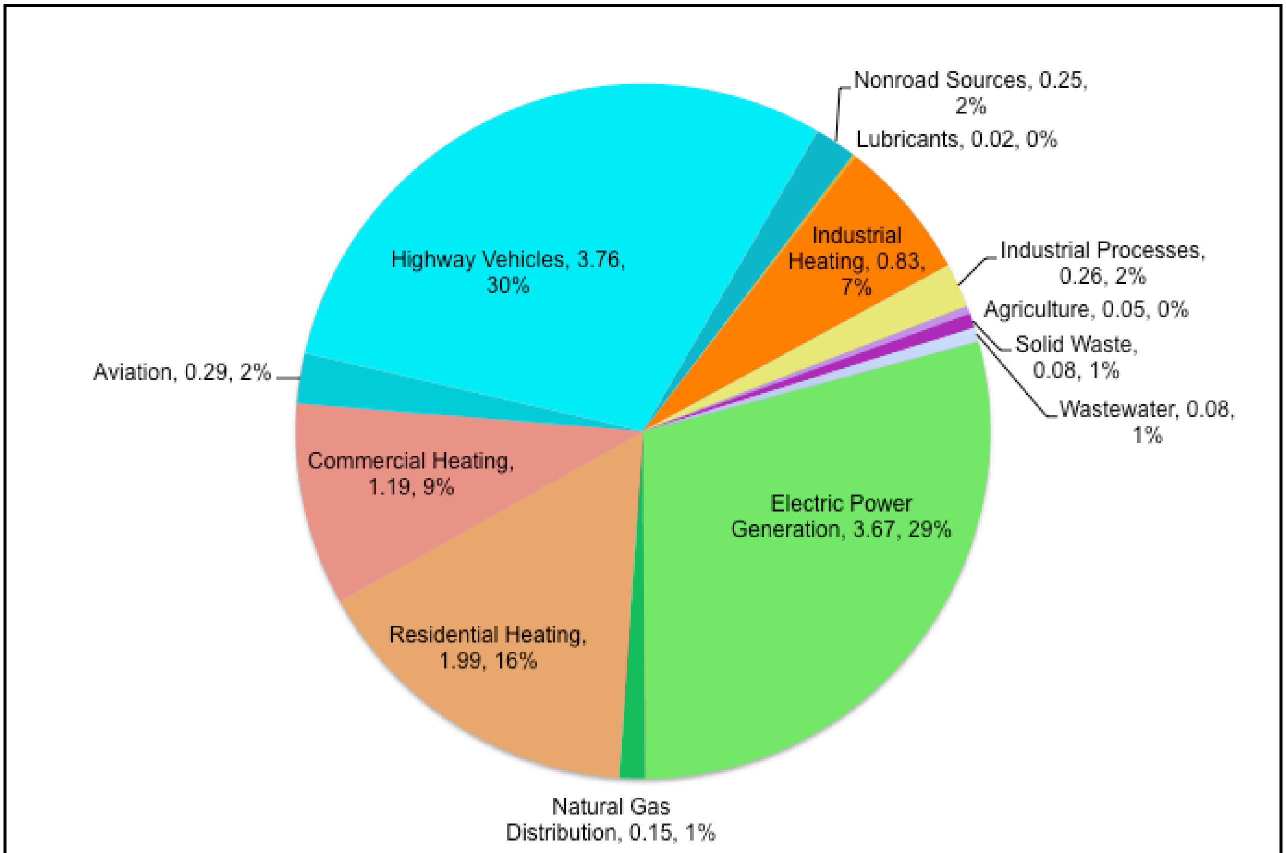
Note: Values are rounded to the nearest 0.01 MMT CO_2e or 0.1 percent. This rounding accounts for discrepancies in subtotals and totals.

Table 3 presents a summary of GHG emissions by source sector for the 2020 business-as-usual projection. The information is displayed graphically in Figure 3. The data reflect the outputs from SIT, adjusted to include assumptions for 2020 consistent with the Rhode Island Energy

[6] SIT documentation describes the following end uses: "motor vehicle air conditioning, commercial and industrial refrigeration and air conditioning, residential refrigeration and air conditioning, aerosols, solvent cleaning, fire extinguishing equipment, foam production, and sterilization."

Plan forecast model[7] and otherwise using default projection methodology, except where noted in Attachment A.

Figure 3. Summary of 2020 Rhode Island GHG Emissions by Source Type (MMT CO_2e)



Note: Values are rounded to the nearest whole percentage point or nearest 0.01 MMT CO_2e.

In the 2020 business-as-usual emissions projection, as in historic years, highway vehicles are estimated to be the largest source sector contributor (29.8 percent), with transportation overall responsible for 34.2 percent of GHG emissions. Electric power generation emissions are 16 percent higher (0.51 MMT CO_2e) compared to 2010 levels, and represent 29.1 percent of projected 2020 GHG emissions. Residential and commercial heating are responsible for a combined 3.18 MMT CO_2e, or 25.2 percent of statewide GHG emissions. According to the projection, emissions from industrial heating and industrial processes total 1.09 MMT CO_2e, approximately unchanged from that sector's 2010 GHG emissions.

[7] Environment Northeast (ENE), 2013, Rhode Island State Energy Plan Business-as-Usual Forecast. V. Kumar & J. Howland. Submitted to the Rhode Island Office of Energy Resources. October 2013. Available at http://www.energy.ri.gov/energyplan/index.php. Spreadsheets of underlying data are available at the same website.

Rhode Island’s total GHG emissions in 2020 are projected to be 12.63 MMT CO_2e, not including carbon fixing from land use changes and forestry. We do not project the carbon flux in 2020 from changes in land use or forestry management and related activities.

As with 2010, the 2020 projection shows important progress in reducing fuel consumption in the residential (16 percent), transportation (13 percent), and waste (45.4 percent) sectors below 1990 levels. This progress, however, is counteracted by continued increases in emissions from the electric power generation sector.

5. Summary of Overall Results and Conclusions

Table 4 presents a side by side comparison of the sector emissions summary data for 1990, 2010, and 2020 that were presented in Tables 1, 2, and 3, respectively. Figure 4 presents the same data as a stacked bar chart with emissions from each sector contributing to the total height of the bar.

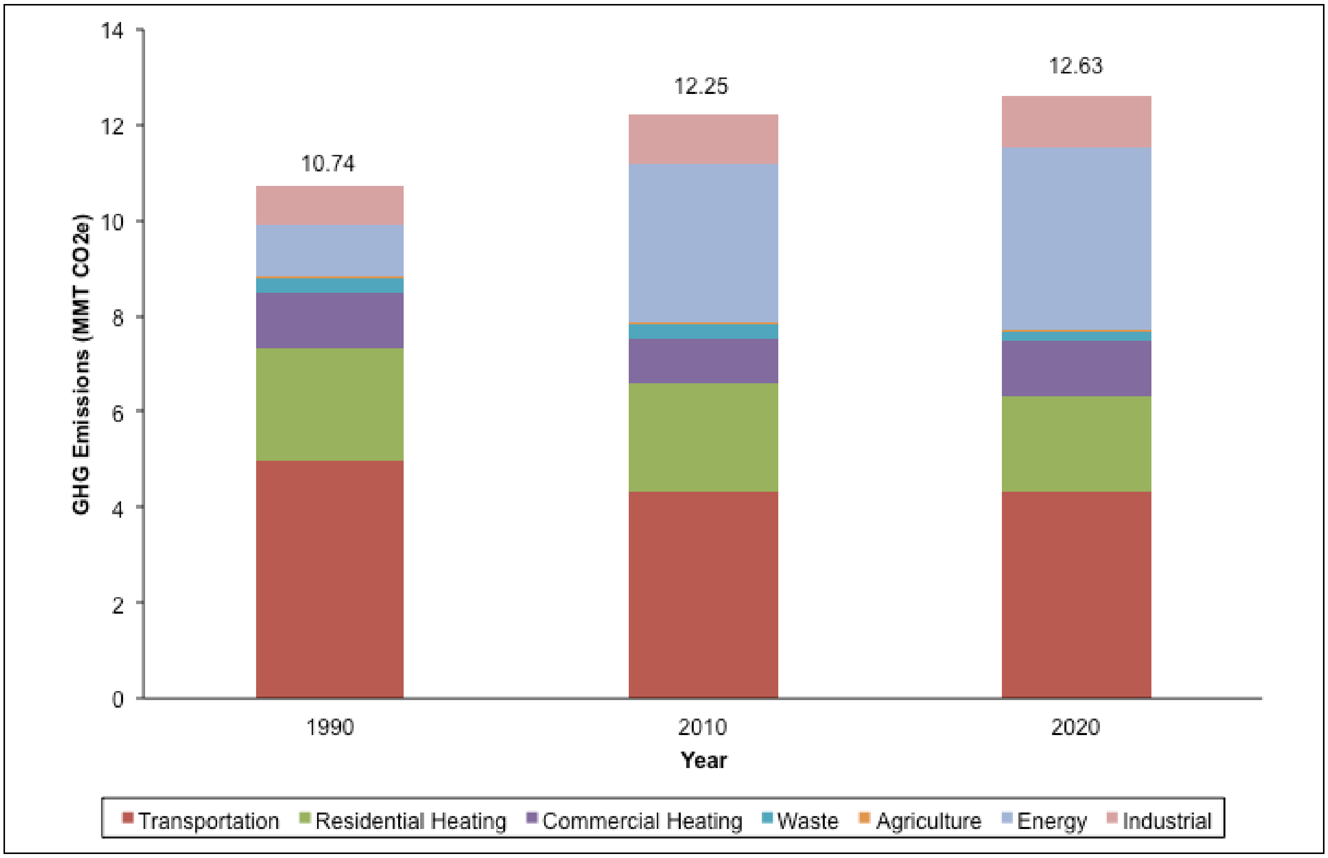
Table 4. Summary of Rhode Island GHG Emissions Estimates (MMT CO_2e)

Sector	**1990**	**2010**	**2020**
Energy	1.09	3.32	3.82
Electric Power Generation	*0.79*	*3.17*	*3.67*
Natural Gas Distribution	*0.30*	*0.15*	*0.15*
Residential Heating	2.37	2.28	1.99
Commercial Heating	1.15	0.93	1.19
Transportation	4.97	4.33	4.32
Aviation	*0.33*	*0.27*	*0.29*
Highway Vehicles	*4.37*	*3.70*	*3.76*
Nonroad Sources	*0.24*	*0.33*	*0.25*
Lubricants	*0.03*	*0.02*	*0.02*
Industrial	0.81	1.07	1.09
Industrial Heating	*0.71*	*0.64*	*0.83*
Industrial Processes	*0.09*	*0.43*	*0.26*
Agriculture	0.04	0.02	0.05
Waste	0.31	0.30	0.17
Solid Waste	*0.23*	*0.22*	*0.08*
Wastewater	*0.08*	*0.08*	*0.08*
TOTAL	**10.74**	**12.25**	**12.63**

Note: Values are rounded to the nearest 0.01 MMT CO_2e. This rounding accounts for discrepancies in subtotals and totals.

Figure 4 clearly displays that the increases in GHG emissions from the energy sector are largely responsible for driving overall emissions up between 1990 and 2010, and the energy and industrial sectors for projected increases through 2020, whereas all other sector emissions either decline or remain relatively unchanged.

Figure 4. Summary of Rhode Island GHG Emissions Estimates (MMT CO_2e)



Note: Values are rounded to the nearest 0.01 MMT CO_2e.

Because the electric power generation sector experienced significant growth in the years since 1990, emissions have increased commensurately, despite the lower carbon output emissions rates of the newer electric power sources. Electricity markets in New England, however, are not restricted by state political boundaries. It is possible that the increased electricity generation in Rhode Island may be exported to other states where it could be displacing generation by higher GHG emitting oil and coal power plants.

As an alternative approach, Rhode Island could look at actual electricity consumption in-state as a useful method for gauging performance with respect to the *Greenhouse Gas Action Plan* goals, as opposed to electricity generation, where emission trends might be better placed in a regional context. Our analysis does not choose between these two alternatives, but for completeness, we provide in Attachment B an assessment of Rhode Island's GHG emissions from an in-state electricity consumption perspective rather than an electricity generation perspective.

An archive data file is provided in Attachment C to this memorandum.

Attachment A:
Technical documentation for the Rhode Island greenhouse gas inventory

This document provides technical documentation for the development of the Rhode Island Greenhouse Gas (GHG) inventories for 1990 and 2010 and the business-as-usual emissions projection for 2020.

This document is divided into two subsections:

- **Section A-1** provides documentation for the GHG emissions inventories that NESCAUM developed for Rhode Island for 1990 and 2010.
- **Section A-2** provides documentation for the business-as-usual GHG emissions projection that NESCAUM developed for Rhode Island for 2020.

