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SJTPO Region Greenhouse Gas Emissions Inventory

Final Summary Report

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INTRODUCTION

The SJTPO region consists of four New Jersey counties—Atlantic, Cape May, Cumberland, and Salem—and 68 municipalities. There is broad scientific consensus that human-caused greenhouse gas (GHG) emissions are impacting the earth's climate, and that increasing atmospheric GHG concentrations will result in very significant adverse global, regional, and local environmental impacts.[1] Projected effects of climate change include sea level rise, increased frequency and severity of storms, increased storm surge, and temperature rise, all of which could affect the region and require consideration in planning for the future. The GHG inventory for the SJTPO region will be a basis for local and regional planning efforts to reduce emissions and is designed to facilitate that future use of the inventory.

Efforts to quantify and reduce GHG emissions and to plan for resilience to climate change have been ongoing at the State, regional, and local levels. New Jersey's Global Warming Response Act (GWRA) calls for a reduction in GHG emissions to 1990 levels by 2020, approximately a 20% reduction below estimated 2020 business-as-usual emissions, followed by a further reduction of emissions to 80% below 2006 levels by 2050. Some of the emission reduction programs within the SJTPO counties include the development of the landfill gas-to-energy plant in Deerfield Township, the Pilesgrove Township solar farm, as well as numerous smaller scale solar panel installations facilitated by New Jersey's Solar Energy Advancement and Fair Competition Act, the anti-idling education campaign undertaken by Cape May City, the conversion of coal and oil burning plants to natural gas, and many others. The region's resources make many areas a summer destination, and therefore this inventory also addresses GHG emissions associated with the seasonal population.

This region-wide GHG inventory is part of a larger, long-range climate change initiative at SJTPO, which will include a forecast of the inventory, and may include mitigation and adaptation research and planning, undertaking an inventory of climate vulnerable facilities within the region, and the creation of a framework for incorporating climate impacts into evaluation criteria for programs and project selection and prioritization. The SJTPO inventory has been developed to be consistent with similar efforts in the neighboring Metropolitan Planning Organizations (MPOs)—North Jersey Transportation Planning Authority (NJTPA) and Delaware Valley Regional Planning Commission (DVRPC), as well as available guidance for developing regional GHG inventories (*e.g.*, the U.S. Environmental Protection Agency's (EPA's) Draft Regional Guidance).

The inventory will serve as the basis for formulating and evaluating GHG reduction policies and action plans, at the regional, county, and municipal levels. This effort has been designed to not only produce a quality inventory, but to also set the foundation and begin to define the approach for those future efforts by addressing emissions in a format most useful for that future work and specific to SJTPO. The inventory presents GHG emissions from fuel combustion and electricity consumption in the residential, commercial, and industrial uses (RCI); on-road, non-road, aviation, marine, and rail transportation; industrial processes and fossil fuel industry (IP&FF); agricultural sources, including crop production and livestock management; solid waste and wastewater management; and land use, land use change, and forestry (LULUCF).

The detailed methodology is presented in the Protocol included in **Appendix D**, including a methodology for forecasting to future years. The Protocol also outlines additional details regarding accounting approaches, terminology, and acronyms. Emissions are reported for a

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[1] Intergovernmental Panel on Climate Change, Climate Change 2007: Synthesis Report, Summary for Policymakers, Fourth Assessment Report, November 2007, https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf.

baseline year, 2010, for the entire SJTPO region and by county. Additional detailed data at the municipal level are reported in **Appendix A** to the extent practicable.

The inventory effort resulted in the gathering and development of extensive information which may be useful for future emissions mitigation planning efforts, not all of which could be reported in this document. Two emissions accounting approaches were used where practicable: consumption-based and direct—see the Protocol in **Appendix D** for an extensive discussion of these approaches. In general, direct emissions are most useful when evaluating the mitigation of a source (e.g., electricity power plants) while consumption based emissions are most useful when evaluating mitigation of a use (e.g., emissions associated with consumption of fuels and products). While both may be useful in some cases, the report focuses on the consumption-based results at the region and county levels. In addition to these consumption-based accounting emissions, estimates of the additional emissions associated with the full energy-cycle emissions (i.e. the upstream emissions associated with producing fuels, power, or materials) were derived. The full energy cycle estimates provide a more complete understanding of the GHG impacts of measures that reduce consumption of energy and materials. The following exceptions apply: aviation and commercial marine emissions do not include full consumption-based emissions from origin to destination but rather only local emissions; and industrial process and waste management emissions do not include the full upstream emissions associated with extracting, manufacturing, transport, and disposal of products. A detailed discussion of accounting methods and the reasoning for these exceptions is provided in the inventory Protocol, included in **Appendix D**.

For additional results at the municipal level and alternative results (direct accounting method results) see **Appendix B**. Some useful details regarding activity data, emission estimation methods, and other details regarding the analyses can be found in **Appendix C**. Additional useful data developed as part of this effort are available, including physical units such as fuel use and vehicle miles traveled (VMT), emissions of each specific GHG, and more detailed subsector and source-specific data and results; these full details are available in the inventory workbooks.

EXECUTIVE SUMMARY

Total gross SJTPO region emissions from all sectors in 2010 are estimated at 9.94 million metric tons carbon dioxide equivalent (MMtCO_2e), with an additional 1.93 MMtCO_2e of energy cycle emissions associated with the production and transport of fuels;[2] however, energy cycle emissions associated with the production and transport of goods/materials was not included (e.g., emissions upstream of the Waste Management sector). These emissions are reduced by 0.97 MMtCO_2e due to sequestration of carbon in forested lands, equivalent to approximately 9.8% of the gross emissions.

The Residential, Commercial, and Industrial (RCI) sector contributes to 44% of total gross CO_2e emissions within the SJTPO region in 2010. The sector emissions stem from residential, commercial, and industrial use of fuel and electricity. Emissions account for energy used in buildings (for heating, cooling, and lighting), fuels used for processes in manufacturing, and fuel used to power non-road equipment associated with residential, commercial, and industrial uses, such as lawn mowers, recreational vehicles, and construction equipment.

Electricity use in the RCI sector generates 72% of the sector's emissions, while direct fuel use (for example natural gas and fuel oil used for home heating) accounts for the remaining 28% of RCI emissions. The greatest share of emissions is produced by commercial uses—49%. Residential use is responsible for 34% of the RCI emissions. Industrial use and non-road engines used in the RCI sector generate 11% and 6% of the RCI sector emissions, respectively.

RCI emissions by subsector (fuel and electricity) and by use (residential, commercial, and industrial) are allocated to the municipality level. The share of emissions for residential use is consistent with population share by municipality, and emission increases (in some case substantial) are observed during the summer season for municipalities that have large seasonal populations. Commercial and industrial emissions by county are consistent with employment share by county, but at the municipality level differences arise in areas that include a relatively large commercial or industrial emission source that is not a large employment center (i.e., that need only a handful of workers to operate).

The Transportation sector represents 45% of total gross CO_2e emissions within the SJTPO region in 2010. The sector is comprised of five major subsectors, including: on-road vehicles, aviation, marine, rail, and off-road recreational vehicles. The on-road vehicle subsector includes all passenger and commercial vehicles. The aviation subsector includes emissions from aircraft landing and takeoff cycle (on-ground and below 3,000 feet) and ground support equipment. The marine subsector includes emissions both commercial and recreational marine vessels. The rail subsector includes emissions from both passenger rail and freight rail locomotives.

The on-road vehicle subsector is the dominant subsector within transportation, accounting for 85.6% of total Transportation sector GHG emissions. The recreational marine subsector represents the second largest share, with 9.3% of total Transportation sector GHG emissions, associated with the large amount of boating activity in the region. The other subsectors make up the remaining 5.1%. 99% of all Transportation sector GHG emissions are CO_2.

Transportation emissions by subsector are allocated to the county level, and where data is available, to the municipality level. The share of emissions by county is consistent overall with population and employment shares by county within the region. By subsector, the allocation by county shows more variance, as special transportation generators such as the location of a

[2] Note that some double-counting exists within energy cycle emissions, inherent in the fact that upstream emissions are generally also direct emissions when occurring within the same boundaries. For example, upstream emissions for fuel include transport of fuels, including a small amount within SJTPO.

major airport (Atlantic County), port (Salem County), freight rail terminus (Salem County), or multiple large marinas (Cape May County), can drive the subsector inventory results.

The on-road sector shows the most variance at the municipality level, particularly when evaluating GHG emissions per capita. Major destinations on the shore all show larger shares of total regional GHG emissions than their share of regional annual resident population. The on-road subsector inventory quantifies the role of summer season emissions compared with annual emissions, to reflect how tourism and recreational activity impact total emissions.

Future GHG emissions in the Transportation sector are reliant on three primary inputs: (1) total activity in terms of vehicle miles, passenger miles, or ton miles travelled, (2) the efficiency of the travel in terms of miles per gallon, passenger miles per gallon, or ton miles per gallon, and (3) the carbon content and type of the fuel consumed. For example, we anticipate total transportation activity in the region to continue to grow at a rate comparable to the growth in the regional economy. The primary question, particularly in the on-road passenger vehicle subsector is the extent to which growth in travel activity occurs in single-occupant vehicles versus shared-ride, public transportation, or non-motorized modes. New federal standards already finalized or proposed will lead to significant reductions in energy consumed by on-road vehicles, locomotives, and marine engines. More extensive penetration of low-carbon fuel and electric vehicle infrastructure and associated vehicle technologies improving the reliability of these fuels, will lead to a shift in the profile of fuel consumed away from gasoline and diesel and towards biofuels and electricity.

Industrial Process and Fossil Fuel (IP&FF) sector emissions represent 7.7% of the 2010 regional gross GHG emissions. These emissions come mostly from natural gas transmissions and distribution losses and ozone depleting substance (ODS) substitutes, in addition to small amounts from non-energy industrial processes and the use of certain chemicals. This fraction is somewhat large as compared with other regions. While the emissions in this sector represent a fraction of the state-wide emissions (presented in the NJDEP GHG inventory) in line with the region's share of population and employment, it is possible that a detailed bottom up analysis would reveal other differences in the region (e.g., gas leaks can be associated with specific facilities, which may or may not be in the region). Should mitigation efforts focus on this sector, a more detailed examination of these emissions would be recommended.

The Agriculture sector contributes about 0.7% of the 2010 regional gross GHG emissions. These emissions are produced during crop cultivation (including non-road engine fuel use) and livestock management activities. Overall, the agriculture emissions represent a smaller fraction of the region wide emissions than may have been expected due to the large amount of agricultural activity in the region. This is because there is not much large livestock (especially cattle and pigs), and most of the crops grown in the region are not large consumers of nitrogen fertilizers (aside from some corn/sorghum/vegetables mainly in Salem County). The data and procedures used to develop municipal-level emission estimates represent a bottom-up approach and are a marked improvement over similar efforts that have relied on top-down approaches (e.g., allocation of state-level emissions to counties and municipalities). For municipalities with significant agricultural activity, the contributions to total GHG emissions are larger than mentioned for the regional total. Unless there was significant growth in livestock operations (particularly dairies, hog farms, or poultry) or large shifts to crops with much higher nutrient requirements, there should not be much growth in future year emissions.

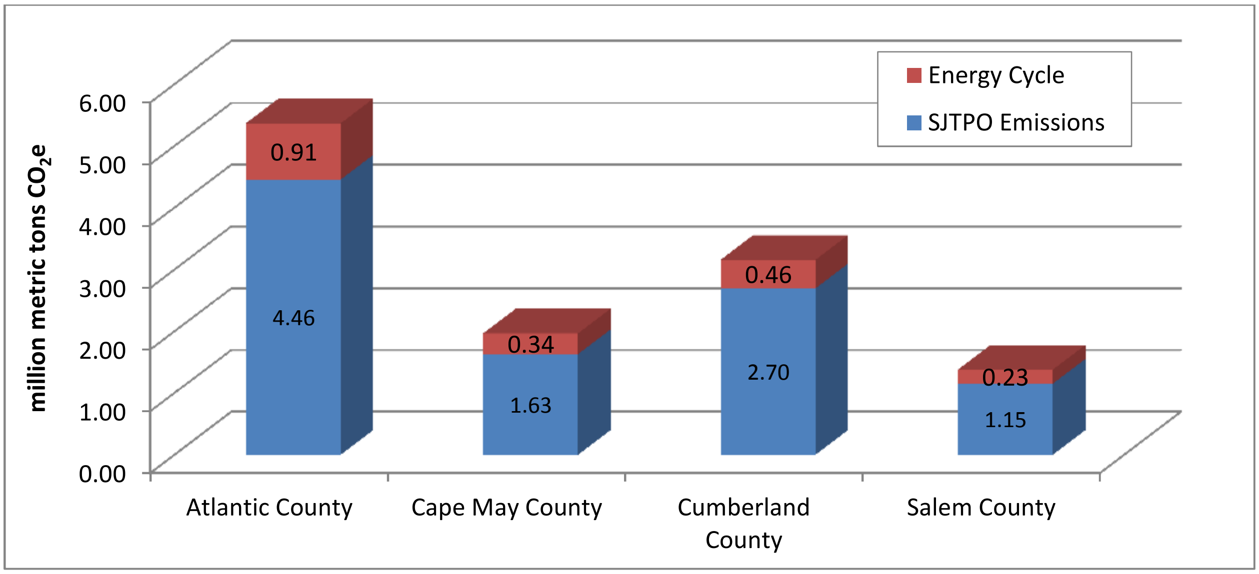
The Land Use, Land Use Change, and Forestry (LULUCF) sector was estimated to sequester 0.97 MMtCO_2e in 2010, equivalent to roughly 9.8% of the gross emissions in the region. Nearly all of this sequestration occurred within the region's forested lands. About 2% of the sequestration came from urban forests. Overall, regional forests appear to be nearing their peak carbon density; this means that the carbon sequestration rates in coming decades are expected to decline from current estimated rates.

The Waste Management sector includes emissions from solid waste management (mainly landfilling and composting) and wastewater treatment (municipal only, since no industrial wastewater treatment operations were identified in the region). On a gross emissions basis, the sector contributes 1.9% of the 2010 regional total. Emissions for this sector are presented in the body of this report on a consumption-basis, meaning that they are attributed to the point of waste generation rather than the point of emission (i.e., landfill or treatment plant location). Direct emissions were also generated and are presented in **Appendix B**. Importantly, even though the emissions were developed on a consumption-basis, the upstream emissions associated with these waste materials were outside the scope of analysis for this project (these emissions are referred to in this report as “energy cycle” emissions). Previous studies indicate that inclusion of these upstream emissions could result in a 10-fold increase in GHG emissions associated with the sector. About two-thirds of the GHG emissions are attributed to solid waste management. Over 90% of the solid waste emissions (119,000 metric tons carbon dioxide equivalent, or $mtCO_2e$) come from landfill methane releases.

BASE YEAR 2010 INVENTORY REGION-WIDE AND COUNTY SUMMARY

Total SJTPO gross region emissions from all sectors in 2010 are estimated at 9.94 MMtCO_2e, with an additional 1.93 MMtCO_2e of energy cycle emissions associated with the production and transport of fuels;[3] however, energy cycle emissions associated with the production and transport of goods/materials was not included (e.g., emissions upstream of the Waste Management sector). The distribution of emission by county is presented in **Figure 1**. These emissions are offset by carbon sinks of 0.97 MMtCO_2e associated with the LULUCF sector, due to increases of carbon storage in forests and urban trees, resulting in net emissions of 8.97 MMtCO_2e, or 10.90 MMtCO_2e including energy cycle emissions. In the LULUCF sector, the annual sequestration of carbon substantially exceeds emissions of GHGs from land use change and urban fertilizer use (these are minor sources as compared with the sinks). Net emissions, excluding sequestration, are presented in **Figure 2**.

Figure 1
SJTPO GHG Gross Emissions by County, 2010 (All Sectors)



As expected, the emissions in the SJTPO region are much less than other larger, more populated regions including NJTPA (84 MMtCO_2e in 2010) and DVRPC (82 MMtCO_2e in 2010).

The following sectors and subsectors were analyzed in this inventory:

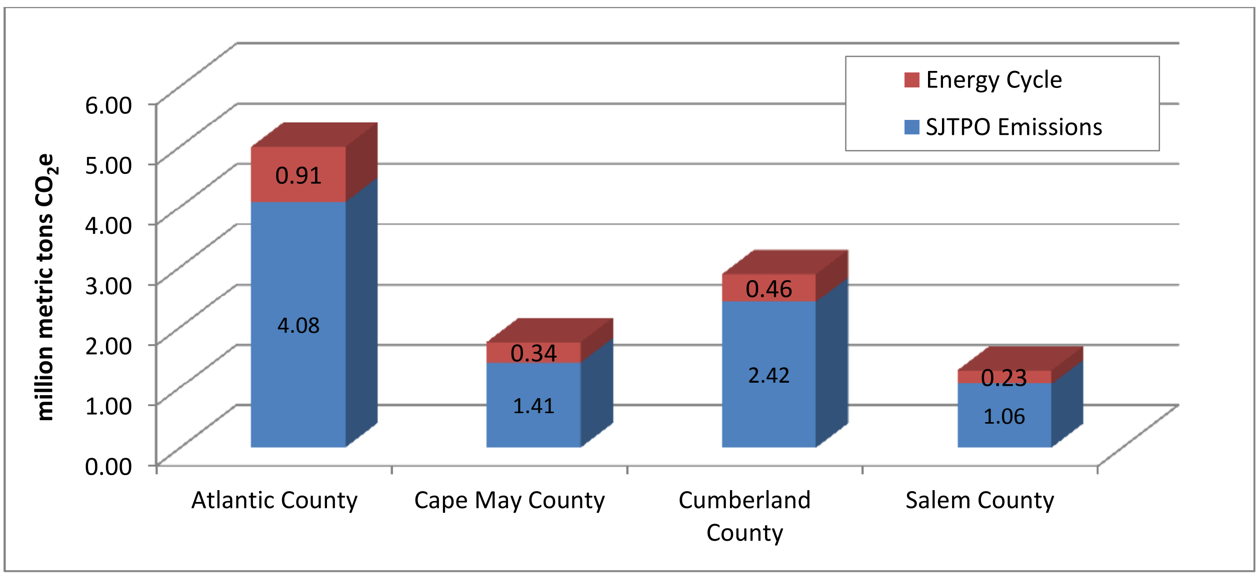
1. Residential, Commercial, and Industrial (RCI) Fuel Use and Electricity Consumption
   - Electricity (all electricity consumption for all uses)
   - Fuel Use (including building and process energy, and non-road engines for industrial, commercial, construction, lawn and garden)
2. Transportation
   - On-Road

[3] Note that some double-counting exists within energy cycle emissions, inherent in the fact that upstream emissions are generally also direct emissions when occurring within the same boundaries. For example, upstream emissions for fuel include transport of fuels, including a small amount within the SJTPO region.

- Non-Road Recreational Vehicles
- Aviation
- Rail—Passenger
- Rail—Freight
- Marine (including commercial and recreational)

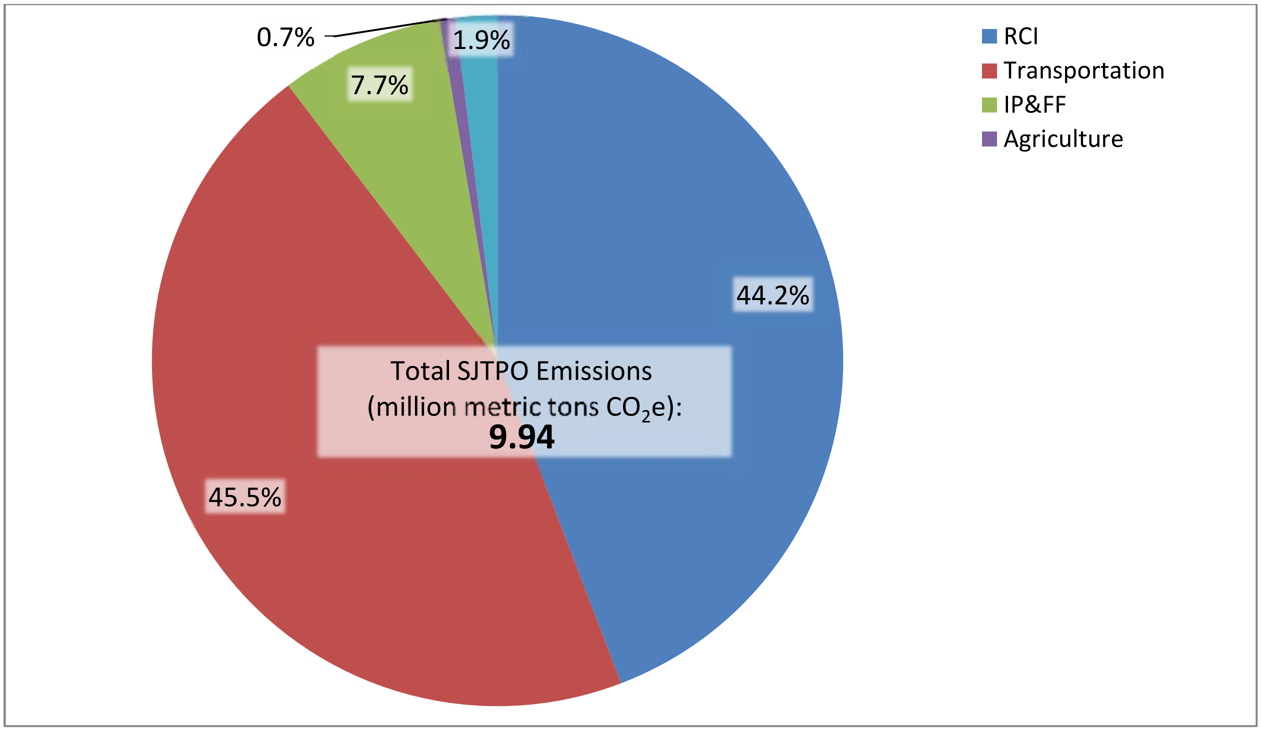
3. Industrial Processes and Fossil Fuel (IP&FF) (including all non-energy process emissions, direct emissions from use of products, and natural gas leakage)
4. Agriculture
   - Crop Production
   - Agricultural Non-Road Engines
   - Livestock Management
5. Waste Management
   - Solid Waste
   - Wastewater
6. Land Use, Land Use Change, and Forestry (LULUCF)
   - Forested Lands (including land use change, forest carbon storage, and wood harvests)
   - Urban Forests (including non-agriculture trees and soils)

Figure 2
SJTPO GHG Net Emissions by County, 2010 (All Sectors)



The distribution of gross emissions by sector is presented in **Figure 3**. The largest emissions sector in the inventory is transportation representing 45.5% of gross emissions (the vast majority of which is from on-road sources), followed by residential, commercial, and industrial (RCI) fuel and electricity use at 44.2% of the total (21% commercial, 15% residential, 5% industrial, and 3% non-road engines). The forest carbon sinks result in an offset equivalent to approximately 9.8% of the gross emissions in the region. The IP&FF emissions represent a somewhat high fraction of the total (when compared with other regions such as NJTPA). These emissions are largely associated with natural gas transmission and distribution losses and ODS substitutes. While the emissions in this sector represent a fraction of the state-wide emissions (presented in the NJDEP GHG inventory) in line with the region's share of population and employment, it is possible that a detailed bottom up analysis would reveal other differences in the region (e.g., gas leaks can be associated with specific facilities, which may or may not be in the region). Given the simplified top-down approach taken for the IP&FF sector, should this sector become the focus of mitigation efforts, a more detailed examination of these emissions would be recommended.

Figure 3
SJTPO GHG Gross Emissions by Sector, 2010



While the importance of the RCI (electricity consumption and fuel use) and transportation are emphasized in the gross emissions distribution, as is expected in general and demonstrated in many GHG inventories, this analysis also demonstrates the importance of forestry preservation and expansion in the SJTPO region. Furthermore, although the upstream component of consumption of goods and materials was not calculated as part of this effort, we would expect the inclusion of those emissions to result in Waste Management sector emissions on the order of those shown for the larger sectors here. Based on this analysis, it is evident that emission reduction efforts in the region cannot focus only on one sector, but rather need to be distributed throughout the economy, including electricity and fuel consumption, transportation, forest preservation and growth, and waste minimization efforts.

BASE YEAR 2010 INVENTORY BY SECTOR

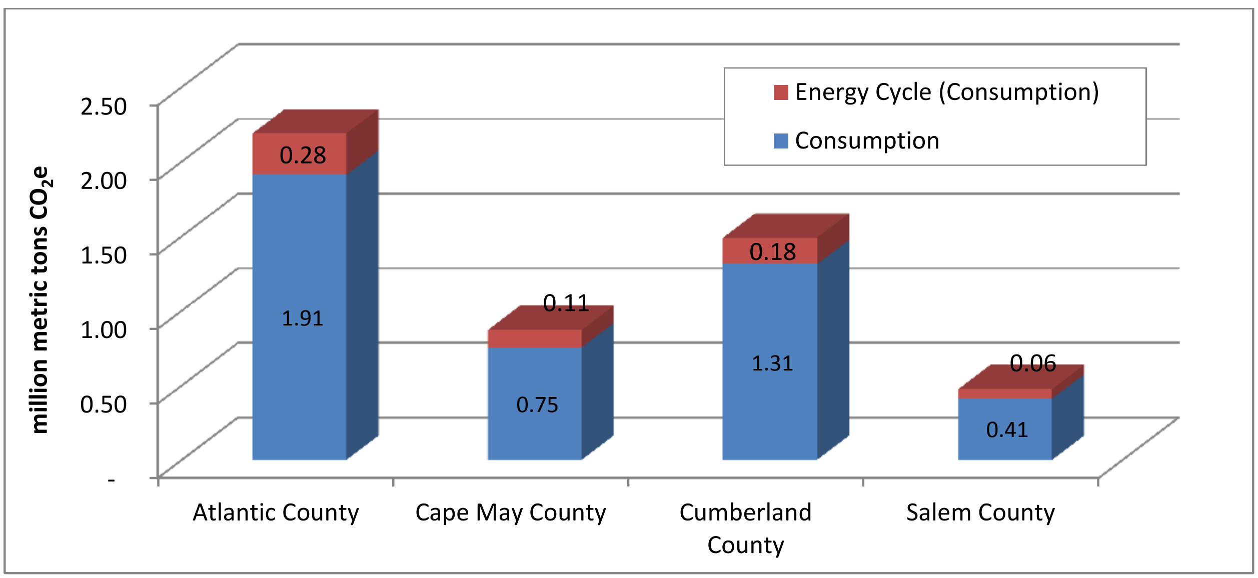
All emissions in the following sections are consumption based where available, and include energy cycle where available, unless specified otherwise.

Residential, Commercial, and Industrial (RCI) Fuel Consumption and Electricity Use

The RCI sector accounts for emissions from all residential, commercial, and industrial uses of electricity and fuel combustion within the SJTPO region. GHG emissions within this sector include the combustion of fossil fuels for space and water heating, food preparation, industrial boilers and dryers, and non-road engines such as construction, lawn and garden, and light commercial, and industrial equipment. Emissions from electricity use stem from the combustion of fossil fuels used in generating electricity. The most significant GHG emitted from electricity generation and on-site fuel consumption is CO_2. CH_4 and N_2O are emitted as well and are included in the inventory. Electricity related emissions in this inventory are associated with the geographic locations at which electricity is consumed.

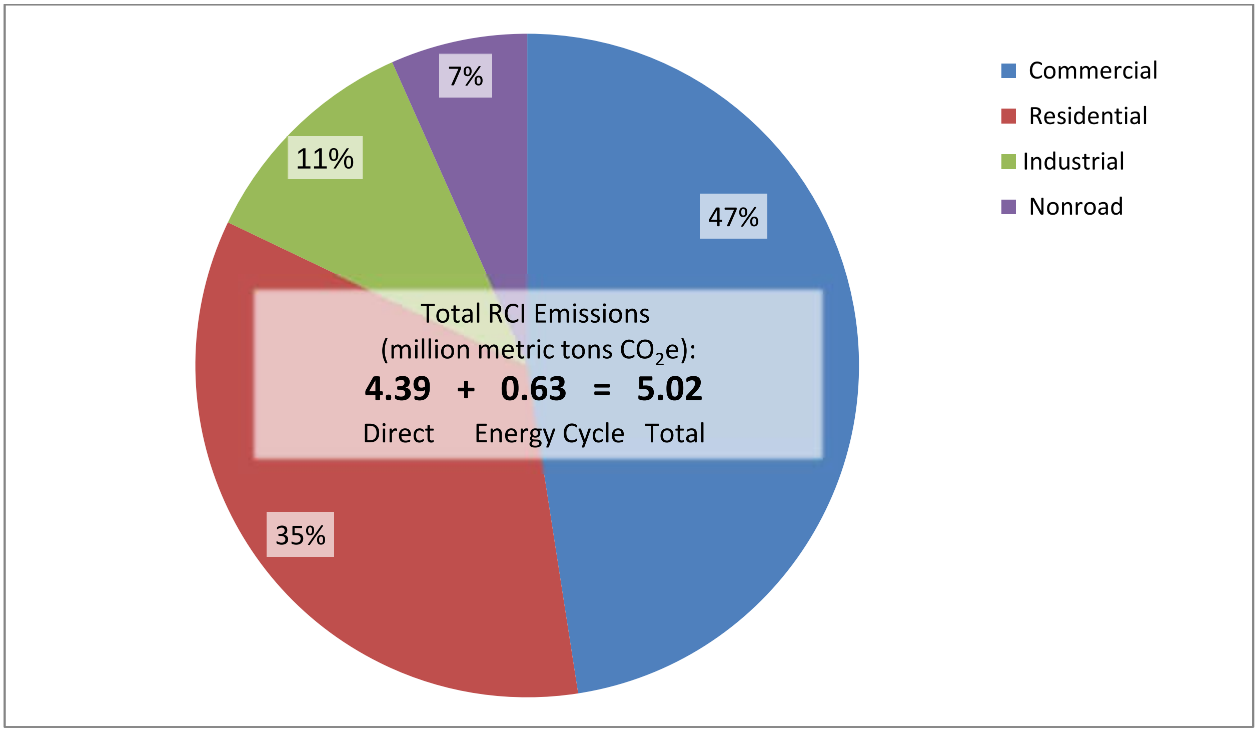
Total 2010 base year GHG emissions from the RCI sector are estimated at 5.02 $MMtCO_2e$. Emissions from the RCI sector represent 44 percent of region-wide emissions (excluding energy cycle emissions). The emissions by county are presented in **Figure 4**. Fuel and electricity consumption are used as the basis for estimating GHG emissions from RCI. Emissions for each subsector (fuel and electricity) and consumption amounts are discussed in the following sections, and additional details including emissions by municipality, can be found in **Appendix A**.

Figure 4
SJTPO RCI Sector GHG Emissions by County, 2010



Electricity use accounts for 74% of the total RCI sector emissions, and the remaining 26% is associated with fuel combustion. When comparing between emissions from residential, commercial, industrial, and RCI non-road sources (as shown in **Figure 5**), emissions associated with the commercial uses represent 47% of the total RCI emissions. Residential and industrial emissions account for 35% and 11% of the sector emissions, respectively. This distribution overall is similar to that found in other regions such as the neighboring NJTPA region. However, at the county level, there are differences in the relative contribution from different uses. For example, while 47% of the emissions are from commercial uses at the regional level, commercial uses contribute nearly 60% of RCI emissions in the in Atlantic County; as another example, 35% of RCI emissions at the regional level are from residential uses, but in Cape May, 50% of RCI emissions are from residential uses.

Figure 5
SJTPO RCI Sector GHG Emissions by Use, 2010



RCI FUEL CONSUMPTION

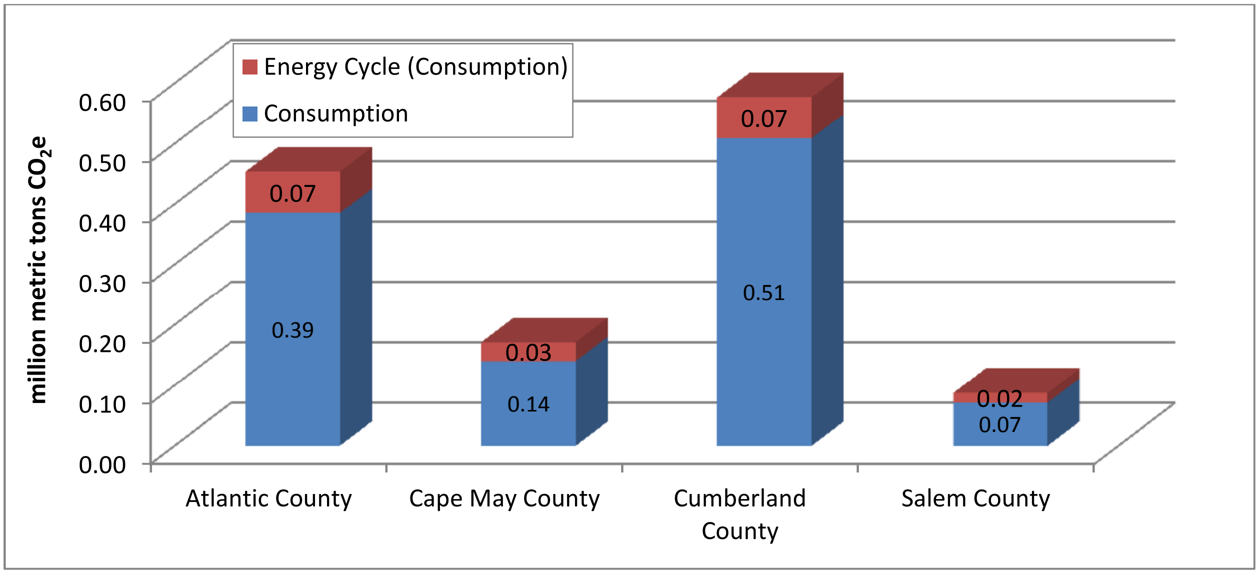
RCI Fuel Consumption includes fuel used for building heating and hot water, industrial processes, and non-road engines used in the RCI sector. The fuel most commonly used in Southern New Jersey by the RCI sector for space and water heating and for industrial processes is pipeline natural gas. Combustion of natural gas as a fuel source results in lower GHG emissions on an energy basis. Natural gas consumption is projected by EIA to increase in the future with consumption within the industrial sector leading overall growth[4]. In the event expansions in natural gas service and renewable energy occur in future years, reductions in emissions are likely to result. Other fuels include fuel oil (residual and distillate), kerosene, liquefied petroleum gas, and to a much smaller extent wood, coal, and landfill gas. The non-road engines in this sector include construction, lawn and garden, light commercial, and industrial equipment such as excavators, bulldozers, portable generator sets, air compressors, forklifts, lawn mowers, etc. Emissions from each source type are available in detail in the inventory files and may be useful when pursuing emission mitigation measures in this sector.

Emissions from RCI fuel use are estimated at 1.29 $MMtCO_2e$. Emissions by county are presented in **Figure 6.** Note that Cumberland County emissions from on-site fuel consumption

[4] EIA, Annual Energy Outlook 2013, Figure 85. Natural gas consumption by sector, 1990-2040 (trillion cubic feet), April 2013.

are higher than in other SJTPO counties, mainly due to glass manufacturing uses in the county. Based on data from EIA, glass manufacturing is 2 to 10 times more energy intensive than the average industry, per economic output.[5] As shown in **Figure 7**, GHG emissions from on-site fuel consumption for commercial uses are greatest, accounting for 45% of the total fuel use emissions from the RCI sector. Note that for natural gas, consumption was classified as residential, commercial, or industrial by the utility. It is possible that some residential consumption of natural gas (such as larger apartment buildings) may have been classified as commercial, and some natural gas customers that could be considered industrial (such as glass manufacturers) are sometimes classified as commercial by the utilities. The utility classification is typically based on the rate structure, rather than by subsector as defined in this inventory.

Figure 6
SJTPO On-Site Fuel Consumption GHG Emissions by County, 2010



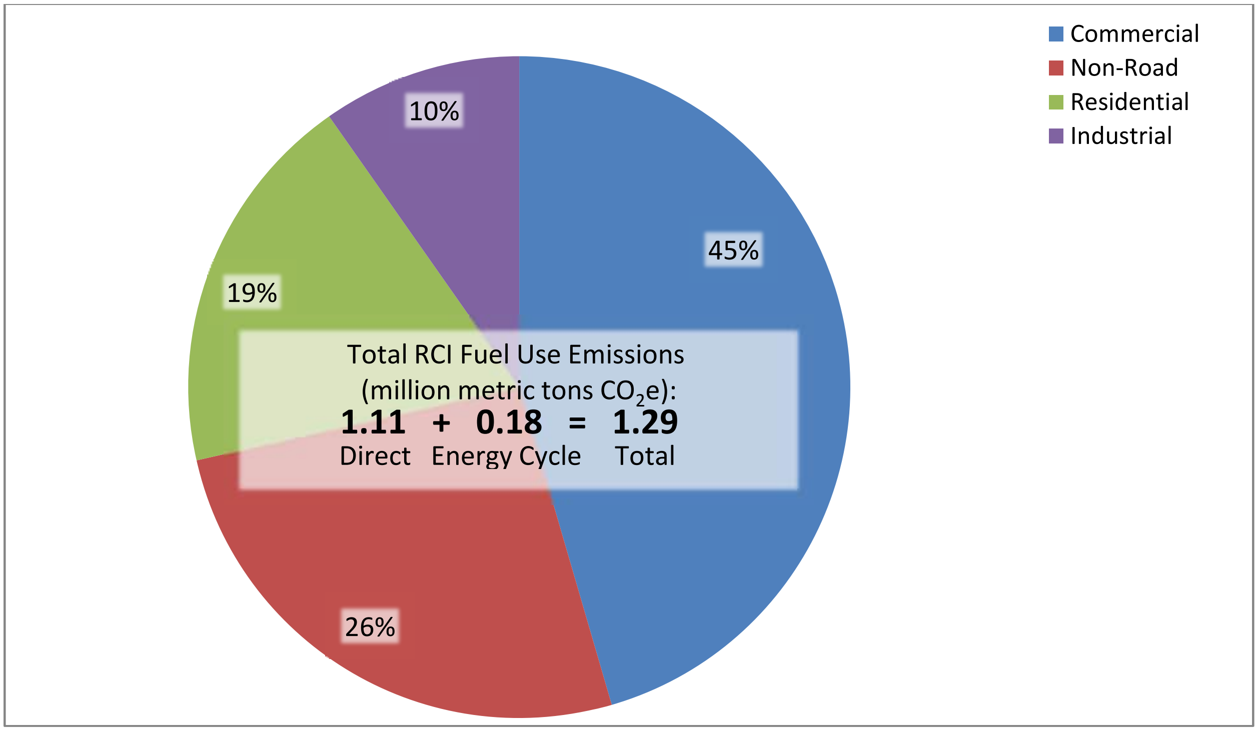
Another point to note is that due to data limitations, consumption data obtained from utilities by zip code were reallocated to municipalities. Therefore, municipalities with higher employment may have been allocated slightly more than their share of emissions (this does not affect county-level results). Municipal-level results are reported in **Appendix A**. For example, industrial consumption of natural gas reported by the utility for a zip code that included multiple municipalities was allocated based on employment. An energy intense use within that zip code (such as a glass manufacturing plant) would result in high consumption within that zip code. The consumption from that zip code (including the energy intense use) would be allocated mostly to the municipality within the zip code with the highest employment, even if the energy intense source is in a different municipality (with lower employment).

While GHG emissions from the RCI sector would be affected by seasonal changes in population, these would mostly be associated with electricity use rather than fuel consumption, since the vast majority of fuel is used for heating rather than hot water, cooking, and industrial processes. The growth in population during summer months does not have a major effect on

[5] EIA, 2010 Manufacturing Energy Consumption Survey (MECS), accessed May 2014, http://www.eia.gov/consumption/manufacturing.

fuel consumption. Summer season emissions from RCI fuel consumption are reported in **Appendix A**.

Figure 7
SJTPO On-Site Fuel Consumption GHG Emissions by Use, 2010



Annual fuel consumption from residential, commercial, and industrial uses and non-road equipment used in the RCI sector is summarized in **Table 1**. Non-road engines in this sector include construction, lawn and garden, industrial, and commercial non-road engines. Detailed municipal level fuel consumption can be found in the inventory worksheets.

GHG emissions from on-site fuel combustion occur at the point of consumption, and, therefore, direct emissions are the same as consumption-based emissions. Consumption-based GHG emissions for residential, commercial, and industrial uses were calculated by multiplying the fuel consumption by emission factors from The Climate Registry General Reporting Protocol (see **Appendix D**).[6] Emissions for the non-road engines used in the RCI sector were calculated using the NONROAD emissions model.

The GHG energy cycle emissions, which account for the emissions associated with fuel extraction, refining, transport, and delivery (upstream emissions) were estimated as well. Energy cycle emissions, including upstream emissions for biogenic and fossil fuels, as appropriate, were calculated using the GREET model, developed at Argonne National Laboratory[7] and other sources, as discussed in **Appendix C**.

[6] The Climate Registry, General Reporting Protocol (GRP), Default Emission Factors, January 2014, http://www.theclimateregiestry.org/resources/protocols/general-reporting-protocol/#hide.

[7] GREET version 2013, GREET Data version 9444.

Table 1
SJTPO Annual RCI Fuel Consumption, 2010

Fuel	Residential	Commercial	Industrial	Non-road
Natural Gas (MMcf)	2,609	8,216	530	-
CNG (MMcf)	-	-	-	29
Landfill Gas (MMcf)	-	692	-	-
Fuel Oil No 6 (1,000 gallon)	-	379	198	-
Fuel Oil No 2 (1,000 gallon)	5,840	5,234	4,414	-
Kerosene (1,000 gallon)	-	27	257	-
Gasoline (1,000 gallon)	-	-	-	6,255
Diesel (1,000 gallon)	-	435	144	17,477
Jet A (1,000 gallon)	-	-	10	-
LPG (1,000 gallon)	2,226	1,259	704	3,044
Propane (1,000 gallon)	-	-	30	-
Coal (metric ton)	63	-	-	-
Wood (metric ton)	3,556	16,885	13,829	-

Annual and seasonal natural gas consumption by zip code was obtained from South Jersey Gas, the natural gas utility serving the SJTPO region. Residential consumption of natural gas by zip code was allocated to municipalities using census block population data. To allocate commercial and industrial use of natural gas from zip code to municipal level, employment data by municipality provided by SJTPO for 2010 was also used.

Information on the on-site consumption of fuels other than natural gas for residential uses is based on estimates of the number of households in a municipality using each fuel type (utility gas, fuel oil, coal, wood, solar, etc.) obtained from the American Community Survey (ACS) (2008-2012).[8] The residential use of fuels other than natural gas was estimated using this information, along with the data on natural gas consumption reported by South Jersey Gas.

The consumption of fuels other than natural gas for commercial and industrial uses is estimated based on the New Jersey Department of Environmental Protection (NJDEP) point source inventory, allocated to municipalities based on the specific point source locations, and data for New Jersey from the US Energy Information Administration (EIA) State Energy Data System (SEDS), allocated to counties within the SJTPO region, using employment data from New Jersey Department of Labor & Workforce Development (NJDLWD). This is consistent with the area source methodology used for preparation of the NJDEP area source emission inventory[9]. Estimates of fuel consumption were allocated to specific municipalities based on SJTPO employment data.

County level fuel consumption in non-road engines used in the RCI sector such as construction, lawn and garden, light commercial, and industrial equipment was calculated using U.S. Environmental Protection Agency (EPA) NONROAD emission model. Fuel consumption was allocated to specific counties based on SJTPO employment data and GHG emissions were calculated using The Climate Registry General Reporting Protocol emission factors.

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[8] U.S. Census Bureau, Census 2000 Table B25040, House Heating Fuel.

[9] NJDEP, $PM_{2.5}$ Redesignation Request and Maintenance Plan Proposal, Appendix V, Attachment 5: 2007 Area Source Calculation Methodology Sheets $PM_{2.5}$, NO_x, SO_2, 2012.

RCI ELECTRICITY CONSUMPTION

Estimates of emissions associated with electric consumption are based on annual and seasonal electricity consumption data by municipality from electric utilities serving the SJTPO region. These include Atlantic City Electric and Vineland Municipal Electric Utility. Annual electricity consumption by county is presented in **Table 2**. Detailed annual and summer seasonal electricity consumption for the 2010 baseline is presented in **Appendix C**. Due to increased commercial activities and seasonal population, summer electricity consumption is much greater in certain municipalities. For example, summer residential electricity consumption in Ocean City, in Cape May County, accounts for 41% of its annual consumption. In Wildwood Crest Borough, in Cape May County, 41% of annual commercial electricity consumption occurs in the summer season. In these two municipalities, summer seasonal population is more than 7 times higher than the annual average population in those municipalities. For the SJTPO region on average, summer electricity consumption accounts for 30% of the annual total (ranges from 28% to 35% by county).

Table 2
SJTPO Annual RCI Electricity Consumption (GWh), 2010

County	2010 Electricity Consumption
Atlantic	3,342
Cape May	1,344
Cumberland	1,759
Salem	746
SJTPO Region Total	*7,192*

Total emissions from RCI electricity use are estimated at 3.73 MMtCO_2e. Emissions by county are presented in **Figure 8.** The distribution of electricity consumption emissions in residential, commercial, and industrial uses are presented in **Figure 9**.