NESCAUM used the US Environmental Protection Agency (EPA) State Inventory Tool (SIT) to develop estimates of statewide GHG emissions for 1990, 2010, and 2020. We consider the estimates for 1990 and 2010 as GHG inventories, and the 2020 estimate as a projection reflecting business-as-usual assumptions for state-level policy. In general, in preparing these estimates, we relied on default options available in SIT, and refer to these options collectively as EPA SIT defaults. In some cases, multiple default options are provided, and for these we identify which option was selected in our analysis. In other cases, NESCAUM has identified and evaluated state-specific data sources for use in place of default inputs for development of the Rhode Island GHG inventories. Each proposed data substitution or alternative methodology is presented in the subsections below, organized by SIT module input category.[1]

A-1. 1990 and 2010 emissions inventories

- **Carbon dioxide from combustion of fossil fuel**

Facilities report emissions and fuel use to RI DEM on an annual basis. NESCAUM and RI DEM gathered fuel use data from 1990-era RI DEM records, and RI DEM supplied NESCAUM with fuel use data for small stationary sources for 2011 and for major sources (i.e., sources with Title V permits) for 2010. NESCAUM processed these data as described in our November 27, 2013 memorandum to RI DEM[2] and prepared estimates of energy use in British thermal units (Btu) for 1990 and 2010 by sector by fuel type.

[1] US Environmental Protection Agency (EPA). 2013. State Inventory and Projection Tool (SIT) website. http://epa.gov/statelocalclimate/resources/tool.html. See the SIT documentation for a description of SIT, its modules, and default documentation. We do not describe the default SIT inputs or options, and we omit discussion entirely in situations where the default SIT options were selected. Please refer to SIT documentation for information about these options (EPA 2013).
[2] NESCAUM, Memorandum, "Recommendations for use of alternative data in the Rhode Island Greenhouse Gas (GHG) inventories," November 27, 2013, from Leiran Biton, NESCAUM to Doug McVay and Karen Slattery, RI DEM.

Based on comparisons between energy use by fuel available to RI DEM through annual reporting and default data in SIT from the US Energy Information Administration (EIA), NESCAUM replaced default data for select fuel types and sectors with those derived from RI DEM records, as presented in Table A-1.[3] For all other sectors and fuel types, NESCAUM used the default data.

Table A-1. Sector energy use (billion Btu) based on historic RI DEM records

Sector	Fuel Type	Energy Use	Year
Commercial	Residual Fuel	4,044	1990
Commercial	Residual Fuel	396	2010
Electric Power	Distillate Fuel	124	2010
Electric Power	Natural Gas	59,487	2010
Electric Power	Residual Fuel	3,775	1990
Industrial	Natural Gas	4,404	1990
Industrial	Residual Fuel	3,662	1990
Industrial	Residual Fuel	600	2010

NESCAUM based transportation sector onroad motor vehicle gasoline and ethanol energy use on results from the EPA MOVES model.[4] We created input databases for 1990 based on databases prepared by RI DEM and EPA for the 2011 National Emissions Inventory (NEI),[5] and ran default simulations for 2011 and the inventory years to determine growth factors for baseline fleet and vehicle activity, measured in vehicle miles traveled (VMT). We then applied these factors to the 2011 databases to estimate fleet population and VMT demand for the inventory years. For remaining database requirements, e.g., default fuel formulation and age distribution characteristics, we used MOVES default information for 1990. We adjusted energy demand for all fuels based on the ratio of low heating value (LHV) to high heating value (HHV) to account for the differing treatment of heating value in the MOVES outputs (LHV) vs. SIT inputs (HHV).

MOVES results for natural gas used in transportation are based on national average estimates, whereas EIA has state-specific estimates that include losses from compressor stations. NESCAUM selected the EIA data over MOVES outputs because EIA has more state level detail

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[3] See *ibid.* for these comparisons and a fuller description of data processing, checks, and analysis.
[4] EPA Motor Vehicle Emission Simulator (MOVES), version 2010b, available at http://www.epa.gov/otaq/models/moves/index.htm.
[5] RI DEM, "Rhode Island MOVES CDM Preparation for 2011 NEI", January 4, 2013. Prepared by Karen Slattery (RI DEM) and Ron Marcaccio (RI DEM), with assistance from Alexis Zubrow (EPA). EPA estimated real world fleet economy based on projections of manufacturers compliance strategies using numerous compliance options and flexibility mechanisms in the CAFE rule. These projections were published in the Notice of Proposed Rulemaking rather than in the CAFE rule itself. Since 2011, EPA has updated these projections and the newer values are largely similar (but not identical) to the values used in this analysis.

and includes both highway and non-highway transportation fuel consumption, while MOVES only accounts for highway transportation fuel consumption.

We selected EIA estimates (SIT default) for transportation-sector diesel use and relied on MOVES estimates to determine the portion of transportation diesel fuel consumed on- vs. non-road.

Transportation sector fuel values used in this analysis are presented in Table A-2.

Table A-2. Transportation sector fuel use by fuel type (billion Btu)

Fuel Type	Year		Data Source
	1990	2010	
Distillate Fuel (total)	6,723	9,591	EIA (default)
Onroad	*3,759*	*5,731*	MOVES
Nonroad	*2,964*	*3,860*	Calculation
Ethanol	-	3,300	MOVES
Motor Gasoline	40,398	43,747	MOVES
Natural Gas	129	1,602	EIA (default)

Table A-3. Transportation aviation fuel input methodology for 2010

Fuel Type	Units	Fuel Type		Data Source
		Aviation gasoline	Jet fuel (kerosene)	
Fuel use	gallons	91,059	27,364,833	RAIC 2011
Heat content	MMBtu/bbl	5.048	5.670	EIA 2011
Heat content	MMBtu/gal	120.2	135.0	Calculation
Fuel use	Billion Btu	10.95	3,694.25	Calculation

Source (conversion factors): EIA, 2011, Annual Energy Review, Appendix A: British Thermal Unit Conversion Factors, Table A1, "Approximate Heat Content of Petroleum Products." Available at http://www.eia.gov/totalenergy/data/annual/pdf/sec12.pdf.

Notes: MMBtu = Millions Btu; bbl = barrel (42 gallons)

NESCAUM selected information for aviation fuel use (aviation gasoline and jet fuel) in 2010 provided in the Rhode Island Airport Corporation (RIAC) annual environmental report for 2010 aviation fuel use, reported in gallons.[6] NESCAUM converted these values to billion Btu for consistency with SIT inputs. These values, conversion factors, and resulting fuel use inputs for aviation gasoline and jet fuel (kerosene type) are presented in Table A-3. For 1990 inputs, NESCAUM relied on SIT defaults.

[6] RIAC, T.F. Green Airport 2010 Air Emissions and Greenhouse Gas Inventory, March 25, 2011. Note that because RIAC relied on slightly different emissions factors than those used in this analysis, the emissions levels presented here are subtly different from those presented in RIAC reports. We selected emission rates and fuel heat values for internal consistency rather than consistency with source data.

- **Stationary combustion**

The Stationary Combustion module calculates emissions of methane and nitrous oxide from stationary source combustion. Inputs to the Stationary Combustion module were consistent to those entered in the "Carbon dioxide from combustion of fossil fuel" module (see above).

- **Mobile combustion**

The Stationary Combustion module calculates emissions of methane and nitrous oxide from mobile source combustion. Inputs to the Mobile Combustion module were consistent to those entered in the "Carbon dioxide from combustion of fossil fuel" module (see above).

- **Agriculture**

NESCAUM estimated animal population and crop production levels based on values reported for 1990 and 2010 from the US Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) data.[7] Where appropriate for 2010, we extrapolated from 2002 and 2007 data. Similarly, where appropriate for 1990, we interpolated between 1987 and 1992. Data inputs for 1990 and 2010 for the animal populations are presented in Table A-4, and for crop production in Table A-5. Missing or withheld data from USDA were not filled and default values were used.

The Rhode Island Agricultural Division (within RI DEM) also supplied NESCAUM with estimates of annual fertilizer use for the 2012-2013 growing season.[8] The state does not keep records of historic year usage levels. NESCAUM recommends using these values in place of the default 2010 values from EPA's Inventory of GHG Emissions, and relying on default assumptions for 1990 and 2020 values. According to these records, about 773,000 tons of nitrogen fertilizer were applied to farms in the state in 2010.

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[7] USDA, 2013, NASS Quick Stats website. Available at quickstats.nass.usda.gov. Data filtered by state (Rhode Island). Accessed on November 13, 2013.
[8] Rhode Island Agricultural Division. Total Fertilizer Summary. October 5, 2012.

Table A-4. Animal population levels in Rhode Island for 1990 and 2010

Animal type	Number of animals (000 head)	
	1990	2010
Cattle		
Dairy cows	2.7	0.7
Dairy replacement heifers		0.5
Replacements 0-12 mo		0.5
Replacements 12-24 mo		
Beef cows	1.0	1.2
Beef replacement heifers		0.4
Replacements 0-12 mo		0.4
Replacements 12-24 mo		
Heifer stockers	1.9	0.1
Steer stockers		0.4
Feedlot heifers	3.8	
Feedlot steer		
Bulls	0.7	0.1
Calves		0.8
Sheep	1.5	1.4
Goats	0.3	
Swine	5.2	1.5
Breeding	0.7	0.5
Market under 60 lb		0.5
Market 60-119 lb	2.6	0.4
Market 120-179 lb	2.6	0.3
Market over 180 lb		0.1
Horses	1.0	3.5
Poultry		
Layers		
Hens > 1 yr	227.6	50.4
Pullets	0.2	3.2
Chickens	1.2	
Broilers	23.6	
Turkeys	5.4	2.2

Note: Subcategories are not necessarily mutually exclusive, and therefore are not always additive to total values.

Table A-5. Crop production in Rhode Island for 1990 and 2010

Crop	Production level 1990	Production level 2010
Alfalfa (thousand tons)	7	2
Corn for grain (thousand bushels)	10	42
Oats (thousand bushels)	2	2
Rye (thousand bushels)	4	2

- **Coal**

NESCAUM excluded coal mines from the analysis because by 1990, all coal-mining operations in Rhode Island had ceased.

- **Industrial processes**

SIT is capable of estimating emissions from certain industrial processes, as described in SIT documentation (EPA 2013). Using SIT, we characterized emissions from industrial processes in Rhode Island that use limestone and those related to iron and steel production. NESCAUM found no record of any other industrial activities in Rhode Island for industry types that are included in this SIT module.

For limestone use, NESCAUM relied on the U.S. Geological Survey (USGS) Minerals Yearbook, which reported total limestone use of 8,000 short tons (7,257 MT) in Rhode Island in 1990.[9] Because NESCAUM found no data for limestone use in 2010, and default data were not available, we applied the average of annual in-state limestone consumption default data since 2001 as representative of 2010 consumption, or 16,932 MT.

For iron and steel production, RI DEM sent NESCAUM 1990 annual production output data (137,687 tons produced using electric arc furnace) from RI DEM for Ocean State Steel, the only major operating facility in Rhode Island at that time. The steel mill closed down in the mid-1990s, so we used a value of 0 tons produced in 2010.

- **Natural gas and oil**

No oil or gas is produced in Rhode Island. The only significant emissions from this sector are those from distribution of natural gas.

For 2011, the Narragansett Electric Company, which serves the state for natural gas, reported net distribution GHG emissions of 154,358 MT CO_2e to EPA.[10] 2011 was the first year of such

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[9] USGS, 1990, Minerals Yearbook, Volume 1, Table 6: Destination of Shipments of Lime Sold or Used by Producers in the United States by State, available at http://digicoll.library.wisc.edu/cgi-bin/EcoNatRes/EcoNatRes-idx?type=turn&entity=EcoNatRes.MinYB1990v1.p0698&id=EcoNatRes.MinYB1990v1&isize=M.

[10] EPA Greenhouse Gas Reporting Program, GHG Data Publication Tool, Facility Level Information on GreenHouse gases Tool (FLIGHT). Available at http://www.epa.gov/ghgreporting/. Accessed on November 14, 2013.

GHG reporting for natural gas distributors. Per conversations with RI DEM, NESCAUM will select these emissions for 2011 as representative of 2010 emissions rather than using the estimates from the SIT methodology.

For 1990, NESCAUM used data from US Department of Transportation (DOT) Pipeline & Hazardous Materials Safety Administration (PHMSA) reports for distribution and service level data. NESCAUM used steel and cast iron pipeline and service statistics available through the Office of Pipeline Safety.[11] Table A-6 presents inputs to the natural gas distribution emissions calculations as derived from the DOT PHMSA data, divided into two sections: miles of main, and counts of services. Both values are required to estimate emissions that occur due to leakage from fittings in the main and from services.