Figure 8
SJTPO Electricity Consumption GHG Emissions by County, 2010

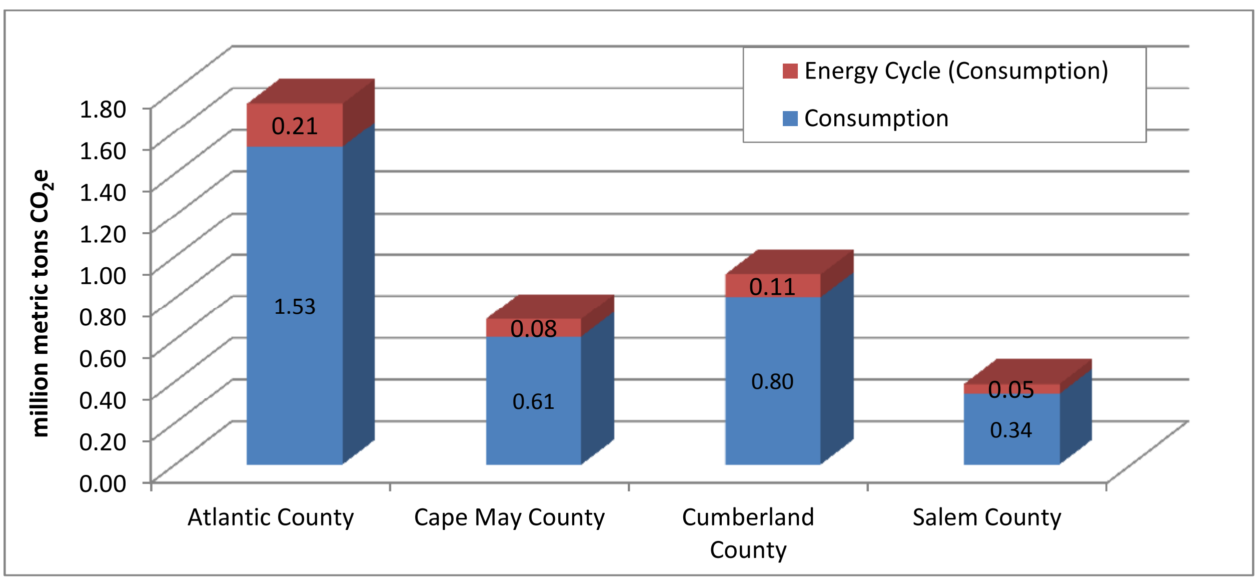
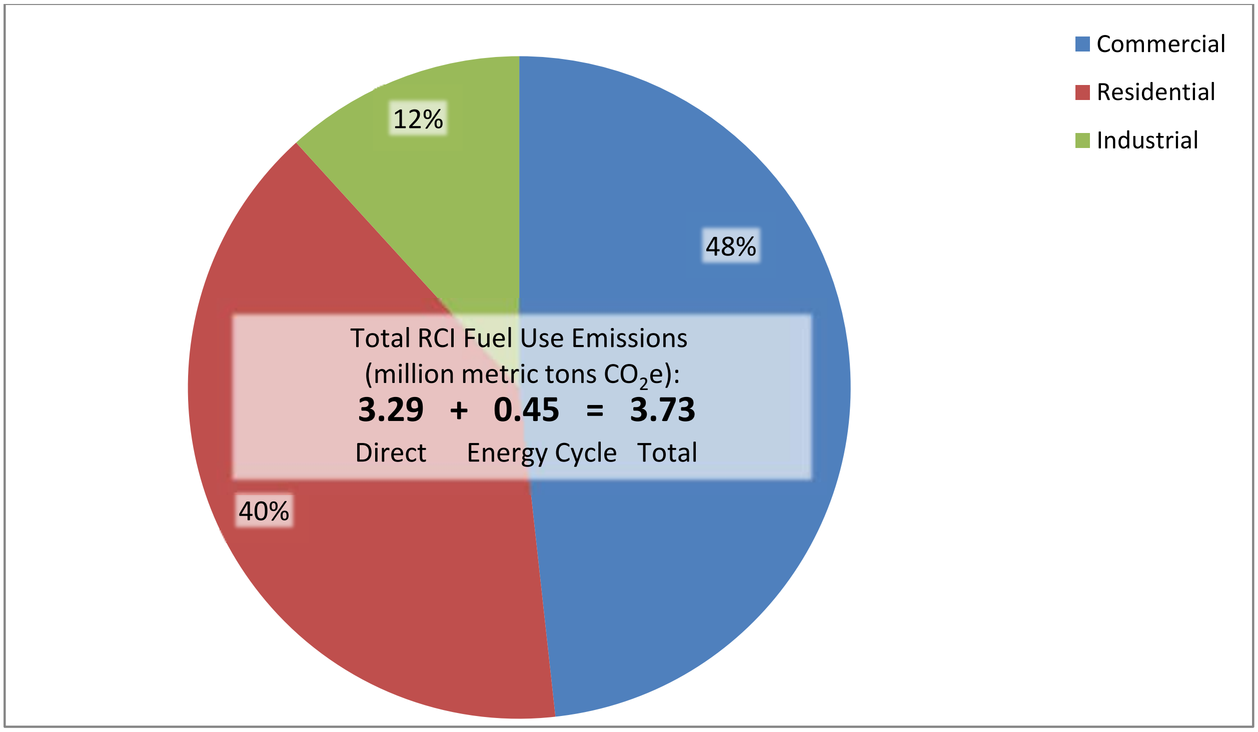


Figure 9
SJTPO Electricity Consumption GHG Emissions by Use, 2010



GHG emissions associated with electricity consumption are calculated by multiplying electricity consumption (see **Appendix C)** by electricity emissions factors obtained from the EPA eGRID[10] database for the eGRID subregion RFCE. Emissions account for transmission and distribution losses, based on eGRID data. Additionally, energy cycle emissions account for the emissions associated with fossil fuel production and transport. The electricity module of the GREET model developed at Argonne National Laboratory[11] was used to develop a factor that accounts for energy cycle emissions. The input to the GREET model was the RFCE subregion energy source mix in 2010, as reported in eGRID.

A direct accounting of emissions from electricity production was not developed for this inventory. Direct electricity emissions are associated with the use of fuels for electricity production at the point of combustion, i.e., power plants. Electricity production and delivery can be regulated at the federal and state level (e.g., via renewable portfolio standards, emissions standards, etc.). However, SJTPO, its counties and municipalities have less opportunity to affect power production. Reduction in electricity consumption is the primary mitigation response at the regional and local level, although zoning and other local regulations could influence power production to some extent, by making renewable power siting, development, and grid integration favorable. As electricity consumption is the primary mitigation option at the regional and local level, a GHG accounting system using consumption-based methods has become the standard for community-scale planning purposes.

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[10] USEPA, eGRID2012, http://epa.gov/cleanenergy/energy-resources/egrid/index.html.

[11] GREET version 2013, GREET Data version 9444.

Transportation

The Transportation sector inventory includes 2010 annual GHG emissions from the following transportation sources:

1. On-road mobile sources—all passenger vehicles including transit buses and commercial vehicles (light, medium, and heavy-duty commercial trucks);
2. Aviation;
3. Marine (recreational and commercial vessels);
4. Rail (passenger rail and freight rail); and
5. Non-road vehicles.

In total, the Transportation sector represents 45% of total gross CO_2e emissions within the SJTPO region in 2010 (excluding energy cycle and excluding sequestration). This is generally higher than estimates from other recent inventory efforts in New Jersey primarily as a result of incorporating emissions from trips with an origin in the region and an external destination, or vice versa, with half of the emissions from any trip attributed to the origin and half to the destination if they are in the region.

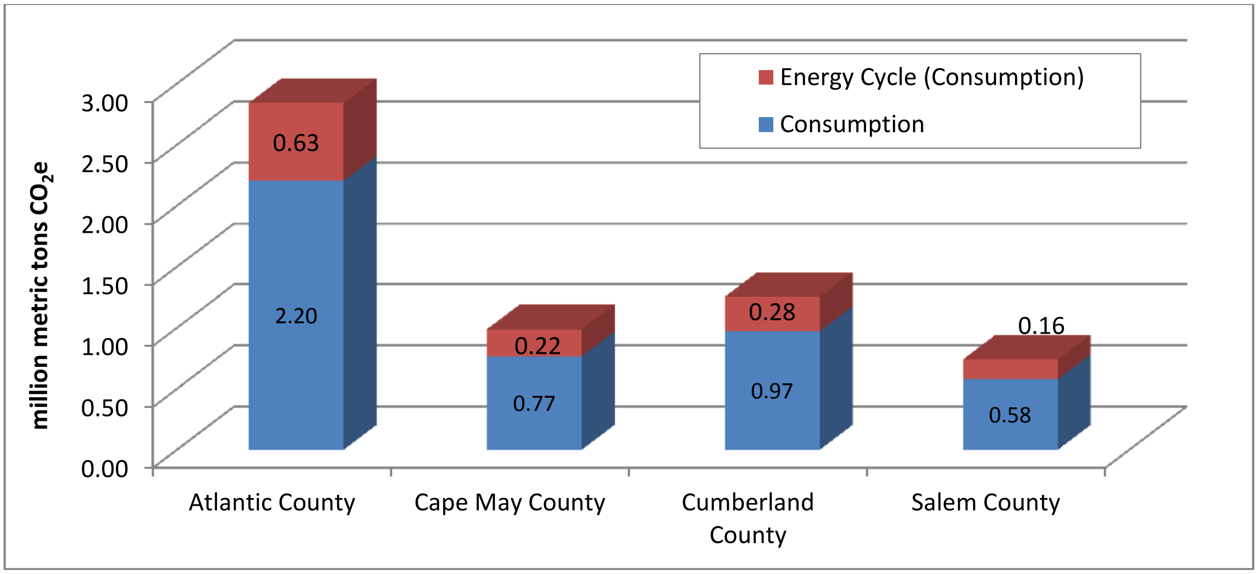
For the Transportation sector, consumption-based emissions were estimated for the on-road, passenger rail, and freight rail subsectors, allocating emissions geographically based on the origin and destination of trips (50% to each). Consumption and direct emissions are identical for the recreational marine and recreational-vehicle (off-road) subsectors. The consumption-based inventory evaluates origins and destinations of passenger trips or freight movement as opposed to the actual network miles traveled as evaluated in the direct inventory.[12] For recreational marine and recreational-vehicle (off-road) total fuel consumption is evaluated. Direct emissions are only estimated for the aviation and commercial marine subsectors.

Total Transportation sector emissions in the SJTPO region during the 2010 base year were estimated at 5.81 $MMtCO_2e$, including energy cycle emissions of 1.30 $MMtCO_2e$ (note that aviation and commercial marine emissions are included, however are not consumption-based—see the Protocol in **Appendix D** for details). Emissions by county are presented in **Figure 10**. Atlantic County has the largest share at 48% of the regional total, with Cape May County at 17%, Cumberland County at 22%, and Salem County at 13%. These regional emission shares by county are comparable to the population shares for the four counties.

The share of consumption-based Transportation sector GHG emissions by subsector are presented in **Figure 11**. Note that direct emission estimates were only analyzed for the aviation and commercial marine subsectors and are included in Figure 11. 92.4% of Transportation sector GHG emissions are from the on-road subsector, including emissions from external trips with an origin or destination outside the SJTPO region. Recreational marine represents 4.9%, aviation represents 1.2%, recreational vehicle (non-road) represents 0.8%, and emissions from freight rail and passenger rail together (including emissions from external trips with an origin or destination outside the SJTPO region) represent 0.6%.

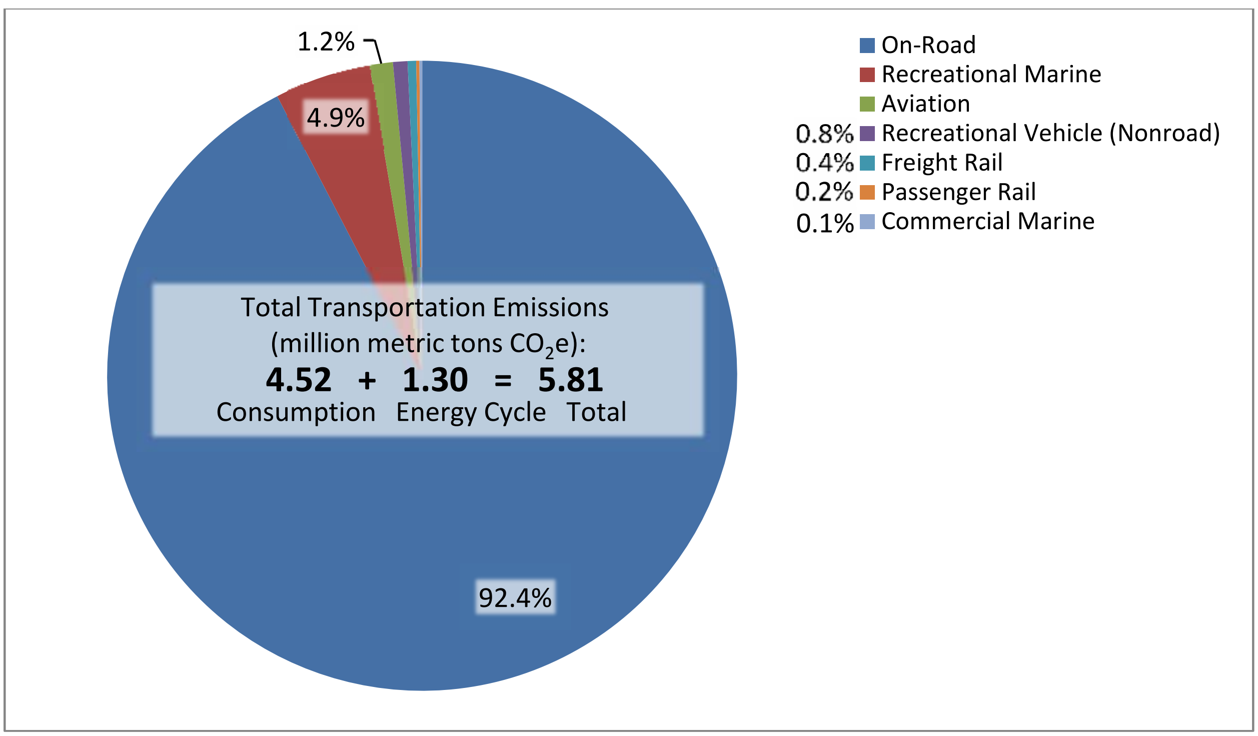
[12] Note that direct on-road and rail emissions were also calculated, and are tabulated in **Appendix A** and discussed in detail in **Appendix B**. While these may be useful for mitigation efforts focused on system changes like speed or locomotive technology, the consumption-based emissions are the focus of the report and are generally most useful for regional planning affecting trips.

Figure 10
SJTPO Transportation Sector GHG Emissions by County, 2010



Note: Total emissions presented here include aviation and commercial marine emissions calculated as direct (local emissions, not based on origin-destination).

Figure 11
SJTPO Transportation Sector GHG Emissions by Subsector, 2010



Note: Total emissions presented here include aviation and commercial marine emissions calculated as direct (local emissions, not based on origin-destination).

The following physical units, supporting the development of emission estimates for each subsector, are discussed in the following sections:

- On-road – vehicle miles travelled and fuel consumption
- Recreational marine – fuel consumption
- Aviation – fuel consumption
- Recreational vehicle (non-road) – fuel consumption
- Passenger rail – passenger miles and fuel consumption
- Freight rail – ton miles and fuel consumption

CO_2 represents 99% of all GHG emissions from the Transportation sector in the SJTPO region, with methane (CH_4) and nitrous oxide (N_2O) representing 0.1% and 0.9% respectively. All three GHGs are addressed from the consumption-based inventory as well as from upstream well-to-pump emissions included in an energy cycle analysis.

Fuels used in the sector include not only gasoline and diesel, but electricity, various biofuels and synthetic fuels, natural gas, and others. In addition to on-road fuels, the Transportation sector includes non-road fuels used in locomotives and non-road engines (e.g., construction equipment), jet fuels used for aviation, and electricity used in some non-road subsectors. Energy cycle emissions associated with the consumption of these energy sources contribute 0.7 $MMtCO_2e$ emissions in the Transportation sector.

Direct on-road and rail emissions were also calculated, and are discussed in detail and compared with the consumption results in the **Appendix B**. While the direct results may be useful for mitigation efforts focused on system or vehicle efficiency strategies, the consumption-based emissions are the focus of this report and are generally most useful for regional planning in terms of transportation demand management and mode shift strategies.

With the direct method, on-road emissions inside the region are higher than the consumption based method due to the inclusion of through trips without an origin or destination in the SJTPO region. This difference is completely offset, and ultimately consumption emissions are greater, when including emissions from the outside-of-region portions of trips with an origin or destination in the region. (This is because outside-of-region trips, half of which are attributed to the region, tend to include long distance trips and heavy duty truck trips moving freight.)[13] For example:

- For on-road vehicles, regional consumption emissions are higher than direct as emissions occurring outside the region from passenger and commercial vehicles trips with an origin or destination inside the region are included (5.37 $MMtCO_2e$ compared with 4.18 $MMtCO_2e$); and
- For freight rail, regional consumption emissions are significantly higher than direct as emissions from the transport of ton-miles outside the region are included (24,832 $mtCO_2e$ compared with 1,258 $mtCO_2e$).

[13] For example, a trip from Vineland to Philadelphia of 40 miles might have 8 miles in Cumberland County and 32 miles outside the region. The direct emissions would include only emissions from the 8 miles in Cumberland County, while the consumption base approach would allocate 20 miles to Cumberland and 20 would be excluded. A through trip with no origin or destination in the region would be excluded completely. More details regarding the various methods can be found in the protocol and in Appendix B where the alternative method results, in this case direct accounting, are reported.

Regional total direct Transportation sector emissions are estimated at 4.60 MMtCO_2e (including 1.06 MMtCO_2e energy cycle emissions). In total this is approximately 1.21 MMtCO_2e (or 21%) less than regional total consumption Transportation sector emissions.

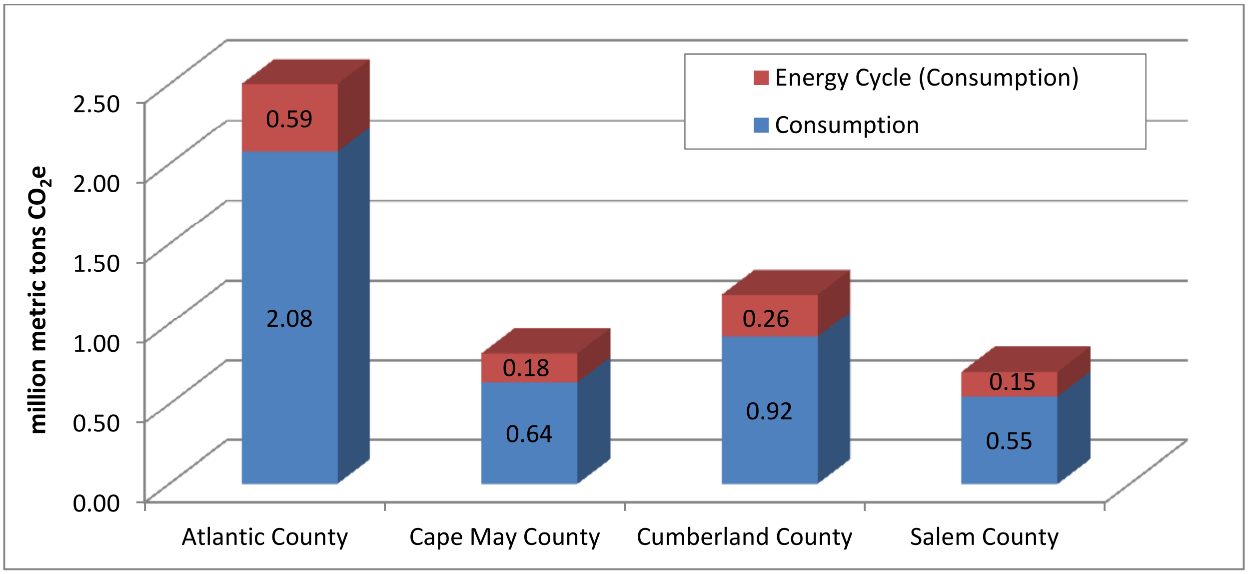
Summer season (June, July, August) direct inventory emissions were also estimated for the on-road subsector and are discussed in the on-road subsector summary. The on-road subsector and passenger rail subsector emissions were also allocated to the municipality level (see **Appendix A**).

ON-ROAD VEHICLES

On-road vehicles account for the vast majority of all Transportation sector GHG emissions in the SJTPO region, and 42% of total regional gross GHG emissions. On-road vehicles include passenger cars and trucks, motorcycles, commercial trucks, heavy-duty vehicles, and buses. These vehicles may be fueled by gasoline, diesel, or other alternative fuels, including electricity. The results indicate that CO_2 represents 98.9% of total GHG emissions from the on-road subsector.

Annual regional on-road vehicle emissions total 5.37 MMtCO_2e, including energy cycle emissions of 1.19 MMtCO_2e. Emissions by county are presented in **Figure 12**. Atlantic County has the largest share at 50% of the regional total, with Cape May County at 15%, Cumberland County at 22%, and Salem County at 13%. When looking at emissions per capita, the results provide additional insight into trips attracted by each county. For example, Atlantic and Cape May Counties show annual per capita GHG emissions of 10.3 mtCO2e and 10.1 mtCO2e respectively, compared with 7.8 mtCO2e for Cumberland County. The key difference, particularly in Cape May County, is the share of trips with a destination in the county from elsewhere in the region or outside the region. Salem County shows the highest annual per capita GHG emissions at 11.2 mtCO2e, primarily attributed to the share of long-distance commercial vehicle trips accessing manufacturing locations in the county. Emissions estimates are also presented at the municipality level in **Appendix A**. Detailed VMT estimates are available in the inventory workbooks.

Figure 12
SJTPO On-Road Vehicle GHG Emissions by County, 2010 (consumption)



Total 2010 annual VMT within the SJTPO region is estimated at 5.852 billion passenger vehicle miles and 518 million commercial vehicle miles. On-road passenger vehicles account for 91% of the total regional VMT. It is important to note that while on-road commercial vehicles only account for 9% of annual regional VMT, they account for 25% of total GHG emissions. On average, the SJTPO region composite GHG emission rate for commercial vehicles is 1,654 grams CO_2e per mile while the rate for passenger vehicles is 458 grams CO_2e per mile. The GHG emission rates were generated through use of the EPA MOVES 2010b model, consistent with the data and assumptions employed in SJTPO's FY 2014 conformity analysis.

For the on-road subsector, estimates of GHG emissions were developed for both the consumption and direct approach. Activity for consumption-based GHG emissions are estimated based on allocating half of the vehicle miles traveled from every trip either originating or ending in each municipality within the SJTPO region, including portions of any trip that are outside of the SJTPO region. Activity for direct GHG emissions is estimated based on total vehicle VMT by vehicle type and average speed on roadways within each county and municipality, including through trips without an origin and destination in that jurisdiction. As mentioned above, the consumption-based accounting is considered a more appropriate approach when evaluating the effect of transportation demand management and mode shift strategies. However, the direct emissions were also calculated since they would be useful in evaluating potential mitigation efforts such as speed limits, signal timing, and other strategies affecting specific roadways.

Regional total consumption-based on-road GHG emissions are estimated at 5.37 $MMtCO_2e$, compared with 4.18 $MMtCO_2e$ for the direct on-road inventory. Direct emissions are presented at the county and municipality level in **Appendix A** and a discussion of the direct emissions and the differences between the two approaches is provided in **Appendix B**.

The SJTPO region is a net importer of commercial vehicle trips and a net importer of recreational trips (trips to shore communities from elsewhere in the Mid-Atlantic and Northeast regions). Both of these trip types are critical to the regional economy and are a significant source of GHG emissions.

For commercial vehicle trips, estimates of consumption based emissions outside the region are generated by multiplying the SJTPO region total internal-external truck trips by the average distance to/from the final destination/origin as documented in the Freight Analysis Framework (FAF). The results of the analysis of FAF data indicate that the average inbound truck trip length to the SJTPO region is 134 miles, and the average outbound truck trip length from the SJTPO region is 117 miles. External truck trips with an origin or destination total 280 million commercial vehicle miles in 2010.

For passenger vehicle trips, the process for estimating emissions from external trips varies by trip type. SJTPO residents commuting to jobs in the Wilmington region or Philadelphia region have different trip lengths depending on their origin and final destination (information on average work trip lengths are sourced from the U.S. Census, American Community Survey). For seasonal trips destined to shore communities from the Northern New Jersey/New York metropolitan region, the Philadelphia region, Delaware/Eastern Maryland, and the remainder of the Northeast and Mid-Atlantic regions, outside-the-region trip lengths may be as much as a few hundred miles. For example, per the New Jersey Beach Travel Survey (NJDOT & SJTPO, 1996), only 15% of seasonal trips to shore communities are within the SJTPO region. Segmenting total external trips by trip type, and assigning average trip lengths to these trips based on commute data and seasonal travel data results in an estimate of 895 million passenger vehicle miles in 2010.

In terms of total magnitude (share of the annual total) and the allocation of emissions by municipality, seasonal on-road vehicle emissions in the SJTPO region provide insight into how summer tourism and recreational travel impacts emissions from the on-road subsector. For the summer season (June, July, August), total direct emissions are estimated at 1.26 $MMtCO_2e$, approximately 39% of the total annual direct emission inventory.[14] **Figure 13** displays the annual distribution of regional direct on-road GHG emissions by month. The consumption inventory for the summer season totals 2.10 $MMtCO_2e$, also approximately 39% of the total annual consumption emission inventory. The annual share is identical for the direct and consumption inventories as the same data is used in both inventory approaches to estimate activity by month (refer to **Figure 13**).