Table A-6. Natural gas distribution system inputs for Rhode Island in 1990

	Input	
Variable	**Value**	**Units**
Steel Unprotected Bare	513	Miles
Steel Unprotected Coated	84	Miles
Steel Cathodically Protected Bare	0	Miles
Steel Cathodically Protected Coated	748	Miles
Plastic	415	Miles
Cast/Wrought Iron	1,035	Miles
Ductile Iron	16	Miles
Copper	0	Miles
Other	0	Miles
Other	0	Miles
Total miles of main	**2,811**	**Miles**
Steel Unprotected Bare	90,765	-
Steel Unprotected Coated	18,212	-
Steel Cathodically Protected Bare	0	-
Steel Cathodically Protected Coated	13,898	-
Plastic	40,481	-
Cast/Wrought Iron	0	-
Ductile Iron	0	-
Copper	288	-
Other	0	-
Other	0	-
Total number of services	**163,644**	-

[11] US DOT, Pipeline & Hazardous Materials Safety Administration, “Distribution, Transmission, and Liquid Annual Data” website. Data retrieved from http://phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print for Rhode Island on August 8, 2013.

- **Solid waste**

For 1990, NESCAUM used default SIT methodology and historic waste quantity inputs.

For 2010, NESCAUM used emissions as reported to EPA from the Rhode Island Resource Recovery Corporation (RI RRC) for the Central Landfill in 2010 (see EPA FLIGHT 2013). Methane emissions for RI RRC in 2010 are 221,626 MT CO_2e.

- **Wastewater**

Fraction of population not on septic

The 1990 value was interpolated as the midpoint value from 1988 and 1992 data from the US Census American Housing Survey for the Pawtucket-Warwick Metropolitan Area. The data used in this calculation are presented in Table A-7. We assumed that values from the 2011 American Housing Survey[12] were representative of those in 2010. In 2011, 139,600 units were on septic, 382,400 on public sewer, which results in 73.3 percent being not on septic.

Table A-7. Interpolation for fraction of population not using septic for 1990

	1988[a]	**1992[b]**	**1990**
Occupied units on public sewer	257.0	269.1	263.05
Occupied units with septic tank, cesspool, chemical toilet	118.4	111.6	115.0
Fraction not on Septic	68%	71%	69.6%

a. US Census, 1990, American Housing Survey for the Providence-Pawtucket-Warwick Metropolitan Area in 1988. Report number H-170-88-56. November 1990. Table 2-4, Selected Equipment and Plumbing – Occupied Units. Available at http://www2.census.gov/prod2/ahsscan/h170-8856.pdf.
b. US Census. 1994. American Housing Survey for the Providence-Pawtucket-Warwick Metropolitan Area in 1992. Report number H170/92-56. April 1994. Table 2-4, Selected Equipment and Plumbing – Occupied Units. Available online at http://www2.census.gov/prod2/ahsscan/h170-9256.pdf.

Per capita protein consumption

NESCAUM assumed that Rhode Island protein consumption was consistent with the natural average: 29.6 kg in 1990, and 32.7 kg in 2010.[13]

Biosolids used as fertilizer

We assumed that the fraction of biosolids used as fertilizer was equal to the national average of 60 percent for both 1990 and 2010.[14]

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[12] US Census, 2013, 2011 American Housing Survey for the Providence, RI AHS. Plumbing, Water, and Sewage Disposal – All Occupied Units. Available at http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=AHS_2011_C04AOM&prodType=table. Accessed on November 13, 2013.

[13] EPA, 2012, Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2010, report number EPA 430-R-12-001, April 15, 2012, available at http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2012-Main-Text.pdf. Table 8-14.

Fruit and vegetable production

In 2010, Rhode Island only released fruit and vegetable production information for fall potatoes, sweet corn, and apples. As a result, we calculated total production from these products. Total production was 24,000,000 lb or 10,886 MT. The original production amounts and subsequent conversion to pounds (where needed) are presented in Table A-8. Because we could not identify a data source for 1990, we assumed that 1990 production was equivalent to 2010 production levels.

Table A-8. Fruit and vegetable production in 1990 and 2010

	Production (original units)	Production (lb)
Fall potatoes	165,000 hundredweight	16,500,000
Sweet corn	49,000 hundredweight	4,900,000
Apples	2,600,000 lb	2,600,000
Total		24,000,000

Source: National Agricultural Statistics Service, 2010, New England Agricultural Statistics, available at http://www.nass.usda.gov/Statistics_by_State/New_England_includes/Publications/-Annual_Statistical_Bulletin/10start.htm.

Red meat production

NESCAUM applied the data used in the Agriculture module (derived from agricultural survey and census data as described in the Agriculture section) for production of red meat. We multiplied the number of beef animals by the associated default animal mass (kg) to calculate total mass (kg). Table A-9 presents the inputs and results of this method.

Table A-9. Calculation of 1990 and 2010 red meat production

Animal	Typical Animal Mass (kg)	Number in 1990	1990 Total Animal Mass (kg)	Number in 2010	2010 Total Animal Mass (kg)
Feedlot heifers	420	3,762	1,580,000	-	-
Beef cows	533	1,033	550,000	1,191	635,000
Beef replacements	420	-	-	400	168,000
Steer stockers	318	-	-	400	127,000
Heifer stockers	420	1,914	804,000	100	42,000
Total			**2,934,000**		**972,000**

Note: Total red meat production (kg) is rounded to the number of significant figures available from calculation input values.

[14] Washington Department of Ecology. 2013. Biosolids FAQ website, “What percentage of biosolids is recycled,” available at http://www.ecy.wa.gov/programs/swfa/biosolids/faq.html#wapercent. Accessed on November 13, 2013.

Poultry production

NESCAUM applied the data used in the Agriculture module (derived from agricultural survey and census data as described in the Agriculture section) for poultry production. We multiplied the number of poultry animals by the associated default animal mass (kg) to calculate total mass (kg). Table A-10 presents the inputs and results of this method.

Table A-10. Calculation of 1990 and 2010 poultry production

Animal	Typical Animal Mass (kg)	Number in 1990	1990 Total Animal Mass (kg)	Number in 2010	2010 Total Animal Mass (kg)
Hens	1.8	227,570	410,000	50,386	91,000
Pullets	1.8	1,908	340	3,219	5,800
Chickens	1.8	1,240	2,200	-	-
Broilers	0.9	23,624	21,000	-	-
Turkeys	6.8	5,369	37,000	2,211	15,000
Total			**470,000**		**112,000**

Note: Total poultry production (kg) is rounded to the number of significant figures available from calculation input values.

ð **Land use, land use change, and forestry**

For area burned in forests, for which there are no default data, NESCAUM relied on average annual fire statistics data. The National Interagency Fire Center reported area burned in 2010. For 1990, NESCAUM used the average annual fire statistics for all available years. Average annual area burned from 2002 through 2011 was approximately 121 acres. Forest fires in 2010 consumed only 23 acres, far below the annual average.

A-2. 2020 business-as-usual emissions projection

ð **Carbon dioxide from combustion of fossil fuel**

For 2020 emissions estimates, NESCAUM relied on electricity generation sector emissions for a business-as-usual projection as described in the October 2013 analysis by Environment Northeast (ENE).[15] We used the ENE analysis because it incorporates state policies, regional cooperative agreements, and is otherwise consistent with the EIA projections on which the default SIT analysis is based. ENE projects emissions in 2020 for the energy sector of 3,665,883 MT CO_2e in 2020 from natural gas, 2,816 MT CO_2e from distillate fuel, and 146 MT CO_2e from residual fuel.

[15] V. Kumar and J. Howland, 2013, Rhode Island Business-as-Usual Forecast, ENE 2013, submitted to the Rhode Island Office of Energy Resources, available at http://www.energy.ri.gov/documents/energyplan/ENE_RISEP_Business_As_Usual_Forecast.pdf. Data files are available from the Rhode Island State Energy Plan website, www.energy.ri.gov/energyplan.

NESCAUM developed transportation sector onroad motor vehicle fuel consumption in 2020 based on the EPA MOVES model in a similar fashion to the process for developing the emissions for 1990 and 2010, using MOVES defaults for database requirements as with 1990.

We post-processed MOVES outputs for 2020 to reflect the 2017-2025 Corporate Average Fuel Economy (CAFE) standards. We post-processed the results by disaggregating the energy demand results by model year, and adjusting the 2017-2020 model year energy demand for light-duty vehicles based on the fuel economy factors included in Table I-2 of EPA's Notice of Proposed Rulemaking (NPRM) for the CAFE standards.[16] Changes in the EPA methodology for fuel economy factors between the NPRM and final rule were minor, and we believe that changes will not significantly affect the results. As with the 1990 and 2010 MOVES results, we adjusted energy demand for all fuels based on the ratio of LHV to HHV to account for the differing treatment of heating value in the two systems.

We selected EIA estimates (SIT default) for transportation-sector diesel use and relied on MOVES estimates to determine the portion of transportation diesel fuel consumed on- vs. non-road.

Transportation sector fuel values used for 2020 are presented in Table A-11.

Table A-11. Transportation sector fuel use in 2020 by fuel type (billion Btu)

Fuel Type	Fuel Use	Data Source
Distillate Fuel (total)	10,244	EIA (default)
Onroad	*7,297*	MOVES
Nonroad	*2,947*	Calculation
Ethanol	3,170	MOVES
Motor Gasoline	42,022	MOVES
Natural Gas	1,456	EIA (default)

T.F. Green Airport has experienced steady declines in passengers since 2005. Overall, 3,650,737 passengers flew from T.F. Green Airport in 2012, 36 percent lower than the 2005 ridership of 5,730,557 passengers.[17] Annual operations at the airport were 81,572 in 2010, well below the capacity level of 221,000 operations per year. A record of decision[18] allowing for expansion of

[16] 75 FR 229. EPA and National Highway Transportation Safety Administration. Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Proposed Rule. November 30, 2010. Available at: http://www.nhtsa.gov/fuel-economy. The final rule contained a range of fuel economy factors, and the central value of the range is, in most cases, approximately equal to the value given in the NPRM.

[17] RIAC, Ridership data, available at http://www.pvdairport.com/corporate/ri-airport-corporation/passenger-numbers, accessed on

[18] DOT, Record of Decision, Airport Improvement Program, T.F. Green Airport, Warwick, Rhode Island, September 23, 2011, available at: http://www.faa.gov/airports/environmental/records_decision/media/rod_pvd_20110923_text.pdf

the T.F. Green Airport indicates project completion to allow flights to and from the West Coast to depart and land by the year 2020. The document discusses efficiency improvements that will occur, but these improvements will almost certainly be accompanied by increases in aviation and jet fuel consumption. The northeast region overall will be increasing operations by 19 percent through 2030 over 2009 levels.[19] Interpolated through 2020, NESCAUM estimated a 9 percent increase in airport activity and associated aviation emissions between 2010 and 2020, and therefore estimated 2020 emissions from aviation at 9 percent higher than 2010 levels.

Table A-12. Transportation aviation emissions estimates for 2020

Year	Emissions (MMT CO_2e)			Method
	CO_2	CH_4	N_2O	
2010	0.2676	0.00016	0.00255	SIT
2020	0.2917	0.00018	0.00278	9% increase

ð **Stationary Combustion**

The Stationary Combustion module calculates emissions of methane and nitrous oxide from stationary source combustion. Inputs to the Stationary Combustion module were consistent to those entered in the "Carbon dioxide from combustion of fossil fuel" module (see above).

ð **Mobile Combustion**

The Stationary Combustion module calculates emissions of methane and nitrous oxide from mobile source combustion. Inputs to the Mobile Combustion module were consistent to those entered in the "Carbon dioxide from combustion of fossil fuel" module (see above).

ð **Agriculture**

Survey data from USDA NASS for 2010-2013 were unavailable for most animal types and crop values. Therefore, NESCAUM relied on default SIT data and methodology for projecting emissions to 2020. We forecast emissions based on historic data where possible, rather than using default projections.

ð **Coal**

NESCAUM excluded coalmines from the analysis because by 1990, all coal-mining operations in Rhode Island had ceased.

ð **Industrial Processes**

NESCAUM projected future emissions from industrial processes based on historic emissions. An error in the projection tool required that NESCAUM manually import historic data results rather than rely on SIT automation.

[19] Federal Aviation Administration (FAA). Terminal Area Forecast Summary. Fiscal Years 2009-2030.

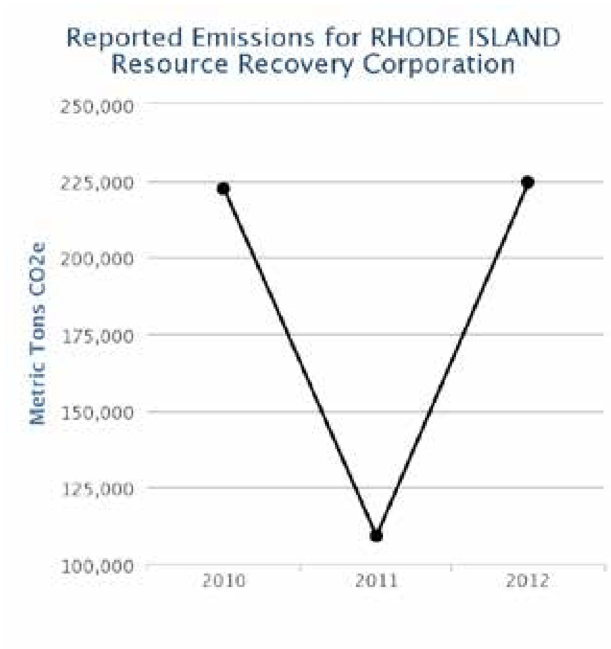
ð **Natural Gas and Oil**

NESCAUM assumed that 2010 level natural gas distribution emissions would continue through 2020. Emissions for 2011 (154,358.2 $MTCO_2e$) and 2012 (149,435.7 MT CO_2e) reported by the Narragansett Electric Company to EPA (through FLIGHT) are approximately level, and emissions calculated through SIT defaults are considerably higher by approximately a factor of two. NESCAUM assumes that future emissions from natural gas distribution will be equal to reported 2012 emissions from the Narragansett Electric Company.

ð **Solid Waste**

NESCAUM reviewed the Rhode Island Comprehensive Waste Management Plan[20] to confirm that SIT methodology would be consistent with planned landfill activities. Default SIT methodology projects emission levels considerably higher for 2010 and future years than reported for 2010 by RI RCC. Actual emissions reported by RI RRC in 2010 through 2012 (EPA FLIGHT) are presented in Figure A-1.

Figure A-1. Reported emissions for the Rhode Island Resource Recovery Corporation (EPA FLIGHT)



Emission levels in 2010 and 2012 are approximately level, though 2011 emissions are considerably lower. We assume that emissions in 2020 will be equivalent to 2012 emissions. NESCAUM identified increased capacity for electricity generation at the Central Landfill from an environmental assessment for the facility,[21] which projects annual methane emission avoidance of 1.4 MMT CO_2e. Because this value appears to be above the total projected emissions from the landfill, we hypothesize that the projected GHG emission prevention levels

[20] RI RRC, 2006, Rhode Island Comprehensive Solid Waste Management Plan.

[21] National Energy Technology Laboratory (NETL), Final Environmental Assessment for the Rhode Island LFG GenCo LLC Combined Cycle Electricity Generation Plant Fueled by Landfill Gas, Johnston, Rhode Island, August 2010, US Department of Transportation. DOE/EA-1742.

are overly optimistic. Therefore, we subtracted 10 percent of the total 1.4 MMT CO_2e (i.e., 0.14 MMT CO_2e) from 2012 level GHG emissions (0.22452 MT CO_2e) to estimate 2020 GHG emissions from the landfill, to derive a value of 0.08452 MMT CO_2e.

For projected emissions from waste combustion, we assumed zero future emissions, consistent with the fact that combustion of solid waste does not occur at the Central Landfill.

- **Wastewater**

Using the SIT Projection Tool to project future emissions based on historic emissions, NESCAUM assumed a linear GHG emissions growth between 1990 and 2010 from wastewater.

- **Land use, land use change, and forestry**

There is no accepted methodology provided within the SIT framework for projecting carbon flux from changes in land use and forestry. We did not characterize future emissions in this sector for this reason.

Attachment B:
Rhode Island greenhouse gas inventory based on electricity consumption

This document presents the same overall GHG emissions levels reflected in the main document, but from an electricity consumption-based perspective rather than from electricity generation alone.

EPA provides a module to calculate GHG emissions resulting from the consumption of electricity by end-users. Such emissions still occur at the electricity generator source (as described in the Fuel Combustion modules earlier), but result from the demand by end-users. Because we are already accounting for emissions occurring in-state by electricity generators, it would be double counting to simply add emissions resulting from end-user electricity demand. This analysis is supplemental to the main analysis, and should not be interpreted as either a replacement for the main analysis or as additive to it. The analysis presented in this document is for contextual purposes only.

NESCAUM relied on electricity consumption levels as presented in ENE 2013.

NESCAUM assumed consumption-based CO_2e emission factors that reflect the Rhode Island generation mix rather than regional consumption factors (from ISO-New England), such as those used by ENE to estimate emissions. We have selected this approach because Rhode Island may be a net electricity exporter, and though it is difficult to determine the source of electricity at the end-user, it is reasonable to expect that much of the electricity consumed in-state is also generated in-state. Table B-1 shows the emission rates that NESCAUM used for the consumption-based approach described here.

Table B-1. Emission rates for consumption-based emissions rates based on Rhode Island electricity generation

Year	Emission Rate (lb/MWh)	Methods
1990	1,307	Calculation using electricity sector emissions estimates from ENE 2013 and EIA electricity generation estimates
2010	959	From 2010 ISO-New England, Electric Generator Air Emissions Report, 2012, available at http://www.iso-ne.com/genrtion_resrcs/reports/emission/
2020	943	Calculation using electricity sector emissions estimates from ENE 2013 and ICF 2013 electricity generation estimates

Based on this approach, NESCAUM divided total Rhode Island electricity generation emissions into portions for in-state consumption and for export, and further divided in-state electricity consumption by sector category. Electricity consumption values are presented by year in Table B-2. NESCAUM developed emissions estimates (Table B-3) by multiplying electricity use

(Table B-2) by the emissions rate (Table B-1). An emission summary figure analogous to Figure 4 from the main document but from an electricity consumption perspective is presented in Figure B-1. From an electricity consumption perspective, the *Greenhouse Gas Action Plan* goals for 2010 and 2020 would be 13.04 MMT CO_2e and 11.74 MMT CO_2e based on the results of this analysis, and are projected to be achieved.

Table B-2. Summary of 1990, 2010, and 2020 Rhode Island electricity consumption (GWh)

Sector	1990	2010	2020
Residential electricity consumption	2,376	3,118	2,369
Commercial electricity consumption	2,688	3,693	3,222
Industrial electricity consumption	1,354	961	761
Transportation electricity consumption	0	27	19
Total in-state electricity consumption	6,419	7,799	6,371

Source: ENE 2013

Table B-3. Summary of 1990, 2010, and 2020 Rhode Island GHG emissions (MMT CO_2e) from in-state electricity consumption

Sector	1990	2010	2020
Emissions from residential electricity consumption	1.41	1.36	1.01
Emissions from commercial electricity consumption	1.59	1.61	1.38
Emissions from industrial electricity consumption	0.80	0.42	0.33
Emissions from transportation electricity consumption	0.00	0.01	0.01
Total emissions from in-state electricity consumption	3.81	3.39	2.73

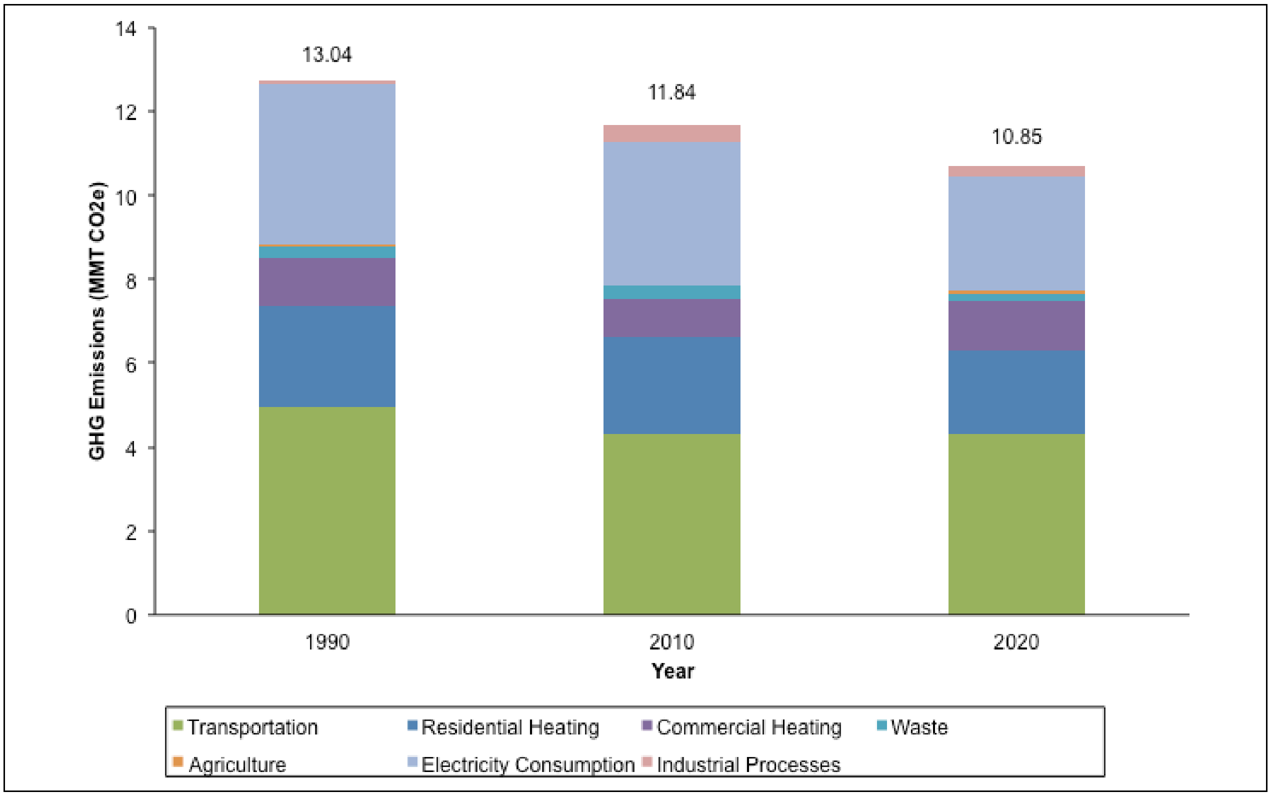
Using values for emissions from electricity generation presented in the main document, NESCAUM estimated the portion of emissions due to electricity exported from (or, in the case of 1990, imported to) Rhode Island. These values are presented in Table B-4.

Table B-4. Emissions from electricity exported (MMT CO_2e)

Sector	1990	2010	2020
GHG emissions from in-state electricity generation	0.79	3.17	3.67
GHG emissions from in-state electricity consumption	3.81	3.39	2.73
GHG emissions from electricity exported from Rhode Island	-3.02*	-0.23*	0.95

* Negative values reported for GHG emissions from electricity exported from Rhode Island may be interpreted as positive GHG emissions from electricity imports to Rhode Island.

Figure 4. Summary of Rhode Island GHG Emissions Estimates (MMT CO_2e)

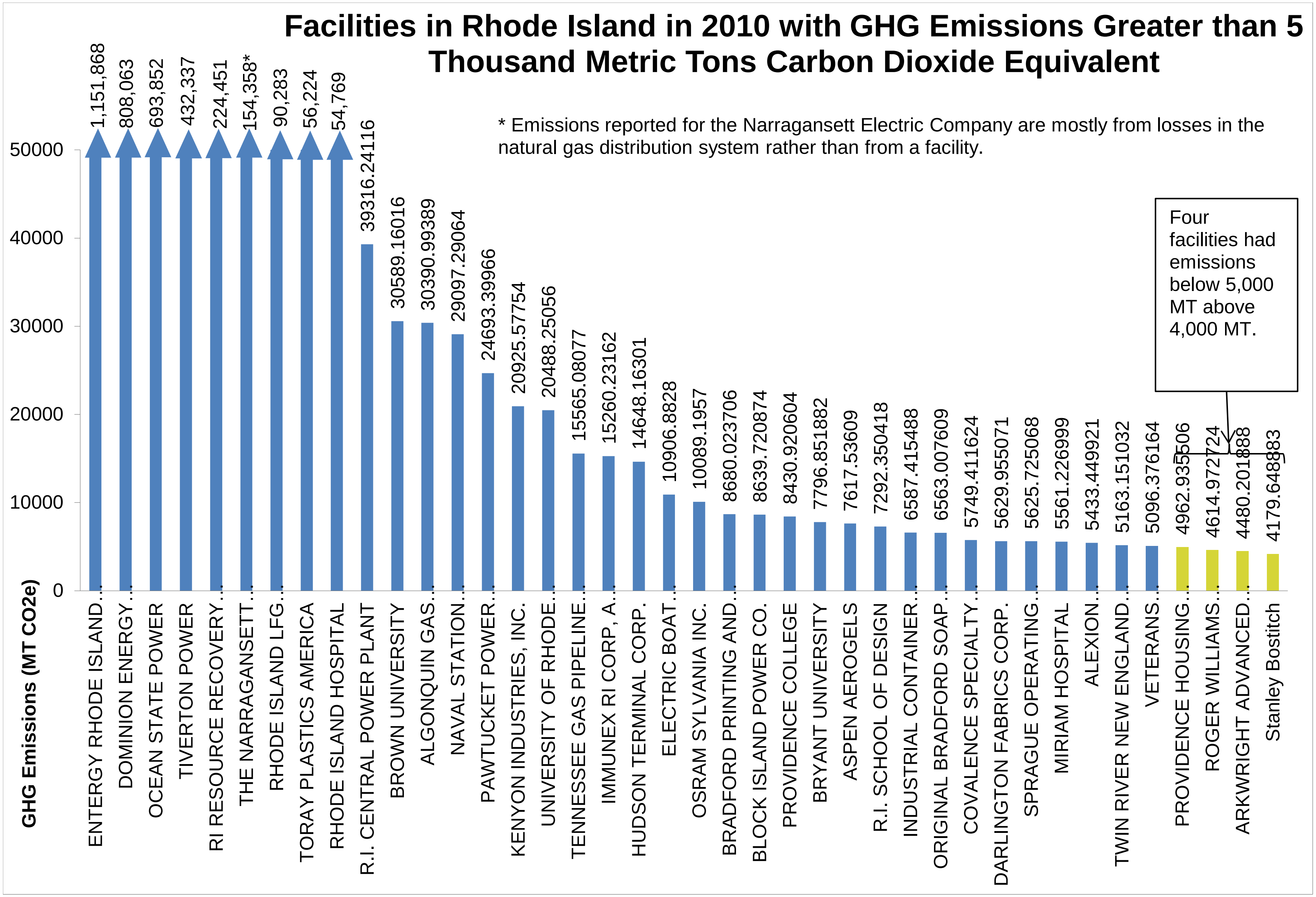


Note: Values are rounded to the nearest 0.01 MMT CO_2e.