Figure 13
SJTPO On-Road Vehicle GHG Emissions by Month, 2010 (direct)

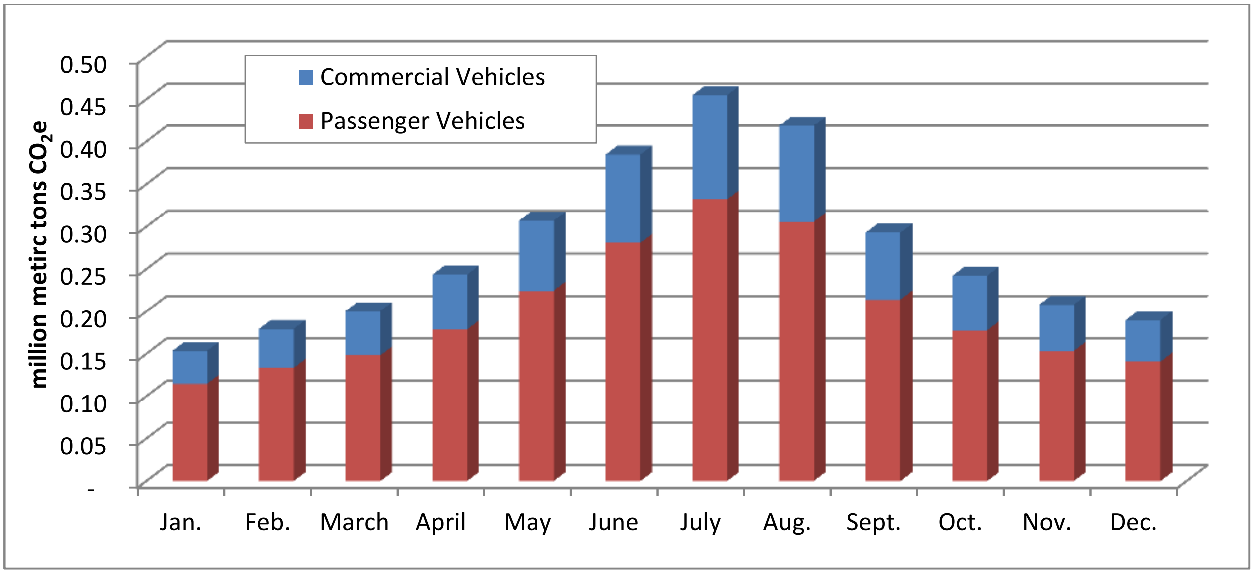


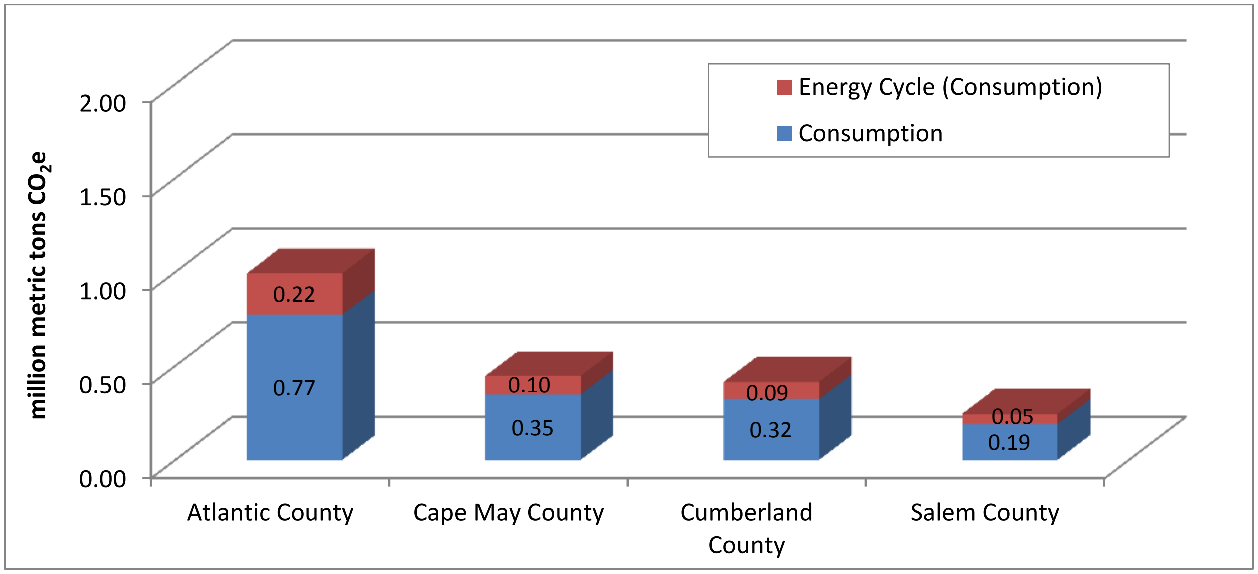
Figure 14 presents the share of GHG emissions from the consumption inventory for the summer season (June, July, and August). The emission shares by county are nearly identical to the shares as reported in the annual results presented in **Figure 12** (primarily because the summer shares represent nearly 40% of the annual shares). If summer is compared to the rest of the year, shares increase slightly in Salem and Cumberland Counties and decrease slightly in Atlantic and Cape May Counties.

As expected, the comparison of on-road activity and emissions at the municipality scale shows significant differences between annual and summer season results. For all shore communities in Atlantic and Cape May Counties (Brigantine City, Atlantic City, Ventnor City, Margate City, Longport Borough, Ocean City, Sea Isle City, Avalon Borough, Stone Harbor Borough, North Wildwood City, Wildwood City, Wildwood Crest Borough, Cape May City, and Cape May Point Borough) the total share of annual regional GHG emissions is 10%, while the total share of summer season regional GHG emissions is 18%.

[14] The direct-based inventory is used for seasonal trips as the regional travel demand model only generates trip tables for an average annual weekday, not by month of the year. As a result, seasonal VMT used in conformity analysis is used to estimate seasonal variation in GHG emissions.

Consumption and direct seasonal emission estimates for all municipalities are provided in **Appendix A** and discussed in **Appendix B**. VMT and other physical units are available in detail in the inventory workbooks.

Figure 14
SJTPO Seasonal On-Road Vehicle GHG Emissions by County, 2010 (consumption, summer)



AVIATION

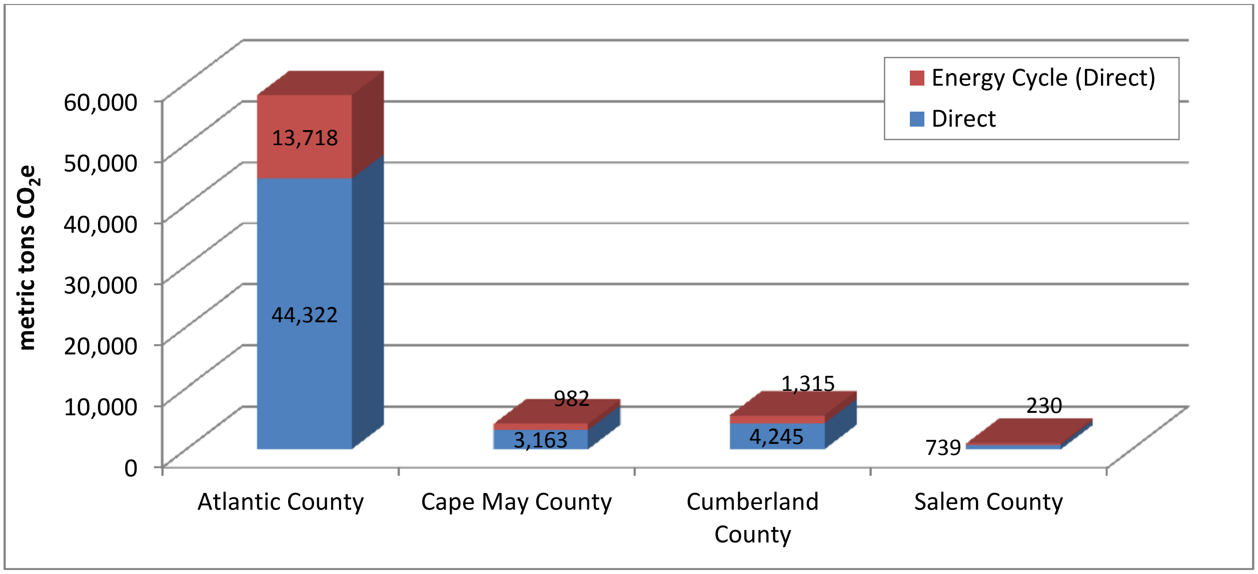
The aviation subsector includes aircraft emissions during the landing-takeoff (LTO) cycle and touch-and-go cycles (TGO),[15] and emissions from auxiliary power units (APUs) and ground support equipment (GSE). The LTO/TGO emissions include emissions up to an elevation of 3,000 feet. GSE includes aircraft refueling vehicles, baggage handling vehicles, aircraft towing vehicles, and on-airport passenger buses.

Total aviation emissions are estimated at 69 thousand $mtCO_2e$, including 16 thousand $mtCO_2e$ from energy cycle emissions, the vast majority of which are from the Atlantic City International Airport. **Figure 15** presents the share of emissions by county. Approximately 92% of emissions are from LTO/TGO, while the remaining 8% are from GSE. As described in greater detail in the Protocol (**Appendix D**), emissions for aviation were calculated only on a local, direct basis. It is not anticipated that SJTPO or local mitigation efforts would focus on reducing aircraft or air passenger trips.

The local aviation activity results in the consumption of 4.76 million gallons of jet fuel, 0.19 million gallons of aviation gasoline, 0.27 million gallons of diesel, and 0.13 million gallons of gasoline. More details about this analysis can be found in **Appendix C**.

[15] A TGO is an aircraft operation where the pilot lands on a runway and takes off again without coming to a full stop.

Figure 15
SJTPO Aviation GHG Emissions by County, 2010 (direct)



MARINE VESSELS

The Marine subsector covers commercial marine vessels (CMVs) and recreational marine vessels. Note that other than vessel emissions, any non-road engines used for port and marina activities are included in the RCI fuel use subsector since the portion of the non-road engines in the inventory applied to each use is not available.

Commercial marine vessels (CMVs) include ocean going vessels (OGVs), harbor boats, towboats, dredging boats, commercial fishing boats, ferry boats (e.g., the Delaware River Port Authority (DRPA) Cape May—Lewes Ferry), excursion vessels, and government boats. The region does not have substantial cargo traffic; however, barges are used throughout the region for construction related activities. Only emissions occurring within the three-mile demarcation line of the shore are recommended for inclusion in this analysis consistent with the NJTPA inventory and also consistent with the boundary used for the ozone nonattainment area in the State Implementation Plan (SIP) emission inventory. Emissions in the CMV subsector come from fuel combusted in these vessels, both in the main engines for propulsion and in the secondary engines for electrical power and other onboard services.

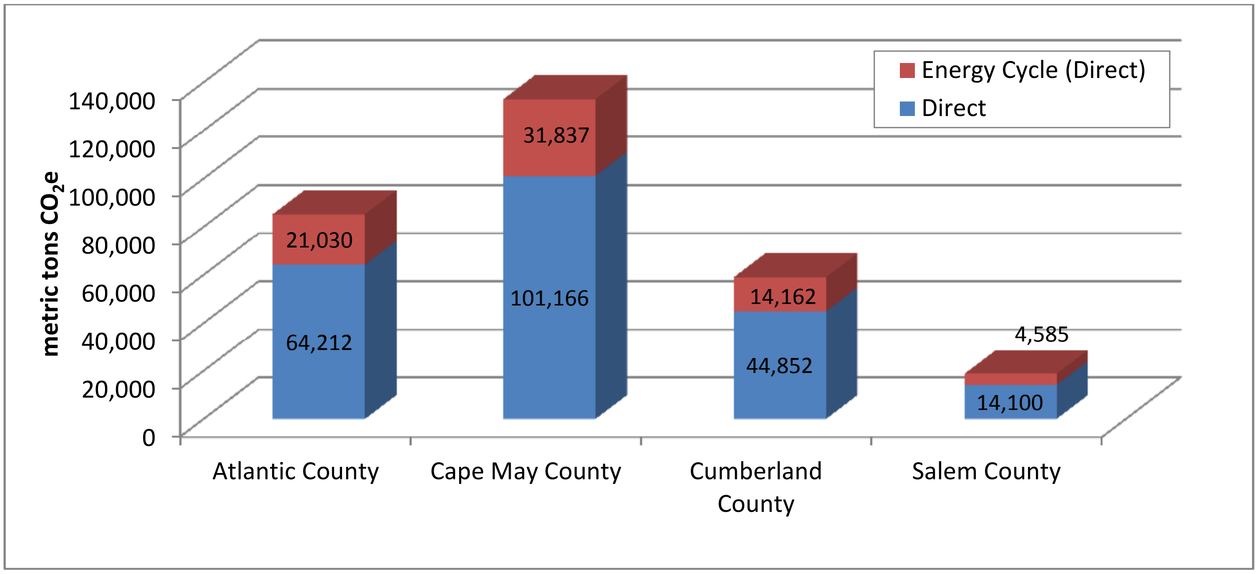
Regional total emissions for the marine subsector in 2010 total 0.30 $MMtCO_2e$. The majority of these emissions are from recreational marine vessels (287,417 $mtCO_2e$) with the remainder from commercial marine activity including container vessels calling at the Port of Salem, barge and tug activity, and the Cape-May Lewes ferry.[16] **Figure 16** presents the allocation of emissions by county for the marine subsector. The inventory allocated to the county scale is based on the combination of:

- Container vessel activity generated at the Port of Salem and passing through Salem, Cumberland, and Cape May Counties as it traverses the Delaware River shipping channel;

[16] Given the small amount of marine freight in the region, origin-destination analysis representing consumption based accounting for these emissions was not analyzed.

- Barge and tug activity generated at the Port of Salem and using the Delaware River shipping channel;
- The Cape May – Lewes ferry (all emission occur in Cape May County); and
- Recreational marine vessel fuel consumption input into the NONROAD model. Approximately 30% of regional recreational marine vessel emissions occur in Atlantic County and 43% in Cape May County.

Figure 16
SJTPO Marine Vessel GHG Emissions by County, 2010 (direct)



Commercial marine vessel emissions were estimated through a direct approach (only emissions associated with activity within the region are estimated) while recreational marine vessel emissions were estimated through a consumption-based approach. However, because recreational marine emissions are generally all within the region, the direct and consumption-based approaches are identical. While consumption based emissions for commercial marine vessels would include higher emissions associated with half of the emissions from any trip from/to origins and destinations in the SJTPO region, due to the small amount of commercial marine activity in the region and the large effort involved in developing the required data, consumption-based emissions for commercial marine vessels was not included. Total fuel consumption is estimated at 649,500 gallons diesel for commercial marine vessels, 20.0 million gallons gasoline and 5.4 million gallons diesel for recreational marine vessels.

Emissions from commercial fishing vessels based in the SJTPO region are not included in this inventory due to the lack of data and difficulty in allocating emissions to the region. However, it is recognized that commercial fishing is an important component of the regional economy, and likely a larger consumer of energy than in other regions. According to the National Oceanographic and Atmospheric Administration (NOAA) National Marine Fisheries Service, Cape May/Wildwood and Atlantic City are #2 and #6 respectively on the U.S. east coast in terms of total pounds of landed fish (totaling 67.3 million pounds in 2010). Profiles created by the Northeast Fisheries Science Center report that 199 vessels called Cape May or Wildwood their home port in 2006.[17]

Some other national statistics from NOAA indicate that roughly 2/3 of the total pounds of landed fish are caught outside the 3-mile limit. Energy intensity required to land this fish can also vary considerably depending on the fishing gear used and the vessel size. All of these factors make it difficult to pinpoint energy consumption attributed to the subsector and assign it accurately to the SJTPO region. In a brief review of other GHG inventories where there was a mention of commercial fishing (not included in either NJTPA or DVRPC inventories), typically emissions from commercial fishing vessels were only counted within the Transportation sector as part of in-port activity (as harbor craft).

Detailed GHG emissions for the subsector, including municipal level emissions, are provided in **Appendix A.**

RAIL

This section describes the emissions associated with passenger rail and freight rail, as well as non-road engines used for railway maintenance. GHGs emitted from this subsector are CO_2, CH_4, and N_2O, primarily from the combustion of diesel fuel. Passenger rail activity in the SJTPO region includes emissions from locomotives on the Atlantic City rail line from Hammonton to Atlantic City. Freight rail activity in the SJTPO region includes emissions from locomotives on the following primary lines: Conrail, Southern Railroad of New Jersey, Cape May Seashore Lines, and Winchester and Western.

Consumption based emissions account for the trip origin and destination instead of the locations the locomotives pass through before reaching the pick-up or drop-off locations for passengers or cargo. For passenger rail, this is the preferred accounting method as it allocates emissions to the location where passengers board or alight the Atlantic City rail line, while not assigning emissions to municipalities without a station. For freight rail, this assigns emissions to the economy producing or consuming the materials instead of the economy it passes through. For both passenger and freight rail, it also accounts for 50% of the emissions from the full length of the trip at any origin or destination in the region (for example passengers from Atlantic City to Philadelphia or freight from Bridgeton to Camden).

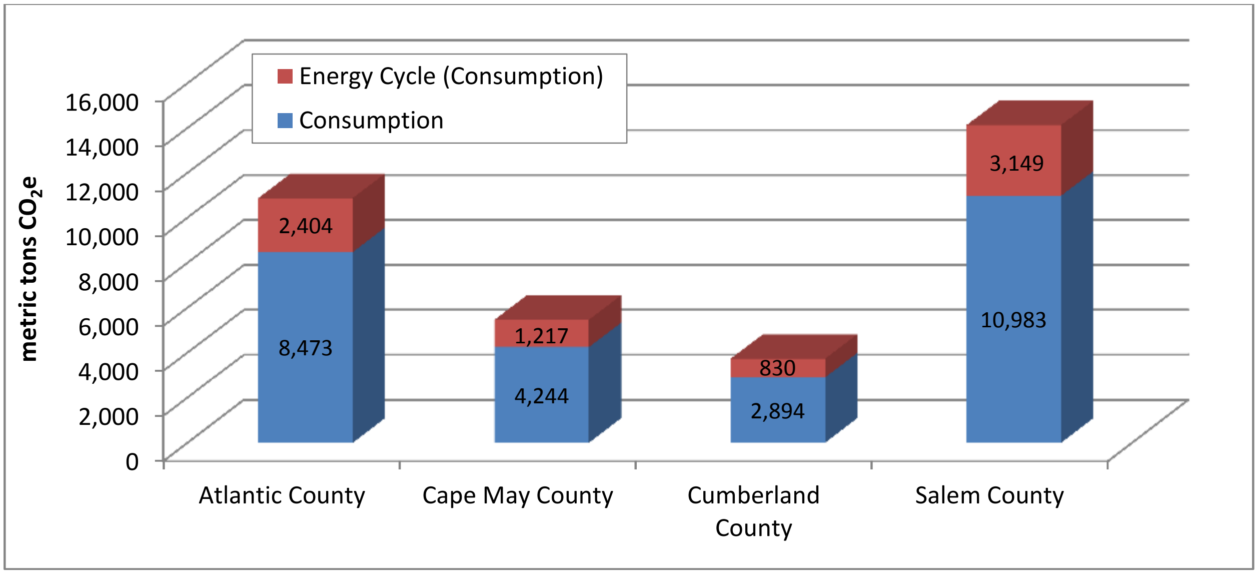
Regional total emissions for the rail subsector in 2010 total 34,193 $mtCO_2e$. 73% of these emissions are from freight rail locomotives (24,832 $MtCO_2e$) with the remainder from the Atlantic City rail line. **Figure 17** presents the emissions for the rail subsector by county. Passenger rail emissions are only allocated to Atlantic County, and represent 86% of all rail consumption-based subsector emissions in Atlantic County (totaling 7,294 $mtCO_2e$). Salem County shows the largest share of rail subsector emissions (41%) as a result of materials transported via rail to the Dupont Chambers Works site in Pennsville Township.

Rail subsector emissions are generated through passenger-mile and ton-mile data and fuel consumption or average per mile emission rates for locomotives. Annual passenger miles on the Atlantic City rail line with an origin or destination in the SJTPO region totals 22.6 million miles in 2010, equivalent to 701,000 gallons of diesel fuel. Annual ton miles with an origin or destination in the SJTPO region totals 908.9 million miles in 2010, equivalent to 1.9 million gallons of diesel fuel. Note that these estimates include miles travelled and fuel consumed

[17] National Marine Fisheries Service Northeast Fisheries Science Center, Community Profiles of Cape May and Wildwood, NJ, accessed May 2014, http://www.nefsc.noaa.gov/read/socialsci/pdf/NJ/capemay-nj.pdf; and http://www.nefsc.noaa.gov/read/socialsci/pdf/NJ/wildwood-nj.pdf.

inside and outside of the SJTPO region. For passenger rail, emissions are presented at the municipal level (refer to results in **Appendix A**).

Figure 17
SJTPO Rail GHG Emissions by County, 2010 (consumption)



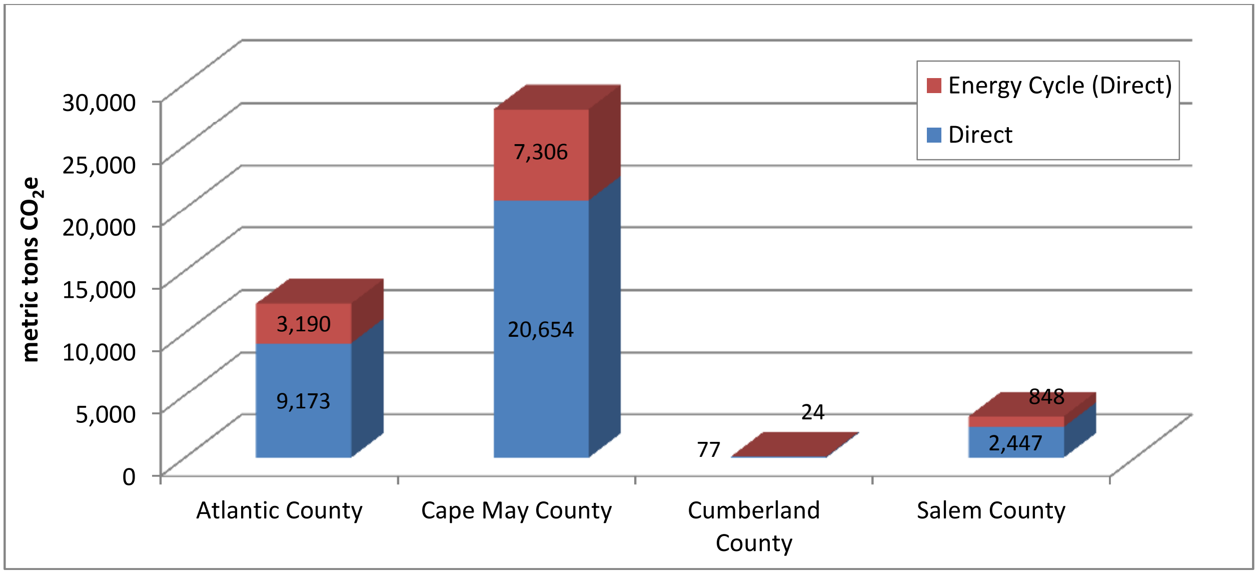
Direct emissions from passenger and freight rail were also estimated in the inventory. The direct method allocates emissions based on the actual miles travelled by the locomotive within each jurisdiction. For the rail subsector the emission results have more to do with the length of the rail line in the jurisdiction than the actual passenger or freight activity generated by the location. As a result total regional emissions exclude external trips, therefore direct based estimates are significantly less (10,191 $mtCO_2e$ direct compared with 34,193 $mtCO_2e$ consumption). Direct results may be useful for region-wide mitigation efforts such as electrification or efficient locomotive technology, and are presented in more detail in **Appendix A** and discussed in **Appendix B**.

NON-ROAD RECREATIONAL VEHICLES

This section describes the emissions associated with non-road recreational vehicles, including snowmobiles, off-road vehicles, golf carts, and other specialty vehicles. Note that other non-road engines, such as agricultural, industrial, commercial, lawn and garden, recreational marine, construction, airport ground support, mining, oilfield, and railway maintenance engines are included with their respective subsectors.

Total emissions from recreational vehicles were estimated at 43,718 $mtCO_2e$, including 11,368 $mtCO_2e$ energy cycle emissions. **Figure 18** presents total non-road recreational vehicle emissions by county. These emission are the result of combustion of 4.0 million gallons of gasoline, 0.15 million gallons of diesel, and 14,000 gallons of LPG. Additional detailed results of this analysis are presented in **Appendix A** and discussed in **Appendix B**.