Task 3 - Facilities in Rhode Island in 2010 with GHG Emissions Greater than 5 Thousand Metric Tons Carbon Dioxide Equivalent

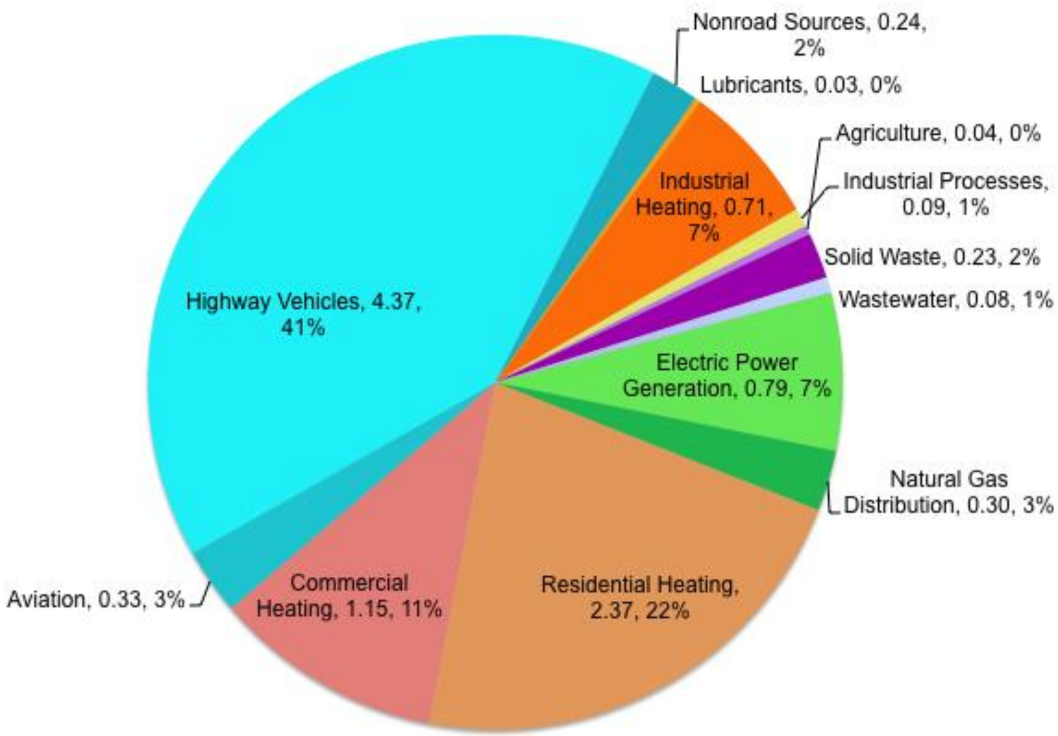
Row Labels	SITE_NAME	ADDRESS	CITY	ZIP	COUNTY	Sum of CO2e Emissions (MT)
3914	ENTERGY RHODE ISLAND STATE ENERGY, L.P.	24 SHUN PIKE	JOHNSTON	02919	PROVIDENCE	1,151,868
936	DOMINION ENERGY MANCHESTER STREET, INC.	40 POINT ST	PROVIDENCE	null	PROVIDENCE	808,063
2998	OCEAN STATE POWER	1575 SHERMAN FARM RD	BURRILLVILLE	02830	PROVIDENCE	693,852
3810	TIVERTON POWER	304 PROGRESS RD	TIVERTON	02878	NEWPORT	432,337
3860	RI RESOURCE RECOVERY CORPORATION	65 SHUN PIKE	JOHNSTON	null	PROVIDENCE	224,451
-	THE NARRAGANSETT ELECTRIC COMPANY	280 MELROSE ST	PROVIDENCE	02907	PROVIDENCE	154,358
3295	RHODE ISLAND LFG GENCO, LLC	65 SHUN PIKE	JOHNSTON	02919	PROVIDENCE	90,283
3052	TORAY PLASTICS AMERICA	50 BELVER AVE	NORTH KINGSTOWN	null	WASHINGTON	56,224
1283	RHODE ISLAND HOSPITAL	593 EDDY ST	PROVIDENCE	null	PROVIDENCE	54,769
1248	R.I. CENTRAL POWER PLANT	null	CRANSTON	02920	PROVIDENCE	39,316
187	BROWN UNIVERSITY	164 ANGELL ST	PROVIDENCE	02912	PROVIDENCE	30,589
53	ALGONQUIN GAS TRANSMISSION CO.	54 ALGONQUIN LN	BURRILLVILLE	02830	PROVIDENCE	30,391
1044	NAVAL STATION NEWPORT,CODE N8N	1 SIMONPIETRI DR	NEWPORT	02841	NEWPORT	29,097
3000	PAWTUCKET POWER ASSOCIATES	181 CONCORD ST	PAWTUCKET	02860	PROVIDENCE	24,693
824	KENYON INDUSTRIES, INC.	36 SHERMAN AVE	RICHMOND	null	WASHINGTON	20,926
1584	UNIVERSITY OF RHODE ISLAND/CONTIGUOUS	523 PLAINS RD	SOUTH KINGSTOWN	02881	WASHINGTON	20,488
3915	TENNESSEE GAS PIPELINE COMPANY, L.L.C.	null	BURRILLVILLE	02830	PROVIDENCE	15,565
3250	IMMUNEX RI CORP, A SUBSIDIARY OF AMGEN INC	40 TECHNOLOGY WAY	WEST GREENWICH	02817	KENT	15,260
3869	HUDSON TERMINAL CORP.	29 TERMINAL RD	PROVIDENCE	02909	PROVIDENCE	14,648
594	ELECTRIC BOAT CORPORATION	165 DILLABUR AVE	NORTH KINGSTOWN	null	WASHINGTON	10,907
572	OSRAM SYLVANIA INC.	1193 BROAD ST	CENTRAL FALLS	02863	PROVIDENCE	10,089
174	BRADFORD PRINTING AND FINISHING	460 BRADFORD RD	WESTERLY	null	WASHINGTON	8,680
167	BLOCK ISLAND POWER CO.	100 OCEAN AVE	NEW SHOREHAM	02807	WASHINGTON	8,640
1223	PROVIDENCE COLLEGE	1 CUNNINGHAM SQ	PROVIDENCE	02918	PROVIDENCE	8,431
3280	BRYANT UNIVERSITY	1150 DOUGLAS PIKE	SMITHFIELD	02917	PROVIDENCE	7,797
4031	ASPEN AEROGELS	3 DEXTER RD	EAST PROVIDENCE	02914	PROVIDENCE	7,618
1245	R.I. SCHOOL OF DESIGN	2 COLLEGE ST	PROVIDENCE	02903	PROVIDENCE	7,292
1051	INDUSTRIAL CONTAINER SERVICES - RI, LLC	455 GEORGE WASHINGTON	SMITHFIELD	02917	PROVIDENCE	6,587
1846	ORIGINAL BRADFORD SOAP WORKS INC.	200 PROVIDENCE ST	WEST WARWICK	02893	KENT	6,563
3261	COVALENCE SPECIALTY ADHESIVES	51 BALLOU BLVD	BRISTOL	null	BRISTOL	5,749
356	DARLINGTON FABRICS CORP.	48 CANAL ST	WESTERLY	02891	WASHINGTON	5,630

203	SPRAGUE OPERATING RESOURCES LLC	144 ALLENS AVE	PROVIDENCE	02903	PROVIDENCE	5,626
1514	MIRIAM HOSPITAL	164 SUMMIT AVE	PROVIDENCE	02906	PROVIDENCE	5,561
4040	ALEXION PHARMACEUTICALS, INC.	100 TECHNOLOGY WAY	SMITHFIELD	null	PROVIDENCE	5,433
4033	TWIN RIVER NEW ENGLAND GAMBLING CASINO	100 TWIN RIVER RD	LINCOLN	null	PROVIDENCE	5,163
1605	VETERANS ADMINISTRATION MEDICAL CENTER	830 CHALKSTONE AVE	PROVIDENCE	02908	PROVIDENCE	5,096
1228	PROVIDENCE HOUSING AUTH.-HARTFORD PARK	300 HARTFORD AVE	PROVIDENCE	02909	PROVIDENCE	4,963
3275	ROGER WILLIAMS UNIVERSITY	ONE OLD FERRY RD	BRISTOL	null	BRISTOL	4,615
100	ARKWRIGHT ADVANCED COATING, INC.	538 MAIN ST	COVENTRY	null	KENT	4,480
1438	Stanley Bostitch	0	0	00000	0	4,180


Facilities in Rhode Island in 2010 with GHG Emissions Greater than 5 Thousand Metric Tons Carbon Dioxide Equivalent
* Emissions reported for the Narragansett Electric Company are mostly from losses in the natural gas distribution system rather than from a facility.
Four facilities had emissions below 5,000 MT above 4,000 MT.
GHG Emissions (MT CO2e)
0
10000
20000
30000
40000
50000
1,151,868
808,063
693,852
432,337
224,451
154,358*
90,283
56,224
54,769
39316.24116
30589.16016
30390.99389
29097.29064
24693.39966
20925.57754
20488.25056
15565.08077
15260.23162
14648.16301
10906.8828
10089.1957
8680.023706
8639.720874
8430.920604
7796.851882
7617.53609
7292.350418
6587.415488
6563.007609
5749.411624
5629.955071
5625.725068
5561.226999
5433.449921
5163.151032
5096.376164
4962.935506
4614.972724
4480.201888
4179.648883
ENTERGY RHODE ISLAND…
DOMINION ENERGY…
OCEAN STATE POWER
TIVERTON POWER
RI RESOURCE RECOVERY…
THE NARRAGANSETT…
RHODE ISLAND LFG…
TORAY PLASTICS AMERICA
RHODE ISLAND HOSPITAL
R.I. CENTRAL POWER PLANT
BROWN UNIVERSITY
ALGONQUIN GAS…
NAVAL STATION…
PAWTUCKET POWER…
KENYON INDUSTRIES, INC.
UNIVERSITY OF RHODE…
TENNESSEE GAS PIPELINE…
IMMUNEX RI CORP, A…
HUDSON TERMINAL CORP.
ELECTRIC BOAT…
OSRAM SYLVANIA INC.
BRADFORD PRINTING AND…
BLOCK ISLAND POWER CO.
PROVIDENCE COLLEGE
BRYANT UNIVERSITY
ASPEN AEROGELS
R.I. SCHOOL OF DESIGN
INDUSTRIAL CONTAINER…
ORIGINAL BRADFORD SOAP…
COVALENCE SPECIALTY…
DARLINGTON FABRICS CORP.
SPRAGUE OPERATING…
MIRIAM HOSPITAL
ALEXION…
TWIN RIVER NEW ENGLAND…
VETERANS…
PROVIDENCE HOUSING…
ROGER WILLIAMS…
ARKWRIGHT ADVANCED…
Stanley Bostitch