Figure 18
SJTPO Non-Road Rec. Vehicle GHG Emissions by County, 2010 (direct = consumption)



Industrial Processes and Fossil Fuel (IP&FF) Industry

Industrial process emissions include CO_2, CH_4, sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and N_2O released as by-products from industrial activities, excluding combustion of fuels and electricity use (which are included in the RCI sector), and from the use of refrigerants and SF_6. Also included in this sector are fossil fuel industry emissions, including CH_4 emissions released from the distribution of natural gas.

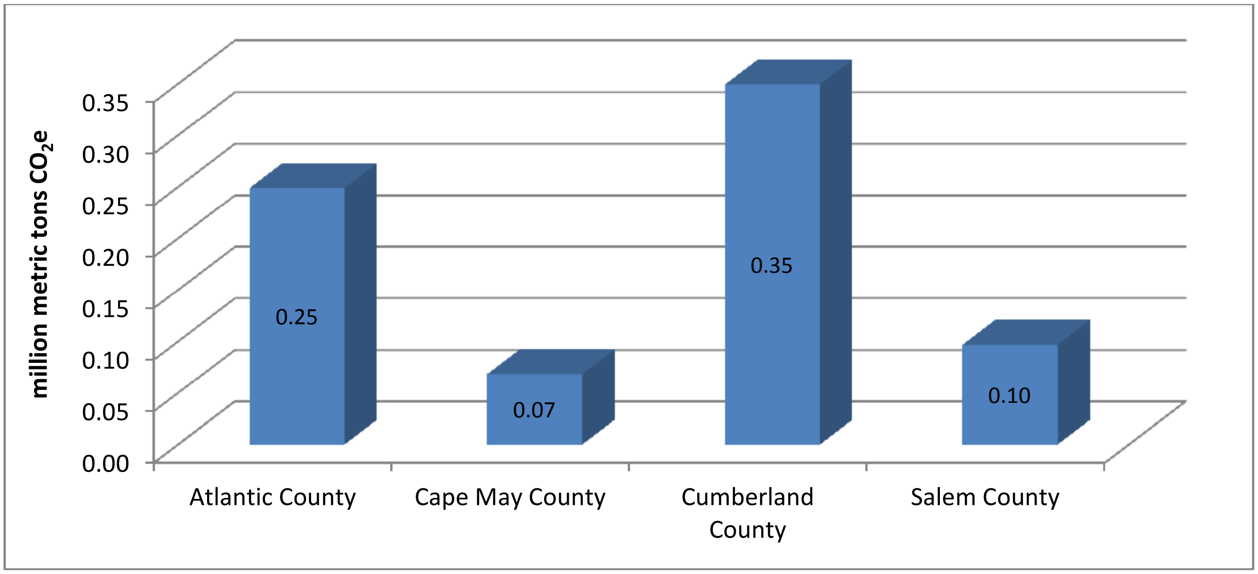
In the SJTPO region, the sector includes limestone and dolomite use (*e.g.*, flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and use, nitric acid production, and semiconductor manufacture. Note that limestone and dolomite are also used to neutralize crop soils. Currently, data have not been identified to divide up the use of these materials (and subsequent CO_2 emissions) between the IP and Agriculture sectors, so the emissions are all allocated to IP. Also included in IP is the use and release of fluorinated compounds including ozone depleting substance (ODS) substitutes used for cooling and refrigeration equipment and aerosols, solvents, and fire protection, SF_6 released from its use for electric power transmission and distribution, and natural gas released from transmission and distribution.

While cement, iron, and steel production are not found in the SJTPO region, production emissions attributed to the use of these materials have also been calculated under an alternative consumption-based accounting approach and are reported in **Appendix B**.

Note that natural gas distribution loss emissions are a portion of the upstream emissions for fuel consumption, included in the energy cycle emissions, which are included for fuel consumption from the RCI. Note that there is a large discrepancy between the natural gas leakage estimate provided here and the energy cycle emissions reported in the RCI sector which include leakage of natural gas during production, processing, and delivery. The amount reported here is approximately ten times that calculated as part of the energy cycle for the RCI sector natural gas use. While the nation-wide average upstream factor for natural gas used for RCI includes some leakage, it may not include local distribution leakage, which represents approximately 90% of the total reported here. However, given that these estimates are derived using two very different methods, it is recommended that this question be investigated in greater detail in the future should action be focused on reducing natural gas leaks.[18]

Total emissions in the IP&FF sector in 2010 are estimated at 0.76 MMtCO_2e, representing 7.7% of region wide gross emissions. The geographic distribution of emissions in the region is presented in **Figure 19**. The distribution of emissions from the various source types is presented in **Figure 20**. The largest source contribution in this sector is natural gas leaks, followed by ODS substitutes.

Figure 19
SJTPO Industrial Processes and Fossil Fuel Industry GHG Emissions by County, 2010



Note: Energy cycle emissions are not relevant to the IP sector since it does not include any fuel-based emissions.

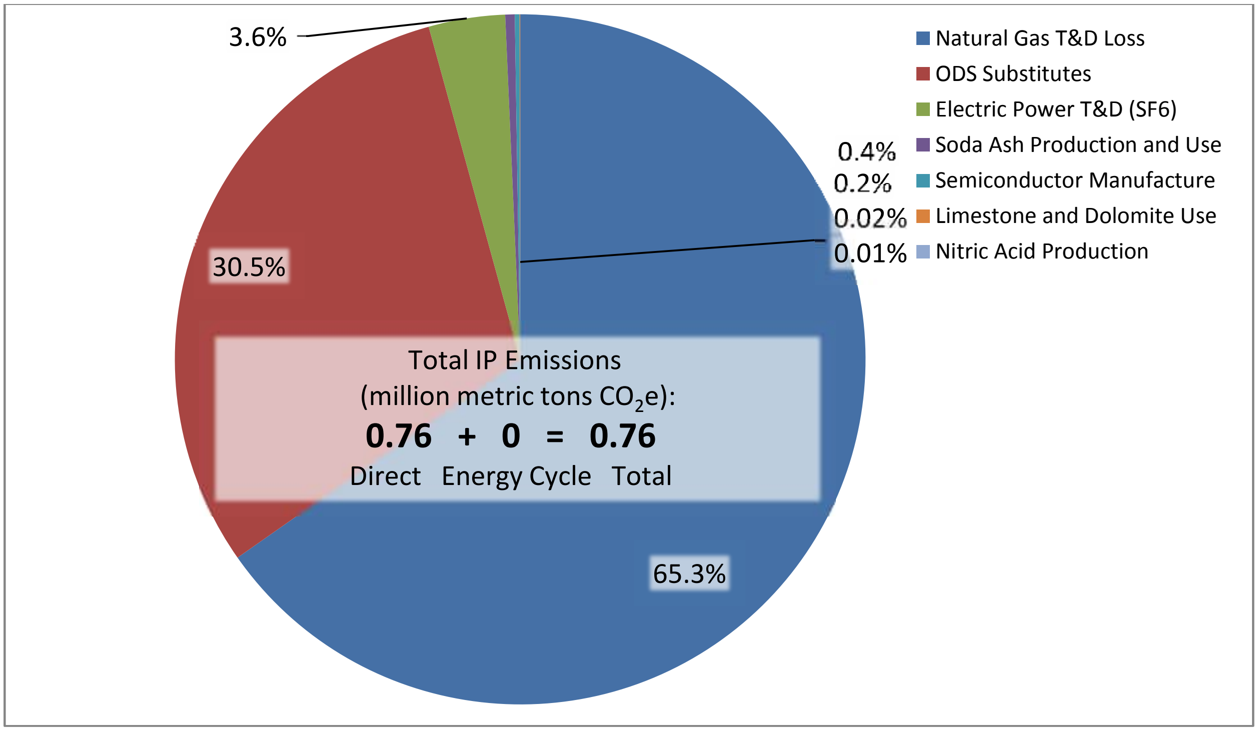
Given the level of effort required to develop reliable estimates of detailed geographic distribution, these emissions have not been allocated to the municipal level.

Note that the question of natural gas leaks has been the subject of recent debate, suggesting that leakage may be more prominent than currently estimated by EPA (this analysis is based on EPA methodology). For example, a recent evaluation of many studies had concluded that EPA estimates of methane leaks from natural gas systems may be underestimated by 25% to 75%.[19] While the total emissions may be small on the scale of the SJTPO multi-sector inventory, they are the largest source within the IP&FF sector and represent an opportunity for reducing emissions while potentially recovering costs through fuel conservation. Also, given the potential growth in future use of natural gas, this subsector may become more prominent in future years.

[18] The energy cycle estimates used for RCI natural gas use emissions is based on a national average factor. The total local leakage reported in this section is estimated based on a state-wide estimate using miles of pipeline, and numbers of services and transmission facilities in the state, allocated to the SJTPO region based on natural gas consumption.

[19] Brandt et al. Methane Leaks from North American Natural Gas Systems. *Energy and Environment,* V. 343. Feb. 14, 2014.

Figure 20
SJTPO Industrial Processes and Fossil Fuel Industry GHG Emissions by Subsector, 2010



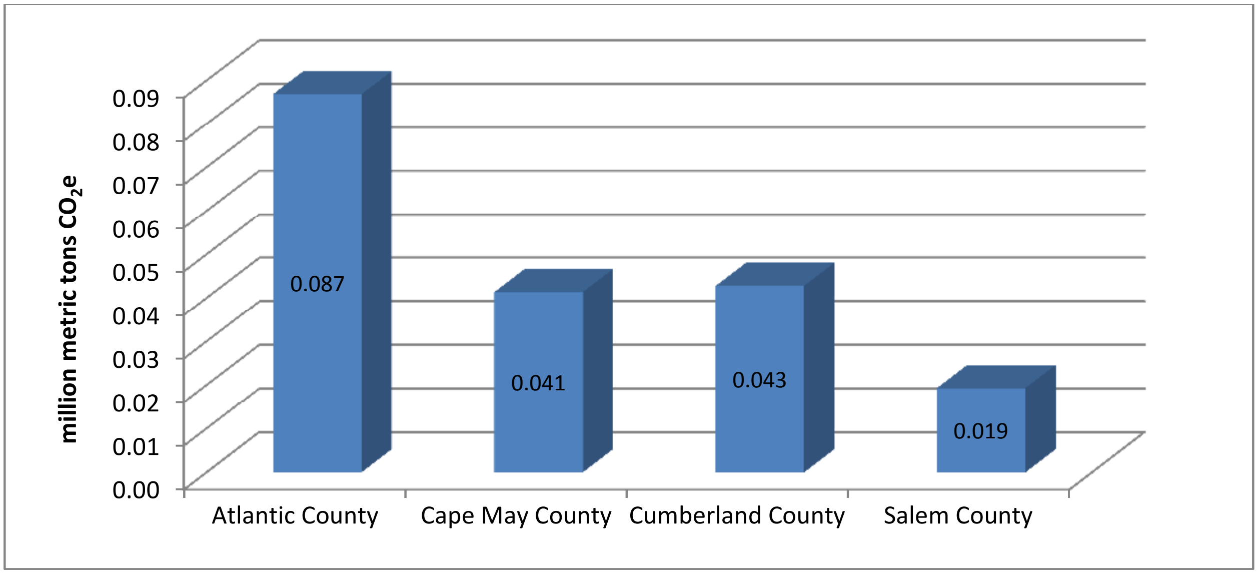
In addition to the direct emissions, emissions associated with the production and transport of cement and steel used in the region have been estimated, and are presented in **Appendix A** and discussed in **Appendix B**. While these represent only a portion of the consumption-based emissions for this sector, based on other work we have undertaken, they represent a large portion of the consumption-based emissions and can be the focus of mitigation efforts in the construction sector. Total emissions from those two components were estimated at 0.91 $MMtCO_2e$—more than the direct emissions from the entire IP&FF sector in the SJTPO region.

Waste Management

The Waste Management sector includes two primary subsectors: solid waste management and wastewater treatment. Emissions are presented on a consumption-basis. Additional results, on a direct basis, can be found in **Appendices A** and **B**.

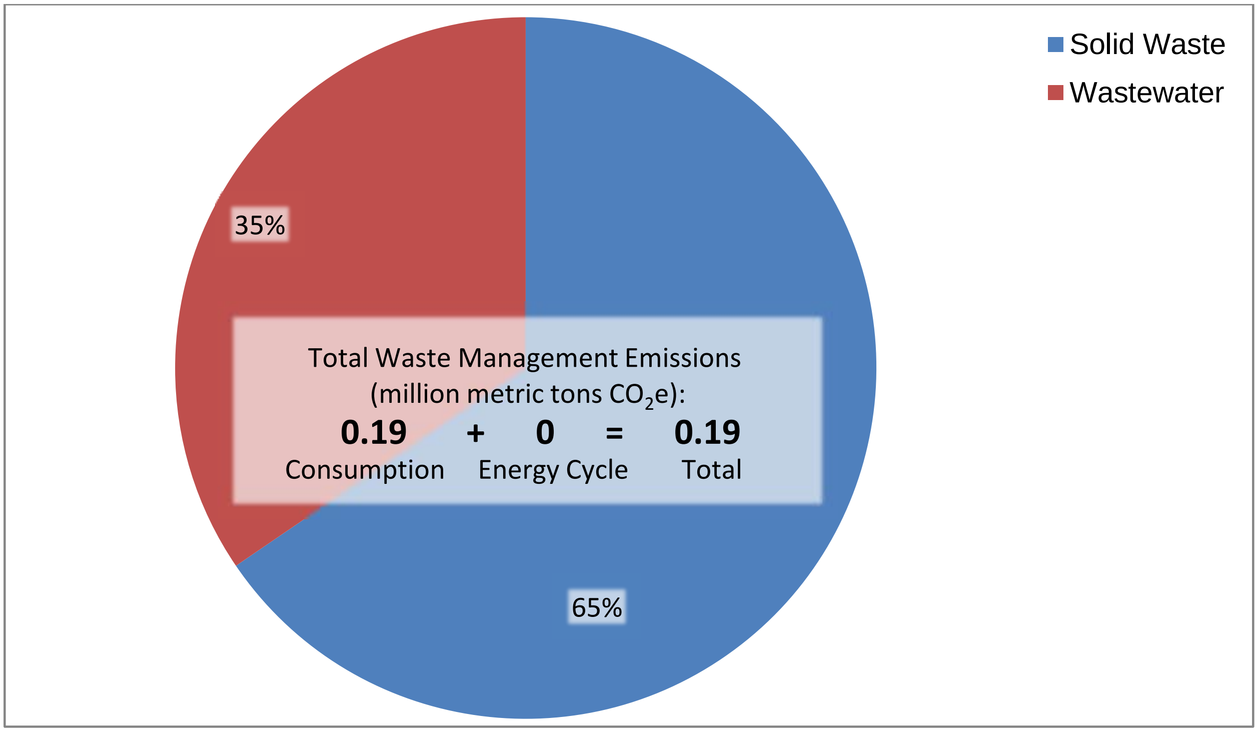
Total emissions in the Waste Management sector in 2010 are estimated at 0.19 $MMtCO_2e$. The distribution of emissions by county is presented in **Figure 21**. **Figure 22** provides a break-down of the regional emissions by subsector. Overall, the Waste Management sector contributes a small amount (1.9%) of SJTPO's gross GHG emissions with about two-thirds of its contribution coming from solid waste management. Importantly, as outlined in the Protocol (**Appendix D**), the emission estimates shown here do not include full energy cycle estimates. We expect that these would change the sector contributions significantly, as was the case in other similar projects including the NJTPA inventory. The Protocol provides background about the importance of considering upstream emissions when assessing the merits of solid waste management GHG mitigation methods.

Figure 21
SJTPO Waste Management GHG Emissions by County, 2010



Note: Energy cycle emissions are not included in the Waste Management sector emissions since any fuel-based emissions are included under RCI.

Figure 22
SJTPO Waste Management GHG Emissions by Sector, 2010

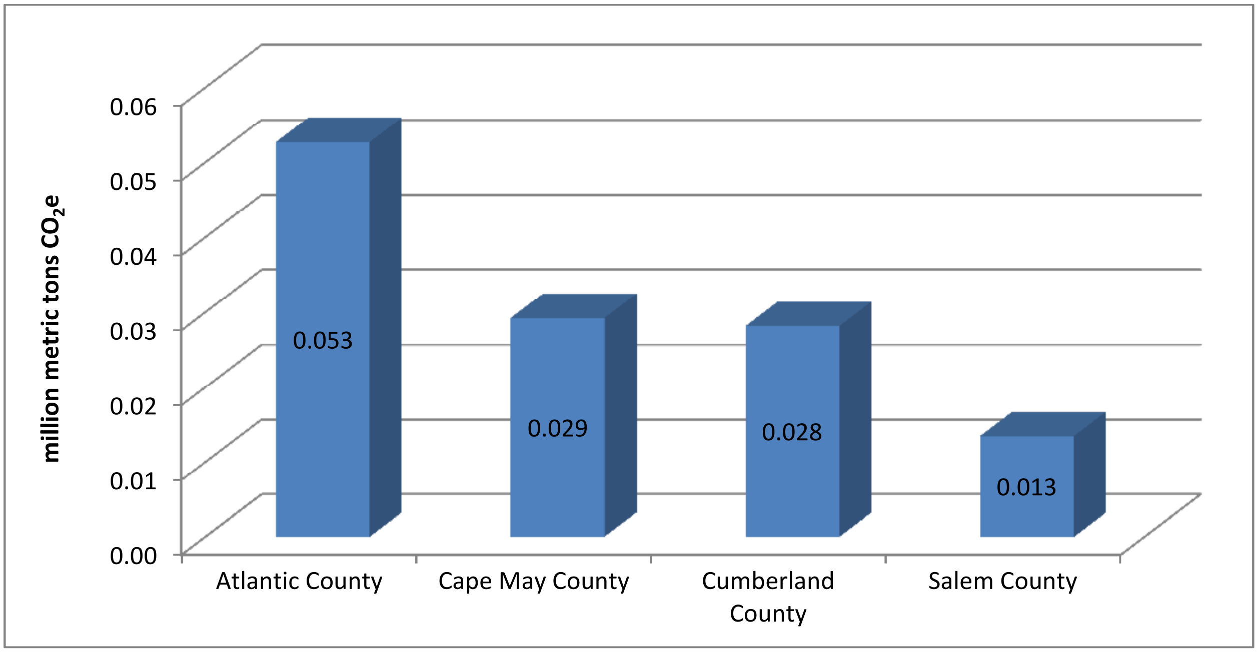


SOLID WASTE

Solid waste emissions include CH_4 and N_2O from solid waste landfilling and composting, as well as GHGs emitted during waste transport.[20] Other waste management processes, including incineration, open burning, and anaerobic digestion, were not practiced in the SJTPO region. Note that these emissions only include non-energy GHG emissions for the subsector—emissions from any fuel combustion or associated with electricity use at waste management facilities or for waste transport are captured within the RCI and Transportation sectors.

Total emissions from solid waste management in 2010 were estimated at 0.13 $MMtCO_2e$. **Figure 23** provides the distribution of emissions by county. The vast majority of the emissions are from landfill methane—119,000 $mtCO_2e$. The remainder is from composting, 2,920 $mtCO_2e$, and waste transportation, 2,545 $mtCO_2e$. Note that the transport emissions would overlap with emissions reported for the Transportation sector.

Figure 23
SJTPO Solid Waste Management GHG Emissions by County, 2010



Note: Energy cycle emissions related to solid waste management processes are not included since any energy related emissions are included under the RCI sector. For consumption-based estimates, solid waste transportation is included, which include a very minor energy cycle component, not displayed here.

Seasonal solid waste emissions were also evaluated.[21] Cumberland and Salem Counties reported no seasonal resident fluctuations.[22] For Atlantic and Cape May counties, seasonal population data at the municipal level were used to allocate annual emission estimates to a

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[20] For waste transport, emissions are estimated using a default EPA Waste Reduction Model (WARM) emission factor of 0.00281 $mtCO_2e$/short ton of waste transported. This accounts for emissions from waste transportation within a county.

[21] In reality, GHG emissions from composting and landfilling won't follow directly from variations in waste generation due to the lag in time between generation of the waste and the actual emission (e.g., due to decomposition of waste via biological processes).

[22] G. Conover and M. Williams, ACUA and SCIAMJ, personal communication with L. Bauer, CCS; 5/30/2014.

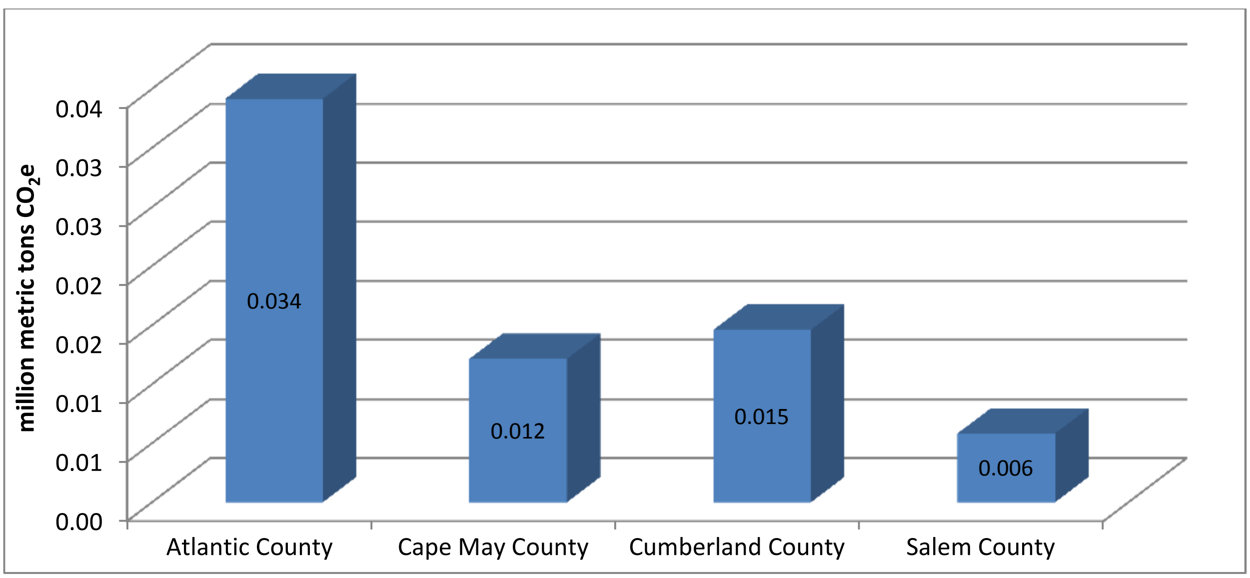
summer season total, as well as a non-summer season total (see **Appendix C**; this affected landfill methane only). This allocation method assumes that seasonal residents and year-round residents generate waste at a similar rate and composition. For landfill methane, these seasonal allocations indicate that one-third to one-half of the emissions could be associated with waste generated by seasonal populations.

WASTEWATER TREATMENT

Wastewater treatment emissions include CH_4 and N_2O from municipal and industrial wastewater treatment processes. Since none of the common sources of industrial wastewater treatment were identified in the SJTPO region (e.g., pulp and paper, red meat, poultry, vegetables and fruit processing), only municipal wastewater treatment emissions are addressed, including wastewater treatment processing in centralized plants and biosolids management. For biosolids management, the emissions include GHGs from biosolids incineration. Land application of biosolids is the other main method for biosolids management within the region. For biosolids that are land applied, the emissions are addressed within the Agriculture sector. Note that these emissions only include non-energy emissions for the subsector. Emissions from any fuel combustion or associated with electricity consumption at these facilities are captured within the RCI sector totals.

Total emissions from wastewater treatment in 2010 were estimated at 0.067 $MMtCO_2e$. The distribution of emissions by county is presented in **Figure 24.**

Figure 24
SJTPO Wastewater Treatment GHG Emissions, 2010



Note: Process emissions only; energy-related emissions are captured within the totals for the RCI sector.