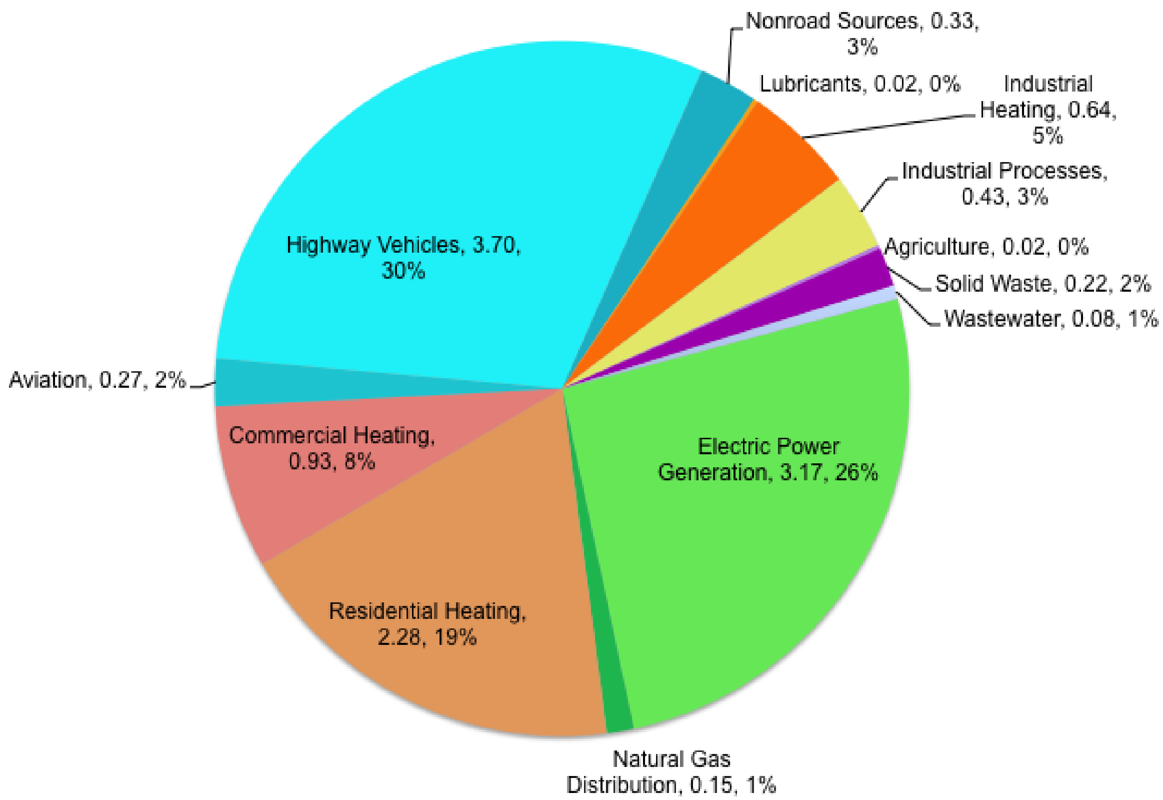
Summary of 1990 Baseline Rhode Island GHG Emissions Inventory

Sector	Emissions (MMT CO_2e)	Relative Contribution
Energy	1.09	10.2%
Electric Power Generation	*0.79*	*7.3%*
Natural Gas Distribution	*0.30*	*2.8%*
Residential Heating	2.37	22.1%
Commercial Heating	1.15	10.7%
Transportation	4.97	46.3%
Aviation	*0.33*	*3.1%*
Highway Vehicles	*4.37*	*40.7%*
Nonroad Sources	*0.24*	*2.2%*
Lubricants	*0.03*	*0.3%*
Industrial	0.81	7.5%
Industrial Heating	*0.71*	*6.7%*
Industrial Processes	*0.09*	*0.9%*
Agriculture	0.04	0.4%
Waste	0.31	2.8%
Solid Waste	*0.23*	*2.1%*
Wastewater	*0.08*	*0.7%*
TOTAL	**10.74**	**100.0%**



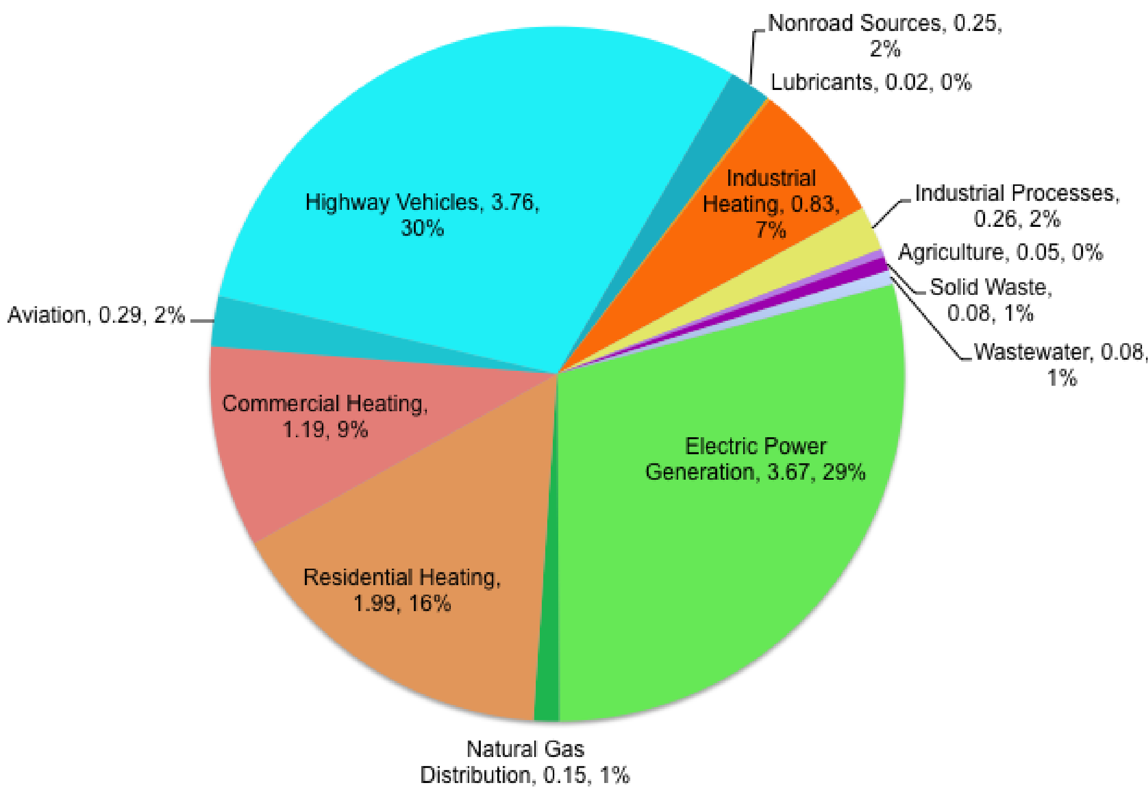
Summary of 2010 Rhode Island Greenhouse Gas (GHG) Emissions Inventory

Sector	Emissions (MMT CO_2e)	Relative Contribution
Energy	3.32	27.1%
Electric Power Generation	*3.17*	*25.8%*
Natural Gas Distribution	*0.15*	*1.3%*
Residential Heating	2.28	18.6%
Commercial Heating	0.93	7.6%
Transportation	4.33	35.3%
Aviation	*0.27*	*2.2%*
Highway Vehicles	*3.70*	*30.2%*
Nonroad Sources	*0.33*	*2.7%*
Lubricants	*0.02*	*0.2%*
Industrial	1.07	8.7%
Industrial Heating	*0.64*	*5.2%*
Industrial Processes	*0.43*	*3.5%*
Agriculture	0.02	0.2%
Waste	0.30	2.4%
Solid Waste	*0.22*	*1.8%*
Wastewater	*0.08*	*0.6%*
TOTAL	**12.25**	**100.0%**



Summary of 2020 Rhode Island Business-as-Usual GHG Emissions Projection

Sector	Emissions (MMT CO_2e)	Relative Contribution
Energy	3.82	30.3%
Electric Power Generation	*3.67*	*29.1%*
Natural Gas Distribution	*0.15*	*1.2%*
Residential Heating	1.99	15.8%
Commercial Heating	1.19	9.4%
Transportation	4.32	34.2%
Aviation	*0.29*	*2.3%*
Highway Vehicles	*3.76*	*29.8%*
Nonroad Sources	*0.25*	*2.0%*
Lubricants	*0.02*	*0.1%*
Industrial	1.09	8.6%
Industrial Heating	*0.83*	*6.6%*
Industrial Processes	*0.26*	*2.1%*
Agriculture	0.05	0.4%
Waste	0.17	1.3%
Solid Waste	*0.08*	*0.7%*
Wastewater	*0.08*	*0.7%*
TOTAL	**12.63**	**100.0%**



Rhode Island's Greenhouse Gas Inventory

Thursday, March 20, 2014

Leiran Biton, NESCAUM

Paul Miller, NESCAUM

Rhode Island Executive Climate Change Council Meeting

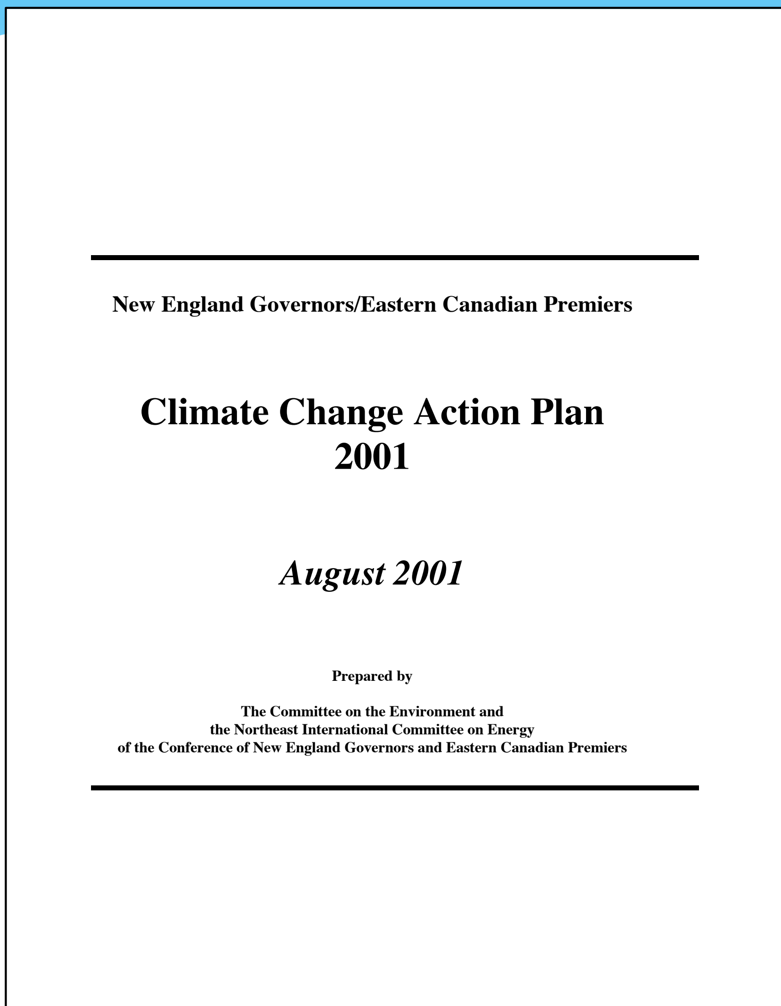
NESCAUM

NESCAUM

Northeast States for Coordinated Air Use Management

- Non-profit association, created by states in 1967
- Board made up of state air directors
- Helps states develop regional policy positions and solutions
- Provides states with scientific, technical, and policy support

Existing GHG Commitments: Regional Goals



New England Governors/Eastern Canadian Premiers

Climate Change Action Plan 2001

August 2001

Prepared by

The Committee on the Environment and
the Northeast International Committee on Energy
of the Conference of New England Governors and Eastern Canadian Premiers

Short-term

- 1990 levels by 2010

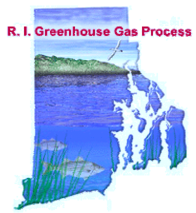
Mid-term

- 10% below 1990 levels by 2020

Long-term

- 75-80% below current levels

Existing GHG Commitments: Rhode Island GHG Action Plan



Rhode Island
Greenhouse Gas Action Plan

Developed by
The Rhode Island Greenhouse Gas Stakeholder Process

Convened by
Rhode Island Department of Environmental Management
Rhode Island State Energy Office

Project Manager/Facilitator
Raab Associates, Ltd.

Technical/Policy Consultant
Tellus Institute

July 15, 2002

- Set Rhode Island goals equal to regional goals
- Proposed program & policy options to meet goals

Report Back on GHG Emissions

35th Annual Conference of New England Governors and Eastern Canadian Premiers

Halifax, Nova Scotia, July 10-12, 2011

35e Conférence annuelle des gouverneurs de la Nouvelle-Angleterre et des premiers ministres de l'Est du Canada

Halifax, Nouvelle-Écosse, du 10 au 12 juillet 2011

RESOLUTION 35-5

RESOLUTION CONCERNING CLIMATE CHANGE

NESCAUM prepared:

1. GHG inventory to assess achievement of goals
2. Major point sources and opportunities for GHG reductions

How Do States Prepare GHG Inventories?