Seasonal wastewater emissions were also calculated.[23] 2010 seasonal population data at the municipal level were used to allocate annual emission estimates to a summer season total, as well as a non-summer season total. **Table 3** provides a comparison of monthly emissions

[23] In reality, GHG emissions from composting and landfilling won't follow directly from variations in waste generation due to the lag in time between generation of the waste and the actual emission (e.g., due to decomposition of waste via biological processes).

derived from these seasonal and non-seasonal estimates. Note that a better allocation procedure could be developed in the future, if data on residential versus commercial/institutional generation of wastewater can be identified.

Table 3
SJTPO Seasonal Emissions from Wastewater Management, 2010

Source	**Average Monthly Non-Summer ($mtCO_2e$)**	**Average Monthly Summer Season ($mtCO_2e$)**
Wastewater Processing	3,371	9,080
Wastewater Biosolids Management	586	1,343

Land Use, Land Use Change, and Forestry (LULUCF)

This sector includes net CO_2 flux from both forested lands and urban forests (including parks, street trees, and trees on non-agricultural private land). Since vegetation and soils sequester carbon from the atmosphere, but also release carbon when decaying, the CO_2 flux in any given area could represent a net source or a net sink. The net CO_2 flux results from a net change in biomass (in soils or forest carbon) on lands that do not undergo land use or land cover change (e.g., early successional forests undergoing densification), or on lands that do undergo a change in land use/cover (e.g., conversion of forest land to another land use without forest cover). This sector also includes emissions of N_2O from non-agricultural fertilizer application (often referred to as "settlement soils"),[24] and GHG emissions from fuel combustion in forestry sector non-road engines. Emissions were estimated on a direct accounting basis only. LULUCF emissions are not substantially affected by changes in seasonal population.

Overall, the LULUCF sector reduced atmospheric GHG by 0.97 $MMtCO_2e$ in 2010 due to net sequestration, equivalent to approximately 9.8% of region-wide gross emissions. **Figure 25** provides the county-level emissions for the LULUCF sector in 2010. This estimate is not directly comparable to the New Jersey State estimates due to some differences in methodology; however, as a point of reference, it is roughly 13% of the 7.6 $MMtCO_2e$ sequestration estimated for the State for 2009.[25] While the SJTPO region has a higher percentage of forest cover than other regions in the state, the region's forests tend to be older and therefore well past their peak carbon sequestration potential. In addition to the forested lands and urban forests sinks described in detail below, this sector includes a very minor contribution (0.0009 $MMtCO_2e$) from non-road engines used for forestry, including some energy cycle emissions from the fuel used in those engines. The distribution of emissions by subsector is presented in **Figure 26**.

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[24] N_2O is produced naturally in soils through the microbial processes of denitrification and nitrification. When nitrogen containing fertilizers are applied to settlement soils, it increases the amount of N available for these processes, and ultimately the amount of N_2O emitted.

[25] NJDEP, Statewide Greenhouse Gas Emission Inventory for 2009, NJ Department of Environmental Protection, Office of Sustainability and Green Energy, Office of Science, November 2012. http://www.nj.gov/dep/sage/docs/ghg-inventory2009.pdf. The work done in the SJTPO project points to the need to review and potentially revise the methods used to construct the overall state-level estimates.

Figure 25
SJTPO LULUCF Sector GHG Emissions, 2010

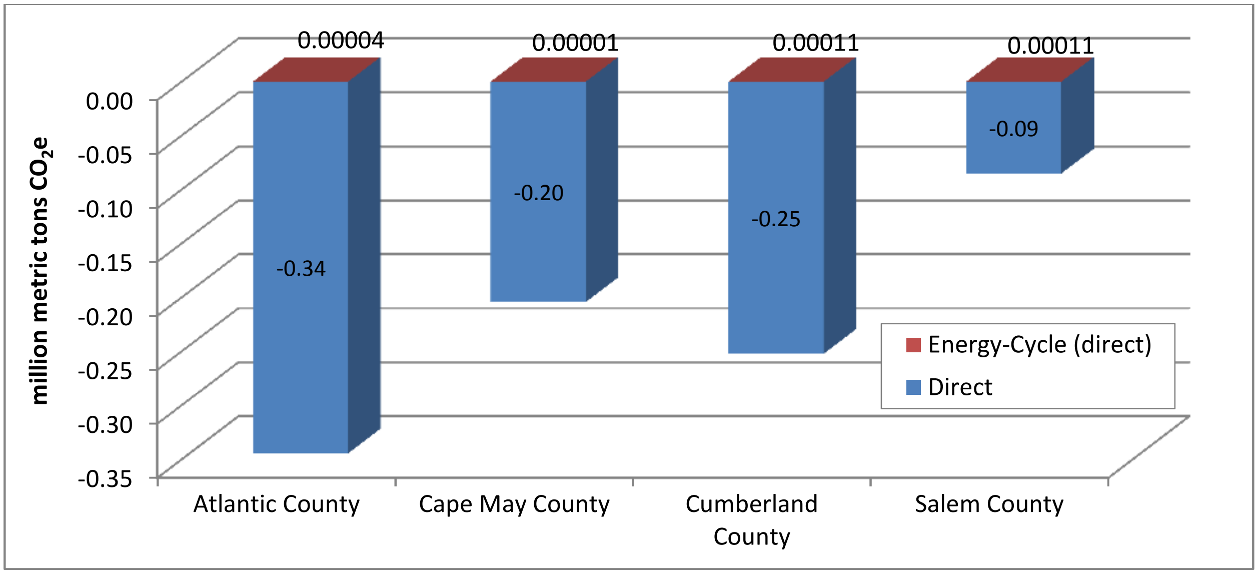
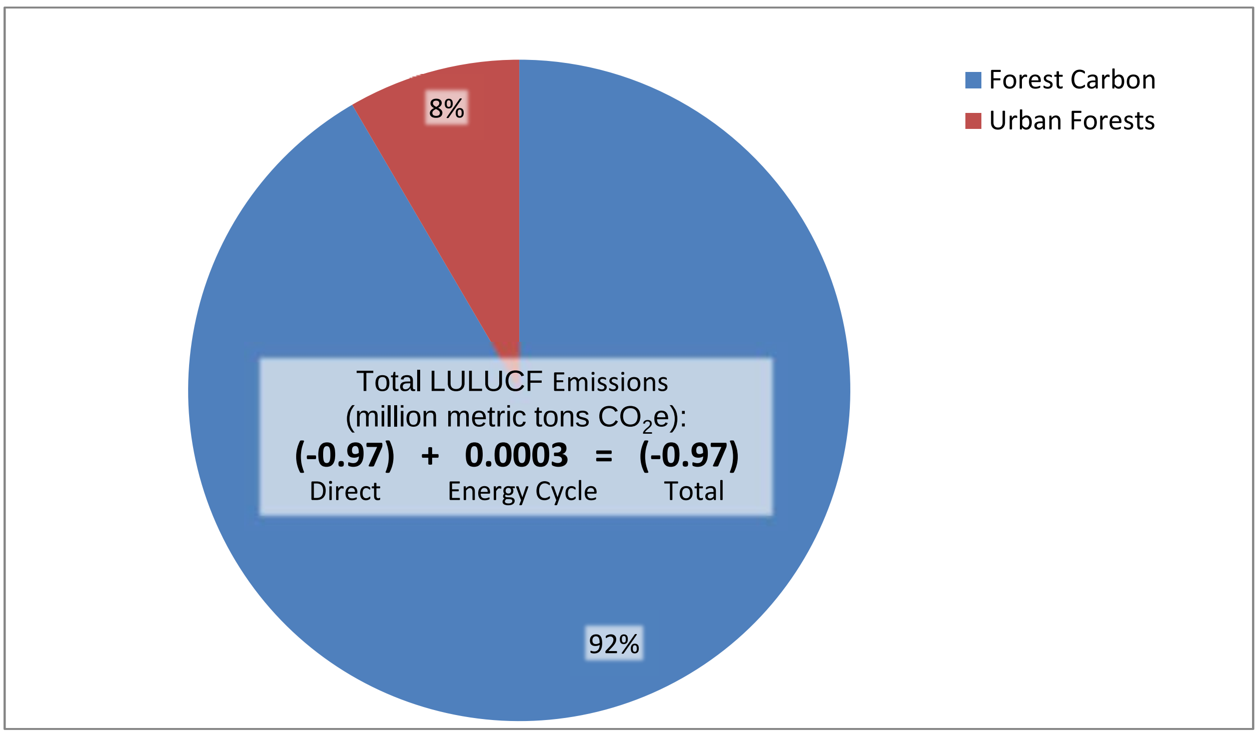


Figure 26
SJTPO LULUCF Emissions by Subsector, 2010



Note: Negative emissions represent sequestration. Chart excludes emissions from non-road engines, which contribute a negligible amount to this sector, and which are also responsible for the energy cycle emissions.

FORESTED LANDS

There are two influences affecting net CO_2 flux from forested lands that need to be considered. First, sequestration or emissions result from changes in forest carbon density, such as increases in carbon density due to growth of vegetation or decreases due to loss of carbon through tree mortality or removal. Second, changes in forest carbon result from land use changes, which increase or decrease the total forested area. For both forest land use change and forest carbon flux, estimates of net CO_2 sequestration/emission were developed using municipal-level acreage estimates for detailed forest and wetland land uses from NJDEP for 2002 and 2007 (2012 data were not available in time for use in this inventory).[26]

Another aspect of assessing net carbon sequestration is the removal of wood from forests to create durable wood products. County-level estimates of wood harvests for roundwood products, excluding residential fuel, were obtained from the USFS Timber Products Output (TPO) database for all available years: 2002, 2007, and 2012.[27] Removals of forest carbon for forest products or energy use were captured within the USFS Forest Inventory & Analysis (FIA)[28] survey data, which underpin the modeled USFS carbon density estimates in a given area. The estimates for durable wood products should be thought of as an upper-level estimate, since they don't account for carbon losses during milling and manufacturing (e.g. scrap and sawdust). More details are provided in **Appendix C** of this report for the forest carbon estimates.

Net GHG emissions were also evaluated for wetlands. While recent work in this area has been completed in NJ, the science regarding carbon accumulation and methane emissions in these areas is still evolving. Ongoing work should provide sufficient information to derive net GHG emissions in the near future. Forestry GHG estimates by county in 2010 are provided in **Figure** 27.

Non-road fuel combustion for forestry uses is also included in this sector. County-level fuel consumption estimates from the EPA NONROAD model served as the primary input to these emission estimates. GHG emissions associated with biomass combustion are included in the applicable energy use sector (e.g., RCI).

A further breakdown of the forested lands emissions by source/sink type is shown in

Table 4. While land use change produces net emissions, forest carbon and wood harvests result in net sequestration.

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[26] J. Reyes, NJDEP personal communication with S. Roe, CCS, January 21, 2014. Note: NJDEP land use data for 2012 are not expected to be available until mid- to late-2014. NJDEP land use data can be found at http://www.state.nj.us/dep/gis/listall.html.

[27] Timber Product Output (TPO) Reports, Knoxville, TN: U.S. Department of Agriculture Forest Service, Southern Research Station, http://srsfia2.fs.fed.us/php/tpo_2009/tpo_rpa_int1.php, accessed March, 2014.

[28] More information about the FIA program can be found at http://www.fia.fs.fed.us/.

Figure 27
SJTPO Forestry GHG Emissions, 2010

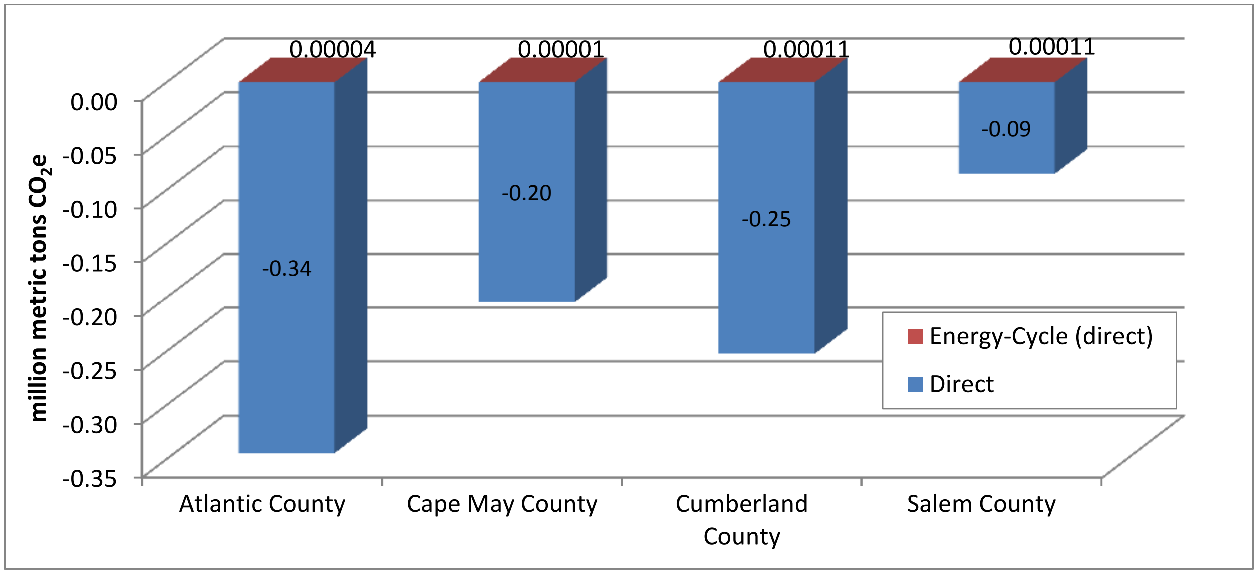


Table 4
Forested Lands Emissions by Source and County

County	Land Use Change	Forest Carbon Sequestration	Wood Harvests	Total County
Atlantic	0.094	-0.43	-0.004	*-0.34*
Cape May	0.040	-0.24	0.000	*-0.20*
Cumberland	0.080	-0.33	-0.002	*-0.25*
Salem	0.047	-0.13	-0.003	*-0.09*
Total Source	**0.261**	**-1.14**	**-0.009**	***-0.89***

Note: Rounding provides significant figures only. Totals are rounded accordingly.

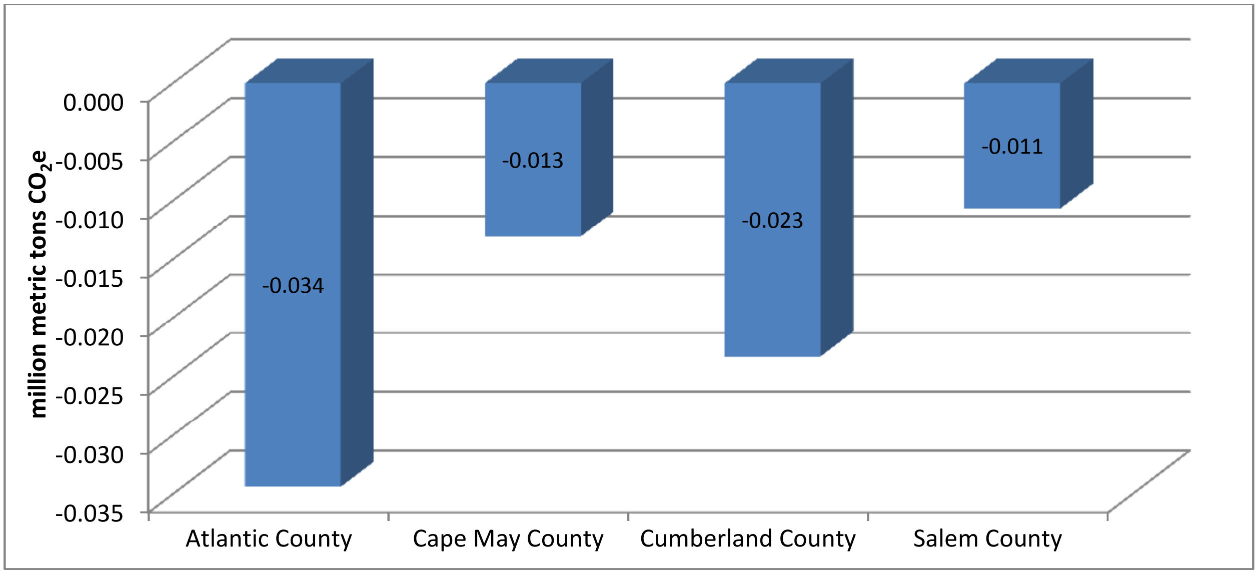
URBAN FORESTS

For urban trees, activity data were developed using the area of urban forested land use in each municipality from the NJDEP land use data and the percent of urban tree canopy cover for each municipality available from USFS.[29] Also within urban forests subsector, estimates of N_2O emissions from "settlement soils" were derived; these result from application of non-agricultural fertilizers. The EPA State Inventory and Projection Tool (SIT) Land Use, Land Use Change and Forestry Module[30] served as the primary data source. **Figure 28** provides a county-level summary of these emissions in 2010.

[29] Urban Forest Data for New Jersey, U.S. Department of Agriculture Forest Service, State Summary Report, Table 5, Tree canopy and impervious surface cover characteristics by community, http://www.nrs.fs.fed.us/data/urban/state/?state=NJ.

[30] USEPA, State Inventory and Projection Tool, http://www.epa.gov/statelocalclimate/resources/tool.html.

Figure 28
SJTPO Urban Forests GHG Emissions, 2010



A further breakdown of the urban forest emissions by source/sink type is shown in **Table 5**. While settlement soils produce net emissions, urban forests overall result in net sequestration.

Table 5
Urban Forest Emissions by County

County	Urban Trees	Settlement Soils	Total
Atlantic	-0.035	0.0004	*-0.035*
Cape May	-0.014	0.0005	*-0.014*
Cumberland	-0.023	0.0002	*-0.023*
Salem	-0.011	0.0003	*-0.011*
SJTPO	**-0.083**	**0.001**	***-0.082***

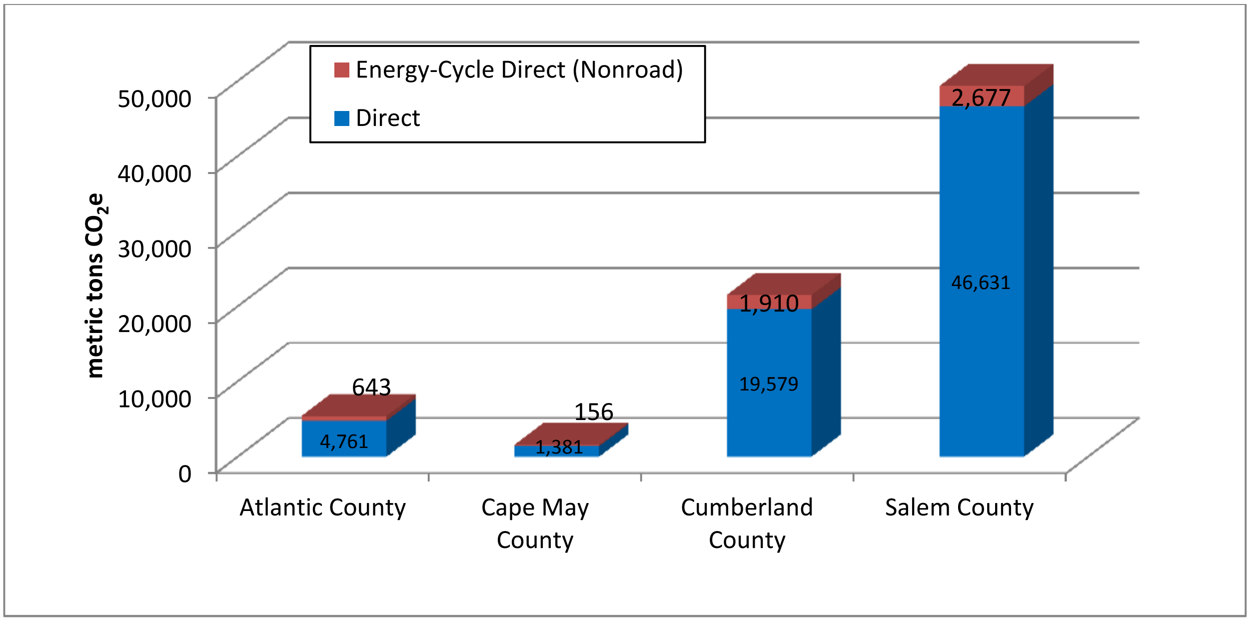
Note: Rounding provides significant figures only. Totals are rounded accordingly.

Agriculture

The Agriculture sector includes three subsectors: livestock management, crop production, and non-road engines. The first two subsectors address non-energy consumption emissions, which mainly cover methane and nitrous oxide emissions. Non-road engine emissions, primarily from diesel and gasoline combustion in crop cultivation equipment, cover CO_2, CH_4 and N_2O.

Total GHG emissions in the Agriculture sector in 2010 were estimated at 78,000 $mtCO_2e$, including 5,700 $mtCO_2e$ associated with the energy cycle of non-road engine fuels. The Agriculture sector emissions represent a small fraction of the region wide emissions (0.7% of gross emissions excluding energy cycle emissions). **Figure 29** provides the county-level emissions for the sector in 2010. The additional upstream emissions for the energy cycle are also shown for non-road fuel combustion (these contribute roughly an additional 13% of GHGs to the non-road fuel combustion emissions). As outlined in the Protocol (**Appendix D**), consumption-based emission estimates for the Agriculture sector were not developed for this project. Agriculture seasonal emissions are not substantially affected by changes in seasonal population.

Figure 29
SJTPO Agriculture GHG Emissions by County, 2010



Overall, the agriculture emissions represent a smaller fraction of the region wide emissions than may have been expected due to the large amount of agricultural activity in the region. This is because there is not much large livestock (especially cattle and pigs), and most of the crops grown in the regional are not large consumers of nitrogen fertilizers (aside from some corn/sorghum/vegetables mainly in Salem County). This analysis is also more accurate than some other similar estimates because it analyzes detailed data (bottom-up).

Figure 30 shows the contribution of GHG emissions by each subsector within the SJTPO region. Crop production is shown to be the largest contributing subsector at 42%. Of this total for crop production (all N_2O emissions from nitrogen inputs to soil), crop residue provides 20%, N-fixation provides 33%, application of synthetic fertilizers provides 36%, application of organic fertilizers provides 6%, and indirect N_2O emissions provide 5%.[31] Since non-road fuel combustion is primarily associated with crop cultivation, over 70% of agricultural emissions could be associated with this activity.

The livestock management and crop production analyses were based on municipal-level livestock populations and crop production land use (area used for specific crops). The analysis methodology is detailed in the Protocol in **Appendix D**. Additional details regarding the analysis, the evaluation of available data, and development of crop nitrogen requirements are included in **Appendix C.**

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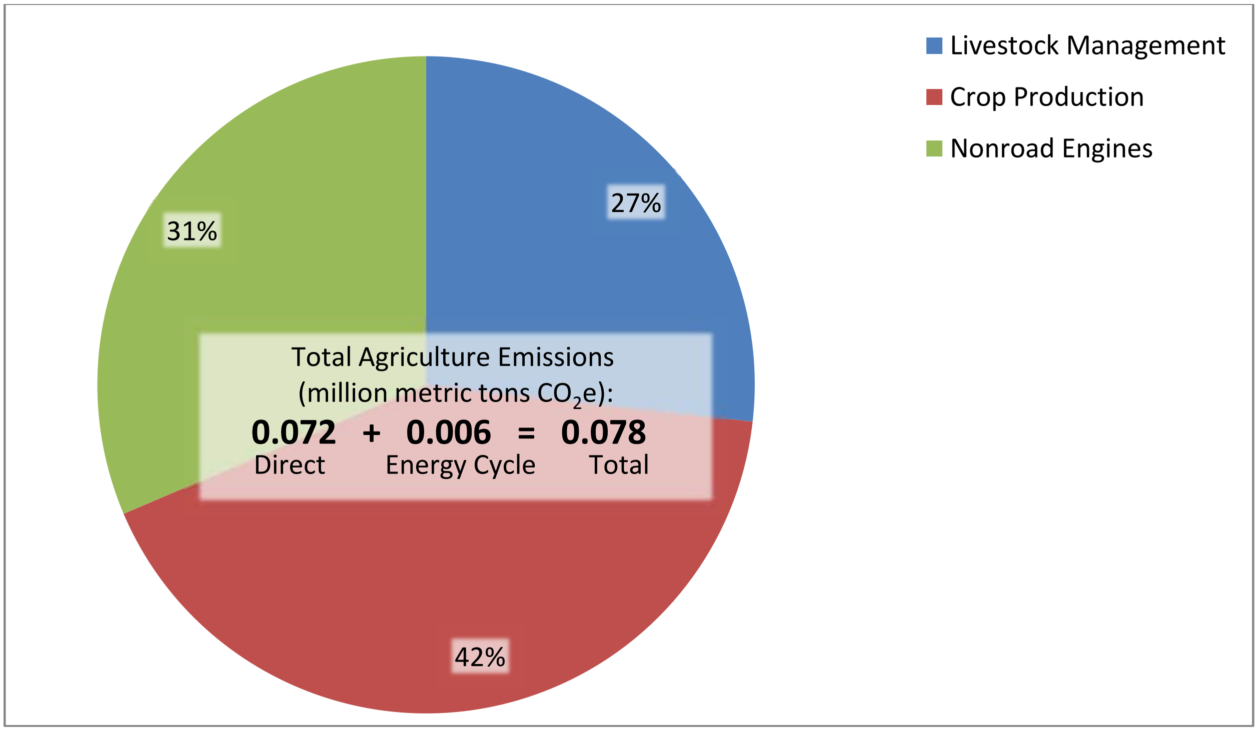
[31] Indirect N_2O results from leaching and run-off of synthetic and organic nitrogen applied to fields, emitted in another location as N_2O, as well as nitrogen from these applications that volatilizes, subsequently deposits elsewhere, and is emitted as N_2O.

Figure 30
SJTPO Agriculture GHG Emissions by Source Type, 2010



CROP PRODUCTION

Crop production emission sources addressed are N_2O emissions that occur as a result of nitrogen (N) inputs to crop soils:

- Crop residues
- Nitrogen fixing crops
- Application of synthetic fertilizers
- Application of organic fertilizers: including manure and sewage treatment plant (STP) biosolids

Other sources of GHG emissions for crop production that were not addressed, include:

- Crop residue burning: NJ has a ban on open burning and none of this is practiced in the State;[32]
- Liming of soils: limestone and dolomite are applied to acidic soils; however, bottom-up information as to where, crop type, and amounts were not identified. It should be noted that the IP sector has estimates for CO_2 emissions from limestone/dolomite use that include all state-level consumption of these materials (both for industrial processes and agricultural use). However, information from local agricultural experts would be needed in order to break-out Agriculture sector use from industrial use.

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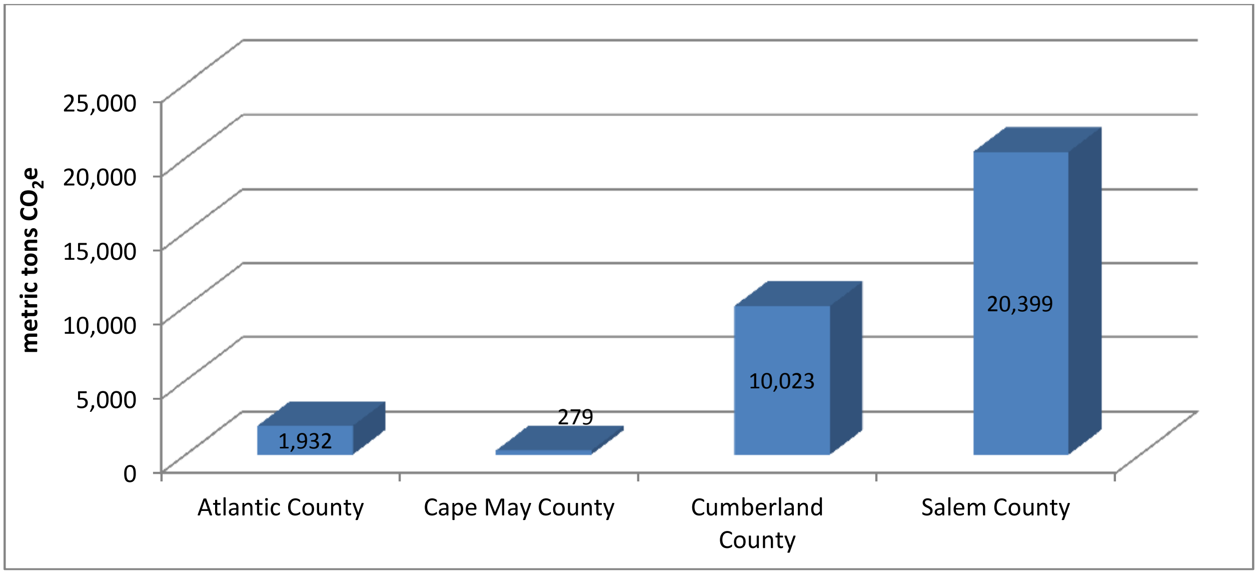
[32] D. Kluchinski, Assistant Director of Extension, Department of Agricultural and Resource Management Agents, Rutgers Cooperative Extension, personal communication with S. Roe, 3/12/2014.

- Urea application: while the N_2O emissions from N application are addressed, the decomposition of urea also emits CO_2. These emissions could be estimated with some local information on the fraction of total synthetic N supplied by urea fertilizers.
- Land use/cover change: within the Agriculture sector, terrestrial carbon gains/losses occur during shifts from one land cover to another (e.g., woodlands to crops), or when crop cultivation practices change (e.g., change from a pasture to annual crops). Very detailed land use and management change data would be needed to assess these net carbon fluxes, along with above and below-ground carbon density data. Currently these data are lacking, at the sub-state level. For example, the USDA Natural Resources Conservation Service (NRCS) develops the Natural Resources Inventory which provides state-level data on changes in land use; however, there are no reliable methods for allocating these changes down to the county or municipal scales.

Total emissions from crop production in 2010 (excluding non-road engine emissions) were estimated at 32,633 $mtCO_2e$. Distribution of the emissions by county is presented in **Figure 31**.

Figure 31
SJTPO Crop Production GHG Emissions by County, 2010

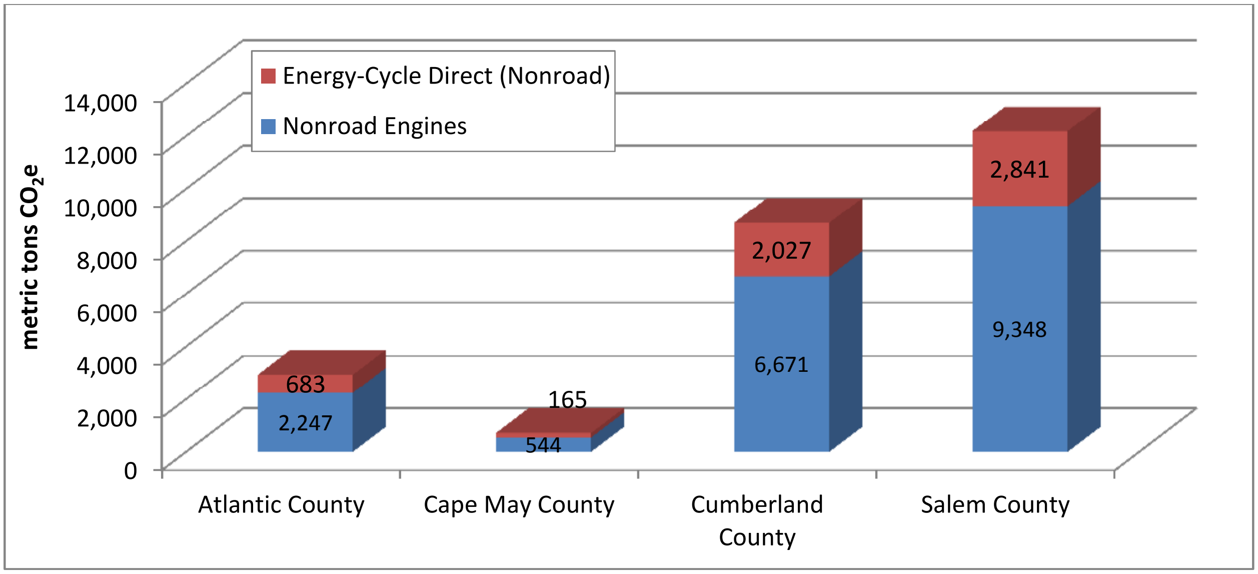


AGRICULTURAL NON-ROAD ENGINES

County-level non-road fuel consumption and emissions were allocated to each municipality based on harvested cropland acres from the 2010 FAP data. In future work, more accuracy could be achieved if data can be identified on the fuel use intensity for different crop types (e.g., gallons diesel/acre). In that case, the non-road fuel consumption estimates could be derived from the bottom-up, like the crop production and livestock management emission estimates.

Total emissions from agricultural non-road engines in 2010 (largely associated with crop production) were estimated at 24,527 $mtCO_2e$, including energy cycle emissions of 5,716 $mtCO_2e$. Distribution of the emissions by county is presented in **Figure 32**.

Figure 32
SJTPO Agricultural Non-Road Engine GHG Emissions by County, 2010



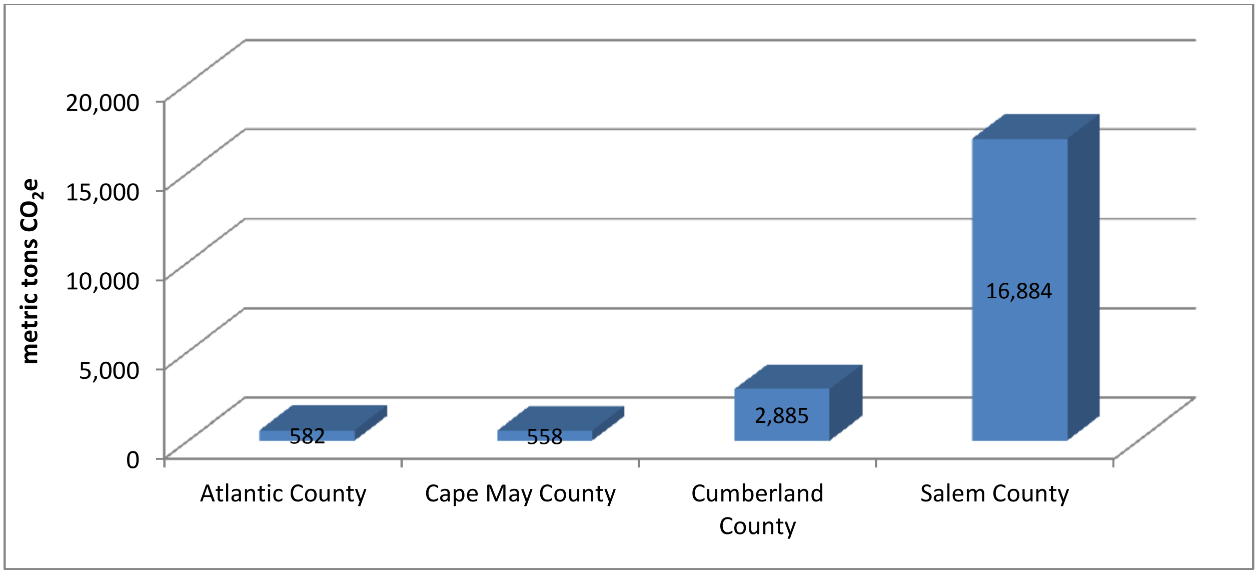
LIVESTOCK MANAGEMENT

Livestock management emissions include CH_4 from enteric fermentation and CH_4 and N_2O from manure management (prior to field application). An uncertainty encountered by the team in applying these emission factors concerns the fraction of beef cattle located on feedlots. The State has relatively few feedlot cattle, and we were unable to find any information on feedlots located in the SJTPO region. As a result, the emission estimates presume that all beef cattle are managed on pasture/range, rather than on feedlots, which results in much lower manure management emissions.

Total emissions from livestock management in 2010 (excluding non-road engine emissions) were estimated at 20,910 mtCO_2e. Distribution of the emissions by county is presented in **Figure 33**.

County-level non-road fuel consumption and emissions were allocated to each municipality based on harvested cropland acres from the 2010 FAP data. In future work, more accuracy could be achieved if data can be identified on the fuel use intensity for different crop types (e.g., gallons diesel/acre). In that case, the non-road fuel consumption estimates could be derived from the bottom-up, like the crop production and livestock management emission estimates.

Figure 33
SJTPO Livestock Management GHG Emissions by County, 2010



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Appendix A

Municipal and County Annual and Summer Emissions by Subsector

Annual Consumption-Based GHG Emissions by Subsector (including energy cycle emissions where available)

CO_2e (metric tons)

County	Municipality	RCI – Fuel Use – Residential	RCI – Fuel Use – Commercial	RCI – Fuel Use – Industrial	RCI – Fuel Use – Non-Road	RCI – Electricity – Residential	RCI – Electricity – Commercial	RCI – Electricity – Industrial	Transportation – On-Road	Transportation – Non-Road[2]	Transportation – Aviation[1,2]	Transportation – Rail-Passenger[2]	Transportation – Rail-Freight[2]	Transportation – Marine[2]	Industrial Processes[3] – Cement Use[2]	Industrial Processes[3] – Iron and Steel Use[2]	Industrial Processes[3] – Electric Power Transmission and Distribution[1,2]	Industrial Processes[3] – Limestone and Dolomite Use[1,2]	Industrial Processes[3] – Natural Gas Transmission and Distribution Loss[1,2]	Industrial Processes[3] – Nitric Acid Production[1,2]	Industrial Processes[3] – ODS Substitutes[1,2]	Industrial Processes[3] – Semiconductor Manufacture[1,2]	Industrial Processes[3] – Soda Ash Production and Use[1,2]	Agriculture – Crop Production[1]	Agriculture – Livestock Management[1]	Agriculture – Non-Road	Waste Management[3] – Solid Waste	Waste Management[3] – Wastewater	Land Use, Land Use Change, And Forestry – Forest Carbon[1]	Land Use, Land Use Change, And Forestry – Urban Forests[1]	Land Use, Land Use Change, And Forestry – Non-Road[1]
Atlantic County	Absecon city	3,638.8	2,106.9	626.4	3,671.3	21,821.0	21,429.4	0	87,428.0	N/A	N/A	1,184.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,677.2	1,030.4	N/A	N/A	0.5
Atlantic County	Atlantic City city	14,725.7	85,702.0	23,472.8	53,379.0	51,030.4	588,775.9	27.1	739,227.3	N/A	N/A	6,748.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	8,193.6	5,109.7	N/A	N/A	<0.1
Atlantic County	Brigantine city	5,090.3	1,165.6	271.7	1,808.6	36,038.6	12,248.2	39.9	44,283.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	2,310.7	1,504.7	N/A	N/A	<0.1
Atlantic County	Buena borough	2,626.7	1,788.6	297.3	1,324.5	17,735.9	10,850.7	7,124.9	34,244.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	309.2	818.8	549.7	N/A	N/A	1.2
Atlantic County	Buena Vista township	3,557.2	3,322.2	423.0	1,514.6	11,904.8	2,504.8	823.1	65,668.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	505.7	1,399.5	909.1	N/A	N/A	18.6
Atlantic County	Corbin City city	58.9	72.4	25.6	155.8	1,394.9	742.6	0	3,046.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.0	91.5	60.1	N/A	N/A	0.7
Atlantic County	Egg Harbor township	11,463.2	23,481.6	554.5	4,460.7	98,959.2	94,682.6	1,021.2	335,273.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	7,860.5	5,128.0	N/A	N/A	2.1
Atlantic County	Egg Harbor City city	1,517.2	7,781.2	2,470.3	13,373.9	10,543.2	9,776.7	314.9	40,576.2	N/A	N/A	701.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	82.0	839.7	520.7	N/A	N/A	18.1
Atlantic County	Estell Manor city	1,140.4	113.7	40.7	281.7	5,050.7	968.3	72.2	11,690.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	68.2	303.9	204.8	N/A	N/A	24.3
Atlantic County	Folsom borough	604.4	1,331.8	222.9	869.8	9,215.0	4,226.6	1,426.0	23,845.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	38.4	331.3	222.1	N/A	N/A	3.5
Atlantic County	Galloway township	13,019.7	5,285.5	1,521.2	9,456.8	75,287.9	107,162.7	1,002.1	270,031.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	184.5	6,919.1	4,442.8	N/A	N/A	21.9
Atlantic County	Hamilton township	9,688.2	10,179.3	1,846.0	10,615.8	60,237.5	65,298.1	1,112.4	262,854.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	314.5	4,772.9	3,143.8	N/A	N/A	46.9
Atlantic County	Hammonton town	2,978.1	7,827.0	9,604.3	8,642.1	38,411.6	36,884.3	2,683.0	194,923.3	N/A	N/A	726.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,011.5	2,681.1	1,759.8	N/A	N/A	9.1
Atlantic County	Linwood city	1,731.4	1,407.0	478.5	2,828.1	20,033.5	12,629.1	<0.1	57,043.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.0	1,263.9	844.3	N/A	N/A	<0.1
Atlantic County	Longport borough	645.1	96.9	27.3	179.5	6,638.0	3,045.5	15.5	4,382.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	305.2	195.6	N/A	N/A	<0.1
Atlantic County	Margate City city	4,523.4	1,054.7	286.8	1,775.7	27,915.2	11,085.1	0	39,565.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,655.2	1,076.3	N/A	N/A	<0.1
Atlantic County	Mullica township	2,099.8	369.1	141.2	788.8	15,392.3	3,015.6	203.4	39,464.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	357.2	1,069.8	722.8	N/A	N/A	24.6
Atlantic County	Northfield city	1,995.4	2,783.8	695.9	4,051.2	19,550.0	19,375.1	0	73,467.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.8	1,524.4	1,016.7	N/A	N/A	0.2
Atlantic County	Pleasantville city	8,830.1	5,757.9	1,339.2	7,813.4	30,568.8	41,271.5	1,491.3	143,615.9	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	3,504.8	2,344.4	N/A	N/A	0.3
Atlantic County	Port Republic city	320.6	40.8	14.8	120.2	4,364.6	1,363.5	0	6,090.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.5	196.4	132.6	N/A	N/A	1.5
Atlantic County	Somers Point city	3,235.5	6,430.5	1,047.5	6,023.9	22,379.3	34,408.1	180.3	104,202.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	2,149.6	1,392.0	N/A	N/A	<0.1
Atlantic County	Ventnor City city	5,929.3	3,965.1	352.8	1,982.5	26,363.6	14,163.5	1,507.5	44,243.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	2,319.4	1,521.1	N/A	N/A	<0.1
Atlantic County	Weymouth township	587.8	120.9	30.7	264.5	6,969.5	1,324.7	16.6	46,803.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	496.9	334.5	N/A	N/A	6.3
Cape May County	Avalon borough	2,012.2	688.6	262.7	2,915.2	23,734.9	8,904.3	0	26,264.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	793.0	374.3	N/A	N/A	<0.1
Cape May County	Cape May city	964.8	2,964.9	1,008.2	11,006.9	15,278.5	25,259.0	2,262.0	33,363.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,064.0	474.8	N/A	N/A	<0.1
Cape May County	Cape May Point borough	111.0	75.9	32.2	370.2	2,521.8	895.3	0	2,226.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	249.9	53.2	N/A	N/A	<0.1
Cape May County	Dennis township	2,332.7	924.8	371.3	4,553.6	20,076.9	12,127.0	48.4	56,244.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	318.2	1,944.2	607.0	N/A	N/A	8.3
Cape May County	Lower township	5,369.7	1,509.5	593.7	8,533.3	69,577.1	32,104.1	4,429.8	115,853.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	80.7	5,427.3	2,417.3	N/A	N/A	1.1
Cape May County	Middle township	5,683.7	5,826.0	2,117.0	24,195.3	52,606.6	71,250.2	502.4	200,167.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	209.9	4,666.4	1,854.1	N/A	N/A	5.0
Cape May County	North Wildwood city	2,101.3	1,003.8	258.8	3,129.4	21,309.8	15,731.3	1.7	27,572.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,598.8	748.6	N/A	N/A	<0.1
Cape May County	Ocean City city	12,296.0	3,459.8	1,126.7	13,074.7	71,748.4	34,041.4	81.9	99,194.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	4,267.3	1,928.7	N/A	N/A	0
Cape May County	Sea Isle City city	1,376.6	635.0	234.6	2,694.7	25,328.4	7,294.0	147.9	27,573.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,141.6	506.1	N/A	N/A	<0.1
Cape May County	Stone Harbor borough	629.1	655.9	182.1	2,015.4	13,112.8	5,567.1	4.7	18,023.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	489.7	228.7	N/A	N/A	<0.1
Cape May County	Upper township	2,666.7	1,513.8	585.7	7,429.0	38,716.4	18,935.4	1,093.0	98,335.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	45.5	2,991.2	1,223.8	N/A	N/A	7.9
Cape May County	West Cape May borough	400.2	99.8	32.2	442.7	4,009.7	1,756.4	0	5,917.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29.1	318.6	128.9	N/A	N/A	<0.1
Cape May County	West Wildwood borough	324.4	43.8	11.1	176.4	2,139.5	295.6	0	2,785.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	216.1	89.8	N/A	N/A	<0.1
Cape May County	Wildwood city	2,722.3	2,583.8	710.3	8,016.8	17,839.6	30,152.4	1,477.2	46,758.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,927.3	738.1	N/A	N/A	<0.1
Cape May County	Wildwood Crest borough	1,812.3	1,067.1	269.5	3,165.0	17,119.7	12,968.4	0	21,056.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,543.5	524.2	N/A	N/A	<0.1
Cape May County	Woodbine borough	378.4	2,716.2	389.0	4,312.0	5,209.7	8,800.0	922.3	33,625.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.1	581.8	233.0	N/A	N/A	1.7
Cumberland County	Bridgeton city	12,139.7	6,036.2	5,527.4	13,110.1	56,615.5	71,859.4	37,164.0	139,112.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.3	4,656.8	2,367.5	N/A	N/A	4.0
Cumberland County	Commercial township	1,943.0	3,893.7	2,066.4	763.0	11,813.9	3,308.6	2,563.3	31,538.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	76.2	912.1	480.9	N/A	N/A	23.0
Cumberland County	Deerfield township	2,274.1	2,921.2	501.4	1,257.5	6,839.5	9,183.2	1,466.2	31,824.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	590.6	550.7	289.8	N/A	N/A	15.0
Cumberland County	Downe township	864.2	236.0	245.7	624.7	4,059.0	894.8	9,159.8	9,313.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	129.4	279.1	147.2	N/A	N/A	31.6
Cumberland County	Fairfield township	3,588.4	5,878.9	551.6	1,475.0	7,495.3	8,271.7	154.6	37,296.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	580.9	1,163.6	588.4	N/A	N/A	39.9
Cumberland County	Greenwich township	461.3	21.8	32.5	118.2	1,969.7	343.9	0	4,965.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	476.4	141.6	74.7	N/A	N/A	6.8
Cumberland County	Hopewell township	2,453.1	49.0	56.6	381.2	5,093.8	3,016.8	3.3	32,087.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,830.5	814.2	425.1	N/A	N/A	11.1
Cumberland County	Lawrence township	1,807.0	1,482.4	372.4	991.6	7,442.1	2,375.3	682.0	24,710.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	713.3	582.0	305.7	N/A	N/A	39.3
Cumberland County	Maurice River township	3,941.0	5,708.4	1,382.3	3,193.0	7,758.0	16,456.2	1,146.5	33,052.9	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	175.9	1,554.8	751.1	N/A	N/A	159.4
Cumberland County	Millville city	13,454.1	161,162.9	5,880.6	13,726.8	62,968.7	61,497.2	88,504.7	220,934.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	352.8	5,012.0	2,638.2	N/A	N/A	58.2
Cumberland County	Shiloh borough	448.5	95.3	47.5	133.5	1,341.7	681.2	0.2	3,110.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	90.9	90.9	47.9	N/A	N/A	<0.1
Cumberland County	Stow Creek township	874.5	119.8	175.5	464.3	2,802.4	511.2	0	7,765.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	937.8	252.0	132.9	N/A	N/A	10.4
Cumberland County	Upper Deerfield township	4,183.0	1,111.0	1,024.2	2,664.2	12,535.5	22,298.9	16,885.3	69,651.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,790.3	1,350.6	711.5	N/A	N/A	16.1
Cumberland County	Vineland city	20,690.9	185,939.8	37,622.9	38,651.5	115,533.9	107,465.7	142,591.4	537,533.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	828.1	10,794.4	5,646.4	N/A	N/A	69.2
Salem County	Alloway township	2,005.9	167.1	257.2	668.8	8,781.0	1,861.2	0	20,191.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,011.5	707.6	305.8	N/A	N/A	84.5
Salem County	Carneys Point township	4,450.1	1,453.2	1,499.7	3,450.9	13,219.3	16,490.9	2,083.1	117,614.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	481.1	1,642.7	709.9	N/A	N/A	20.6
Salem County	Elmer borough	426.8	557.3	2,061.8	1,719.6	7,296.8	6,086.1	452.1	11,235.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	16.0	284.7	123.0	N/A	N/A	0.2
Salem County	Elsinboro township	1,127.3	47.8	74.6	196.4	1,388.9	157.0	0	4,020.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	332.8	211.4	91.4	N/A	N/A	1.8
Salem County	Lower Alloways Creek township	1,727.6	313.5	479.9	1,088.2	4,170.3	873.6	1.0	40,256.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	838.3	361.2	156.1	N/A	N/A	33.1
Salem County	Mannington township	1,466.2	469.7	917.5	1,555.5	3,470.5	3,793.3	124.7	15,686.9	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,927.1	368.6	159.3	N/A	N/A	32.0
Salem County	Oldmans township	583.2	5,064.1	3,672.4	613.6	4,935.4	6,425.5	25,424.8	19,907.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	738.7	361.8	156.4	N/A	N/A	17.4
Salem County	Penns Grove borough	2,742.7	557.9	548.9	1,356.6	16,025.7	9,756.7	1,114.2	37,261.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,050.4	454.0	N/A	N/A	<0.1
Salem County	Pennsville township	4,031.0	1,536.3	2,065.8	4,173.8	35,395.0	17,926.3	8,191.9	199,614.9	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	264.5	2,736.6	1,182.7	N/A	N/A	19.8
Salem County	Pilesgrove township	1,472.7	483.1	736.1	1,703.3	5,556.1	4,710.3	4.5	36,655.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,910.6	819.6	354.2	N/A	N/A	34.9
Salem County	Pittsgrove township	3,360.7	609.0	827.3	2,097.3	18,989.6	6,005.9	4,412.7	64,002.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,255.7	1,917.0	828.5	N/A	N/A	140.2
Salem County	Quinton township	2,356.3	92.9	142.9	399.9	6,037.2	1,564.0	291.5	28,588.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	719.7	544.1	235.1	N/A	N/A	72.1
Salem County	Salem city	4,167.5	1,304.3	1,552.3	3,497.6	17,417.3	20,399.0	65,957.6	40,097.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32.5	1,050.2	453.9	N/A	N/A	0.9
Salem County	Upper Pittsgrove township	1,217.8	216.6	338.2	843.4	10,712.2	4,753.3	212.6	31,970.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,483.9	715.3	309.1	N/A	N/A	35.2
Salem County	Woodstown borough	1,004.8	676.1	925.2	2,100.0	16,100.0	8,398.0	121.9	33,916.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12.4	715.3	309.1	N/A	N/A	0.9
Atlantic County	County Total	100,007.2	172,184.5	45,791.4	135,382.3	617,805.4	1,097,232.8	19,061.4	2,671,970.8	12,363.0	N/A	9,360.4	1,516.4	85,241.7	46,477.4	230,348.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,890.6	52,685.4	34,165.7	N/A	N/A	180.0
Cape May County	County Total	41,181.5	25,768.6	8,185.0	96,030.4	400,329.8	286,082.0	10,971.1	814,960.6	27,960.4	N/A	0	5,460.8	125,365.2	39,027.2	118,791.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	699.6	29,220.7	12,130.6	N/A	N/A	24.2
Cumberland County	County Total	69,123.0	374,656.3	55,487.1	77,554.5	304,268.8	308,164.2	300,321.3	1,182,896.8	100.3	N/A	0	3,723.9	58,569.4	17,690.1	335,851.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8,581.5	28,154.8	14,607.4	N/A	N/A	484.3
Salem County	County Total	32,140.5	13,548.9	16,099.7	25,464.9	169,495.1	109,201.2	108,392.6	701,018.3	3,294.4	N/A	0	14,131.2	18,240.4	4,261.3	115,607.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	12,024.8	13,486.7	5,828.4	N/A	N/A	493.7
SJTPO	Region Total	242,452.2	586,158.4	125,563.2	334,432.1	1,491,899.1	1,800,680.2	438,746.5	5,370,846.6	43,718.0	N/A	9,360.4	24,832.3	287,416.7	107,456.0	800,598.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	24,196.6	123,547.6	66,732.2	N/A	N/A	1,182.2