EPA's State Inventory Tool (SIT)

SIT Modules

- Fossil fuel combustion
- Stationary combustion
- Mobile combustion
- Natural gas and oil systems
- Coal mining
- Industrial processes
- Agricultural processes
- Municipal solid waste
- Wastewater
- Land use, land use change, and forestry
- Indirect emissions from electricity consumption

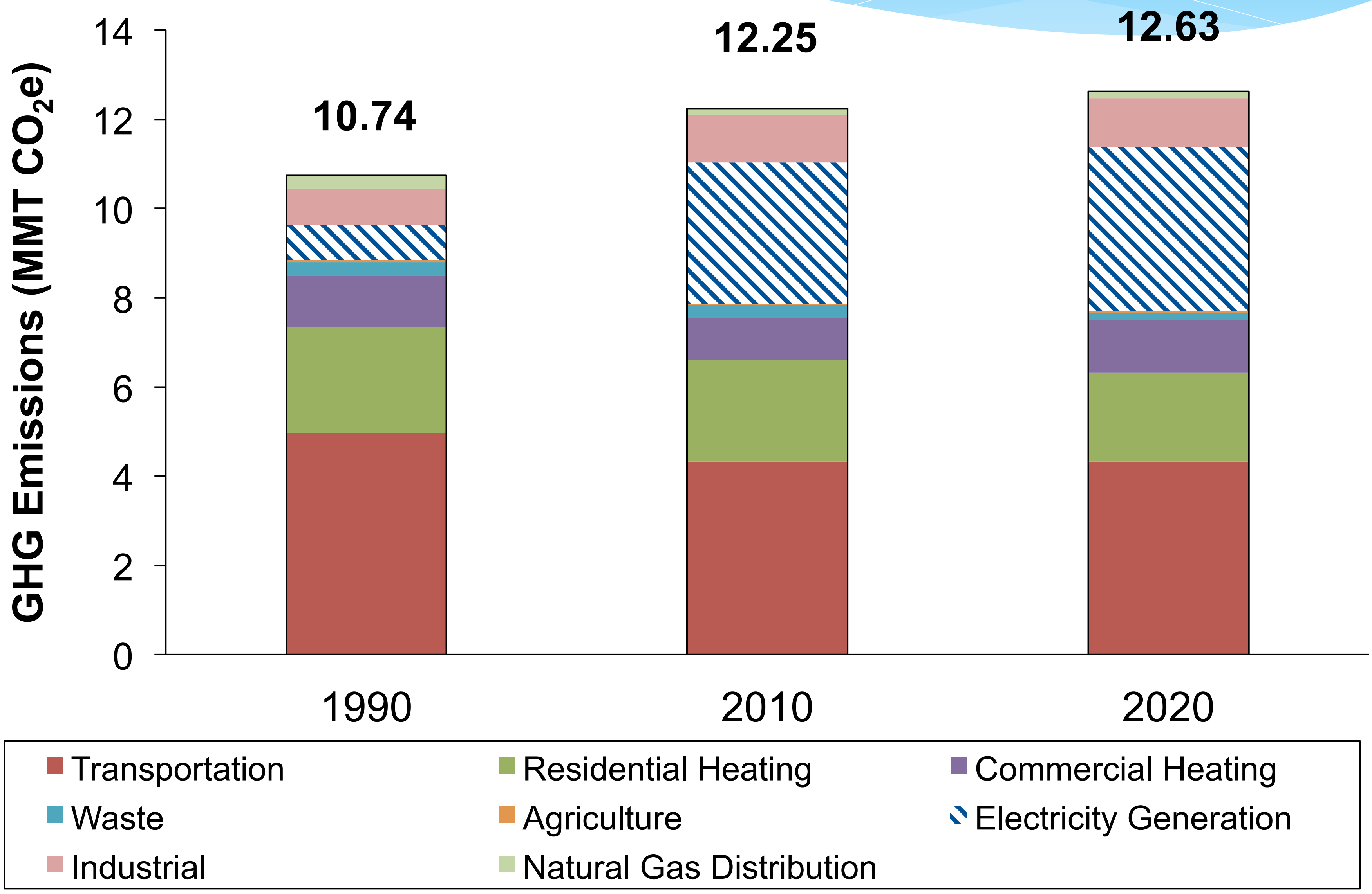
Synthesis Tool

SIT Inventory Sector

- Energy
- Industrial processes
- Agriculture
- Land use, land use change, and forestry
- Waste
- Indirect emissions from electricity consumption

GHG Inventory Approach

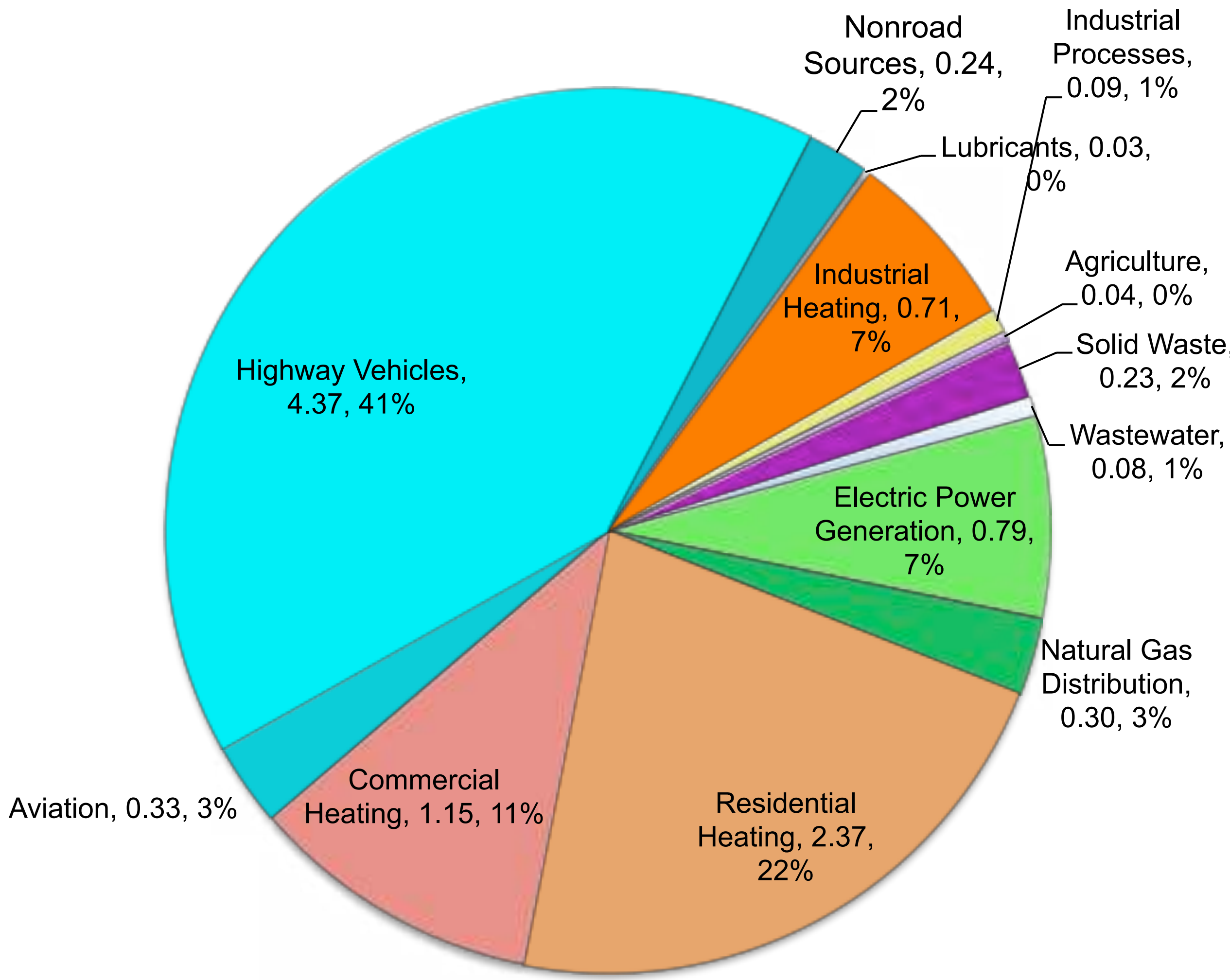
GHG Inventory Summary



1990:

10.74 MMT CO_2e

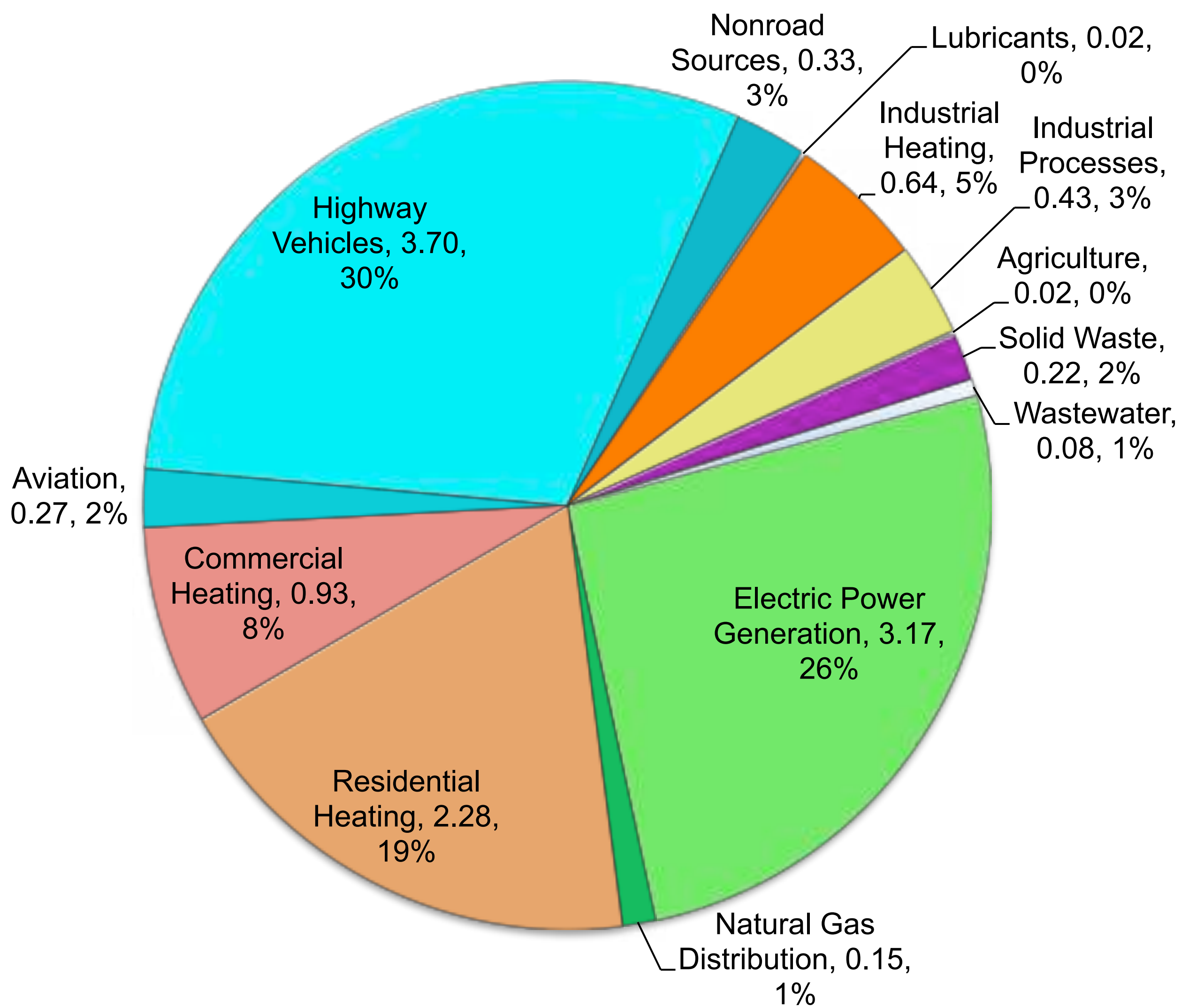
- Sector
- GHG Emissions ($MMT\ CO_2e$)
- Contribution (%)



2010:

12.25 MMT CO_2e

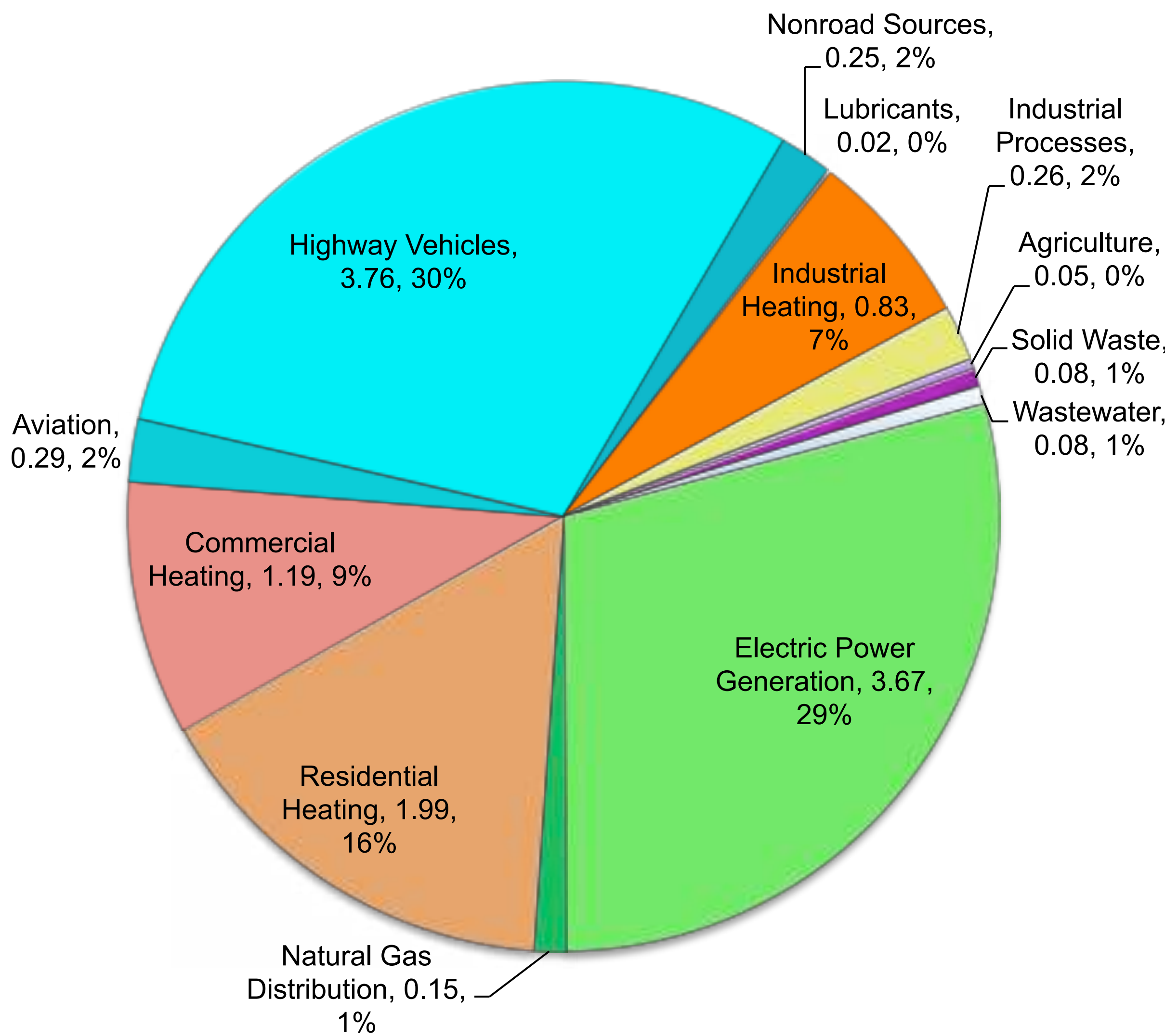
- Sector
- GHG Emissions ($MMT\ CO_2e$)
- Contribution (%)



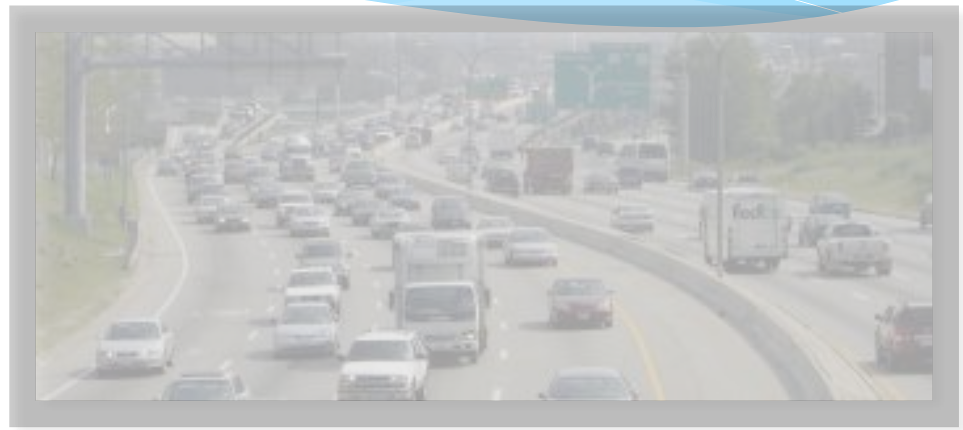
2020 Projection:

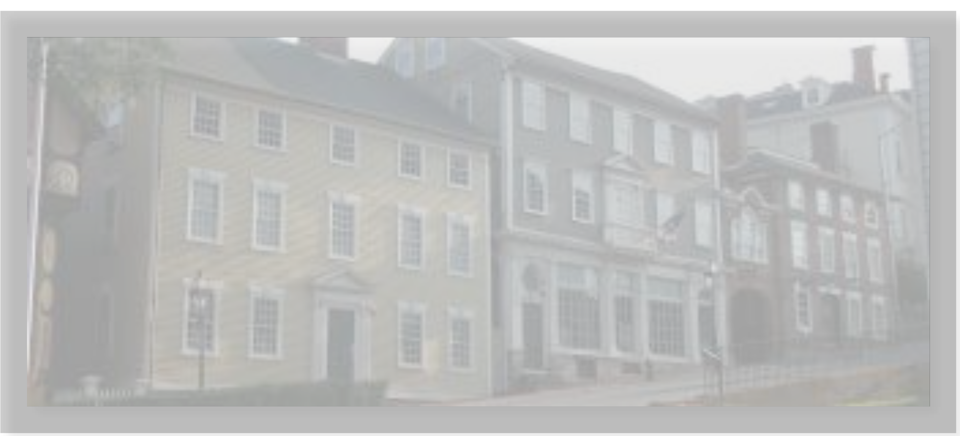
12.63 MMT CO_2e

- Sector
- GHG Emissions ($MMT\ CO_2e$)
- Contribution (%)

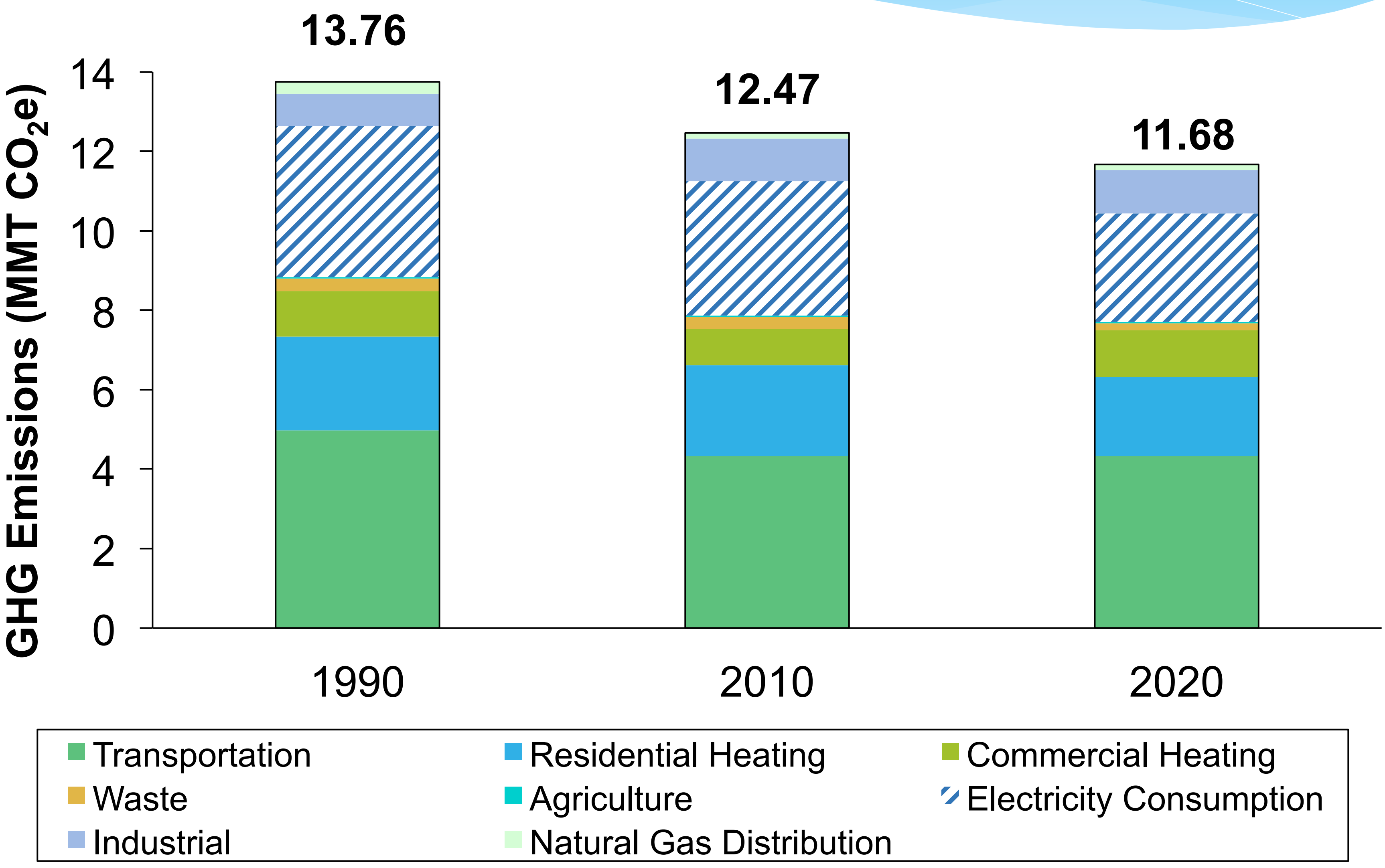


GHG Inventory: Consumption-based Approach





GHG Inventory: Consumption-based



Two Perspectives: Two Results

Short-term

- 1990 levels by 2010

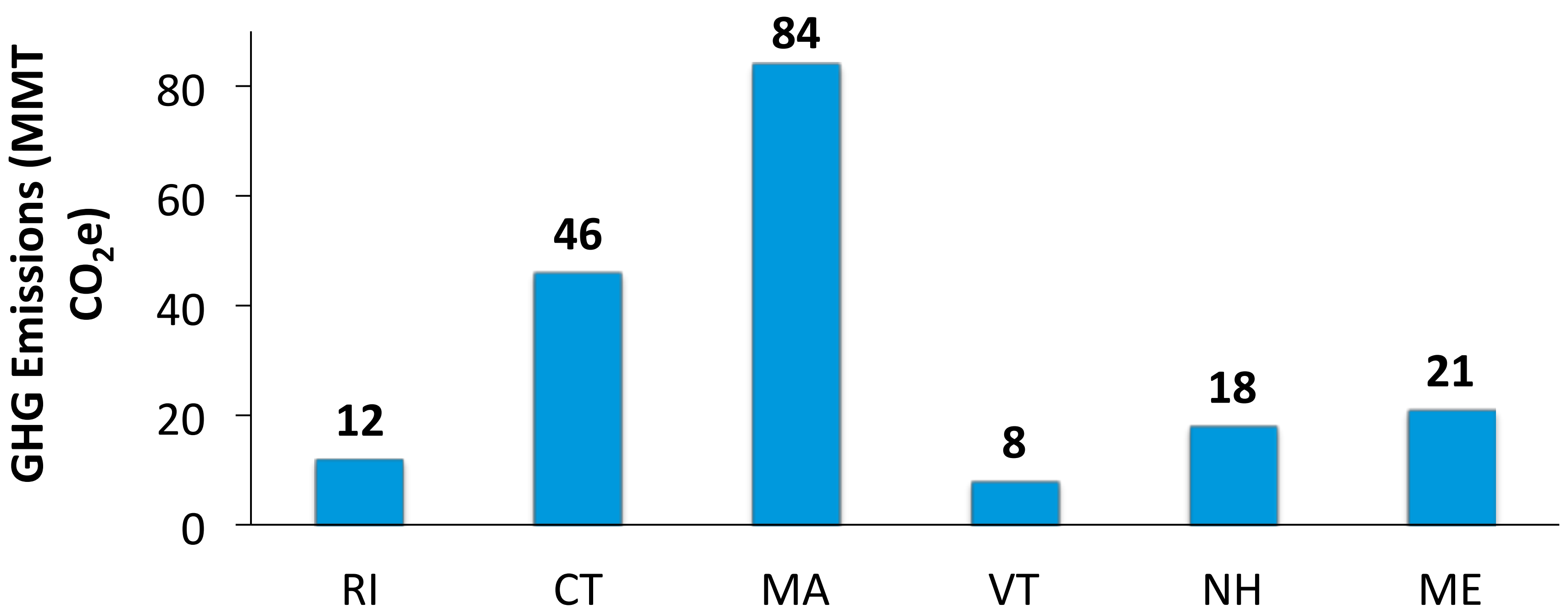
Mid-term

- 10% below 1990 levels by 2020

Rhode Island GHG Emissions (MMT CO_2e)

Emissions Goals/Estimates	2010	2020
Generation-based goal	10.74	9.67
Generation-based emissions	12.25	12.63
Consumption-based goal	13.76	12.38
Consumption-based emissions	12.47	11.68

Regional Perspective: New England States' 2010 GHG Emissions



Source: RI DEM

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