[1] Emissions were calculated on a Direct basis, and no Consumption-Based emissions were prepared.

[2] Municipality-level emissions were not prepared.

[3] Energy cycle not included. These would include upstream emissions from production and transport of goods/materials, and can be very substantial.

Summer Season Consumption-Based GHG Emissions by Subsector (including energy cycle emissions where available)

CO_2e (metric tons)		RCI							Transportation						Industrial Processes[3]									Agriculture			Waste Management[3]		Land Use, Land Use Change, And Forestry		
		Fuel Use				Electricity																									
County	Municipality	Residential	Commercial	Industrial	Non-Road	Residential	Commercial	Industrial	On-Road	Non-Road[2]	Aviation[1,2]	Rail-Passenger[2]	Rail-Freight[2]	Marine[2]	Cement Use[2]	Iron and Steel Use[2]	Electric Power Transmission and Distribution[1,2]	Limestone and Dolomite Use[1,2]	Natural Gas Transmission and Distribution Loss[1,2]	Nitric Acid Production[1,2]	ODS Substitutes[1,2]	Semiconductor Manufacture[1,2]	Soda Ash Production and Use[1,2]	Crop Production[1]	Livestock Management[1]	Non-Road	Solid Waste	Wastewater	Forest Carbon[1]	Urban Forests[1]	Non-Road[1]
Atlantic County	Absecon city	254.8	384.6	177.7	N/A	7,453.0	6,312.9	0	29,462.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	771.4	607.5	N/A	N/A	0.1
Atlantic County	Atlantic City city	1,045.9	12,266.9	3,126.7	N/A	14,238.1	174,489.9	7.9	303,836.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	3,933.8	3,121.0	N/A	N/A	<0.1
Atlantic County	Brigantine city	305.9	231.0	77.1	N/A	12,914.7	3,788.8	15.1	32,767.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,293.1	1,029.6	N/A	N/A	<0.1
Atlantic County	Buena borough	73.3	371.7	79.6	N/A	5,730.8	3,165.7	1,965.7	11,585.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	77.3	323.1	318.3	N/A	N/A	0.3
Atlantic County	Buena Vista township	103.4	896.1	104.6	N/A	3,427.9	682.9	202.7	21,893.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	126.4	584.3	528.5	N/A	N/A	4.7
Atlantic County	Corbin City city	0.7	12.9	7.3	N/A	399.5	206.2	0	1,089.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.2	38.5	35.3	N/A	N/A	0.2
Atlantic County	Egg Harbor township	620.3	3,375.1	151.8	N/A	32,169.8	26,578.2	306.2	106,292.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	3,195.2	2,950.0	N/A	N/A	0.5
Atlantic County	Egg Harbor City city	63.7	1,442.3	697.6	N/A	3,063.6	2,708.6	70.7	13,904.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20.5	382.8	307.3	N/A	N/A	4.5
Atlantic County	Estell Manor city	0.4	20.4	11.6	N/A	1,436.0	322.7	20.5	3,799.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	17.1	117.1	117.6	N/A	N/A	6.1
Atlantic County	Folsom borough	22.4	521.1	45.2	N/A	3,016.1	1,078.5	345.7	7,663.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.6	128.3	127.4	N/A	N/A	0.9
Atlantic County	Galloway township	888.9	916.7	431.1	N/A	26,263.6	28,171.2	272.9	85,697.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	46.1	2,897.1	2,565.1	N/A	N/A	5.5
Atlantic County	Hamilton township	580.1	1,133.3	512.9	N/A	17,944.6	18,894.4	299.6	84,925.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	78.6	1,918.9	1,811.4	N/A	N/A	11.7
Atlantic County	Hammonton town	118.5	908.5	2,246.3	N/A	12,692.5	10,806.1	785.9	63,459.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	252.9	1,088.3	1,016.2	N/A	N/A	2.3
Atlantic County	Linwood city	110.0	246.2	135.8	N/A	6,441.1	3,625.4	<0.1	18,969.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.2	500.2	487.7	N/A	N/A	<0.1
Atlantic County	Longport borough	57.1	24.3	7.7	N/A	2,569.1	945.3	5.5	5,889.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	208.9	150.6	N/A	N/A	<0.1
Atlantic County	Margate City city	353.8	172.7	81.4	N/A	9,823.2	3,292.9	0	33,418.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	971.0	756.9	N/A	N/A	<0.1
Atlantic County	Mullica township	36.8	57.3	31.2	N/A	4,390.8	881.8	36.4	12,676.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	89.3	407.8	413.8	N/A	N/A	6.1
Atlantic County	Northfield city	138.0	397.2	197.4	N/A	6,212.1	5,588.6	0	23,500.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.2	595.8	583.1	N/A	N/A	<0.1
Atlantic County	Pleasantville city	527.4	1,267.4	374.1	N/A	8,698.7	11,575.8	445.6	42,928.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,324.3	1,326.5	N/A	N/A	<0.1
Atlantic County	Port Republic city	<0.1	7.4	4.2	N/A	1,251.4	463.1	0	2,038.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.1	76.3	76.5	N/A	N/A	0.4
Atlantic County	Somers Point city	169.7	805.3	297.2	N/A	6,913.9	9,824.2	67.1	44,168.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	987.1	849.3	N/A	N/A	<0.1
Atlantic County	Ventnor City city	472.9	342.3	84.4	N/A	8,030.0	3,971.6	399.2	25,350.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,172.6	985.7	N/A	N/A	<0.1
Atlantic County	Weymouth township	24.4	17.0	8.7	N/A	2,058.1	396.6	4.2	17,712.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	204.6	198.0	N/A	N/A	1.6
Cape May County	Avalon borough	197.3	140.5	74.5	N/A	9,125.5	2,995.2	0	48,774.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	661.4	307.3	N/A	N/A	<0.1
Cape May County	Cape May city	65.4	576.2	286.1	N/A	5,434.0	8,202.3	560.0	18,902.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	694.0	293.5	N/A	N/A	<0.1
Cape May County	Cape May Point borough	1.1	14.0	9.1	N/A	761.9	265.4	0	2,243.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	163.6	38.6	N/A	N/A	<0.1
Cape May County	Dennis township	32.3	159.5	105.3	N/A	6,576.4	4,842.3	21.7	12,529.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	79.6	1,262.4	282.0	N/A	N/A	2.1
Cape May County	Lower township	195.8	285.0	168.4	N/A	21,146.5	10,326.0	1,582.3	39,072.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20.2	3,175.3	1,268.0	N/A	N/A	0.3
Cape May County	Middle township	167.4	987.6	600.6	N/A	17,633.4	22,168.5	164.0	53,339.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	52.5	2,782.7	903.6	N/A	N/A	1.3
Cape May County	North Wildwood city	227.7	252.5	73.1	N/A	7,217.6	5,859.7	0.3	28,364.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,197.3	545.5	N/A	N/A	<0.1
Cape May County	Ocean City city	595.3	629.5	319.7	N/A	29,429.2	12,223.6	50.9	84,562.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	3,117.9	1,340.5	N/A	N/A	0
Cape May County	Sea Isle City city	102.8	134.9	66.6	N/A	9,754.8	2,620.2	53.5	41,376.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	903.1	399.8	N/A	N/A	<0.1
Cape May County	Stone Harbor borough	59.3	191.0	51.7	N/A	4,750.1	1,836.5	2.2	31,129.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	402.2	185.2	N/A	N/A	<0.1
Cape May County	Upper township	73.8	237.4	166.1	N/A	12,546.4	5,777.4	372.1	26,269.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	11.4	1,776.6	601.9	N/A	N/A	2.0
Cape May County	West Cape May borough	22.5	19.6	9.1	N/A	1,226.9	641.5	0	3,076.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.3	204.8	77.5	N/A	N/A	<0.1
Cape May County	West Wildwood borough	35.7	11.1	3.1	N/A	782.2	92.9	0	1,968.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	148.7	59.5	N/A	N/A	<0.1
Cape May County	Wildwood city	256.7	633.9	200.9	N/A	6,149.3	11,579.9	497.0	29,404.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	1,399.0	470.4	N/A	N/A	<0.1
Cape May County	Wildwood Crest borough	193.2	270.4	76.2	N/A	6,098.9	5,265.8	0	16,879.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	826.4	359.8	N/A	N/A	<0.1
Cape May County	Woodbine borough	3.8	464.7	110.4	N/A	1,579.3	2,924.8	341.9	7,862.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.0	275.4	108.7	N/A	N/A	0.4
Cumberland County	Bridgeton city	267.0	850.0	1,567.2	N/A	17,484.4	19,193.0	9,857.0	48,738.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.1	832.1	1,093.3	N/A	N/A	1.0
Cumberland County	Commercial township	68.0	907.6	579.4	N/A	3,314.0	837.0	853.2	11,049.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19.1	130.9	220.6	N/A	N/A	5.8
Cumberland County	Deerfield township	37.6	610.9	141.4	N/A	2,185.3	2,425.7	404.7	11,149.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	147.6	80.1	133.0	N/A	N/A	3.8
Cumberland County	Downe township	8.5	45.7	69.7	N/A	1,342.4	259.7	2,886.0	3,263.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	32.4	40.0	67.5	N/A	N/A	7.9
Cumberland County	Fairfield township	43.1	1,088.3	156.2	N/A	2,340.9	1,947.3	42.1	13,066.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	145.2	213.8	272.0	N/A	N/A	10.0
Cumberland County	Greenwich township	0.2	3.9	9.2	N/A	609.8	102.9	0	1,739.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	119.1	20.3	34.3	N/A	N/A	1.7
Cumberland County	Hopewell township	22.6	7.7	16.1	N/A	1,614.7	924.0	0.6	11,241.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	457.6	124.5	195.4	N/A	N/A	2.8
Cumberland County	Lawrence township	17.5	335.7	105.2	N/A	2,308.3	813.8	244.4	8,657.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	178.3	85.6	140.3	N/A	N/A	9.8
Cumberland County	Maurice River township	28.5	1,294.0	389.7	N/A	2,254.0	5,078.5	255.6	11,579.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	44.0	351.3	350.2	N/A	N/A	39.9
Cumberland County	Millville city	508.2	37,791.5	1,607.3	N/A	20,099.0	17,226.2	22,665.3	77,403.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	88.2	727.0	1,210.7	N/A	N/A	14.6
Cumberland County	Shiloh borough	5.1	23.5	13.5	N/A	470.1	219.8	<0.1	1,089.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22.7	13.0	22.0	N/A	N/A	<0.1
Cumberland County	Stow Creek township	0.7	21.3	49.8	N/A	876.3	131.0	0	2,720.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	234.4	36.1	61.0	N/A	N/A	2.6
Cumberland County	Upper Deerfield township	52.2	181.1	290.4	N/A	4,106.1	6,821.2	5,820.7	24,402.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	447.6	194.9	326.5	N/A	N/A	4.0
Cumberland County	Vineland city	960.1	41,293.8	9,935.2	N/A	35,741.6	30,090.4	39,035.7	188,324.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	207.0	1,632.3	2,594.1	N/A	N/A	17.3
Salem County	Alloway township	2.2	29.8	73.0	N/A	2,648.3	572.8	0	7,062.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	252.9	182.6	131.5	N/A	N/A	21.1
Salem County	Carneys Point township	96.2	195.0	425.5	N/A	4,104.8	4,199.5	169.0	41,107.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	120.3	424.0	305.3	N/A	N/A	5.1
Salem County	Elmer borough	9.2	94.9	581.2	N/A	2,271.2	1,765.2	123.9	3,928.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.0	73.5	52.9	N/A	N/A	<0.1
Salem County	Elsinboro township	0.6	8.6	21.2	N/A	416.1	44.0	0	1,406.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	83.2	54.6	39.3	N/A	N/A	0.4
Salem County	Lower Alloways Creek township	2.8	55.9	136.2	N/A	1,211.1	214.5	0.4	14,078.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	209.6	93.2	67.1	N/A	N/A	8.3
Salem County	Mannington township	5.0	82.4	259.7	N/A	994.2	1,087.2	52.6	5,484.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	481.8	95.1	68.5	N/A	N/A	8.0
Salem County	Oldmans township	5.6	3,113.9	1,031.8	N/A	1,429.5	1,720.3	4,976.7	6,959.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	184.7	93.4	67.3	N/A	N/A	4.3
Salem County	Penns Grove borough	68.1	73.1	155.7	N/A	4,561.5	2,682.0	300.8	13,028.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	271.1	195.3	N/A	N/A	<0.1
Salem County	Pennsville township	80.6	246.6	585.1	N/A	11,105.2	4,905.7	2,496.4	69,760.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	66.1	706.4	508.7	N/A	N/A	5.0
Salem County	Pilesgrove township	5.8	84.9	208.8	N/A	1,830.0	1,336.1	<0.1	12,815.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	477.6	211.6	152.3	N/A	N/A	8.7
Salem County	Pittsgrove township	47.3	107.8	234.6	N/A	6,058.1	1,715.5	1,253.1	22,381.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	313.9	494.8	356.3	N/A	N/A	35.1
Salem County	Quinton township	2.2	16.6	40.6	N/A	1,735.8	454.8	74.5	9,995.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	179.9	140.4	101.1	N/A	N/A	18.0
Salem County	Salem city	84.7	206.7	440.4	N/A	4,913.1	5,831.3	16,510.1	14,016.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.1	271.1	195.2	N/A	N/A	0.2
Salem County	Upper Pittsgrove township	6.5	38.9	95.7	N/A	3,183.9	1,308.2	62.1	11,178.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	621.0	184.6	133.0	N/A	N/A	8.8
Salem County	Woodstown borough	21.9	108.7	262.5	N/A	4,967.9	2,411.2	35.4	11,858.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.1	184.6	133.0	N/A	N/A	0.2
Atlantic County	County Total	5,968.3	25,817.6	8,891.5	N/A	197,138.3	317,771.5	5,251.0	993,029.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	722.7	23,120.6	20,363.2	N/A	N/A	45.0
Cape May County	County Total	2,230.0	5,007.7	2,320.9	N/A	140,212.4	97,622.0	3,645.8	445,755.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	174.9	18,990.7	7,241.9	N/A	N/A	6.0
Cumberland County	County Total	2,019.4	84,455.1	14,930.2	N/A	94,746.9	86,070.3	82,065.4	414,423.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,145.4	4,481.8	6,720.8	N/A	N/A	121.1
Salem County	County Total	438.6	4,463.9	4,552.0	N/A	51,430.7	30,248.4	26,055.1	245,061.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3,006.2	3,481.2	2,506.9	N/A	N/A	123.4
SJTPO	Region Total	10,656.2	119,744.3	30,694.7	N/A	483,528.3	531,712.2	117,017.3	2,098,269.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6,049.1	50,074.3	36,832.9	N/A	N/A	295.6

[1] Emissions were calculated on a Direct basis, and no Consumption-Based emissions were prepared.
[2] Municipality-level emissions were not prepared.
[3] Seasonal Estimates were not prepared.
[4] Energy cycle not included. These would include upstream emissions from production and transport of goods/materials, and can be very substantial.

Annual Direct GHG Emissions by Subsector (including energy cycle emissions where available)

CO_2e (metric tons)		RCI							Transportation						Industrial Processes[3]									Agriculture			Waste Management[3]		Land Use, Land Use Change, And Forestry		
		Fuel Use				Electricity																									
County	Municipality	Residential	Commercial	Industrial	Non-Road	Residential	Commercial	Industrial	On-Road	Non-Road[2]	Aviation[1,2]	Rail-Passenger[2]	Rail-Freight[2]	Marine[2]	Cement Use[2]	Iron and Steel Use[2]	Electric Power Transmission and Distribution[1,2]	Limestone and Dolomite Use[1,2]	Natural Gas Transmission and Distribution Loss[1,2]	Nitric Acid Production[1,2]	ODS Substitutes[1,2]	Semiconductor Manufacture[1,2]	Soda Ash Production and Use[1,2]	Crop Production[1]	Livestock Management[1]	Non-Road	Solid Waste	Wastewater	Forest Carbon[1]	Urban Forests[1]	Non-Road[1]
Atlantic County	Absecon city	3,638.8	2,106.9	626.4	3,671.3	N/A	N/A	N/A	108,024.4	N/A	N/A	644.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(3,247.8)	(1,080.8)	0.5
Atlantic County	Atlantic City city	14,725.7	85,702.0	23,472.8	53,379.0	N/A	N/A	N/A	217,959.4	N/A	N/A	916.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	25,193.7	33,886.9	(12,468.7)	(25.3)	<0.1
Atlantic County	Brigantine city	5,090.3	1,165.6	271.7	1,808.6	N/A	N/A	N/A	12,677.9	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(7,826.2)	(28.9)	<0.1
Atlantic County	Buena borough	2,626.7	1,788.6	297.3	1,324.5	N/A	N/A	N/A	42,494.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	408.7	22.7	309.2	0	297.2	(954.7)	(413.6)	1.2
Atlantic County	Buena Vista township	3,557.2	3,322.2	423.0	1,514.6	N/A	N/A	N/A	28,821.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	716.3	250.5	505.7	0	3.2	(17,819.9)	(2,287.4)	18.6
Atlantic County	Corbin City city	58.9	72.4	25.6	155.8	N/A	N/A	N/A	416.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.3	0	9.0	0	0	(12,344.1)	(149.0)	0.7
Atlantic County	Egg Harbor township	11,463.2	23,481.6	554.5	4,460.7	N/A	N/A	N/A	316,562.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	90,350.6	0	(8,332.1)	(466.1)	2.1
Atlantic County	Egg Harbor City city	1,517.2	7,781.2	2,470.3	13,373.9	N/A	N/A	N/A	26,545.5	N/A	N/A	436.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	41.6	74.7	82.0	0	0	(18,478.3)	(8,389.3)	18.1
Atlantic County	Estell Manor city	1,140.4	113.7	40.7	281.7	N/A	N/A	N/A	17,610.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27.1	10.1	68.2	0	0	(49,513.1)	(1,415.5)	24.3
Atlantic County	Folsom borough	604.4	1,331.8	222.9	869.8	N/A	N/A	N/A	47,007.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	37.1	2.9	38.4	0	0	(4,539.1)	(701.4)	3.5
Atlantic County	Galloway township	13,019.7	5,285.5	1,521.2	9,456.8	N/A	N/A	N/A	180,874.3	N/A	N/A	2,558.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	104.8	44.4	184.5	0	0	(66,135.8)	(8,200.2)	21.9
Atlantic County	Hamilton township	9,688.2	10,179.3	1,846.0	10,615.8	N/A	N/A	N/A	376,549.9	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	127.4	100.3	314.5	0	0	(68,272.5)	(3,313.4)	46.9
Atlantic County	Hammonton town	2,978.1	7,827.0	9,604.3	8,642.1	N/A	N/A	N/A	176,882.7	N/A	N/A	1,279.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	370.5	7.0	1,011.5	33,695.1	1,321.1	(14,758.9)	(1,930.2)	9.1
Atlantic County	Linwood city	1,731.4	1,407.0	478.5	2,828.1	N/A	N/A	N/A	26,534.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	1.0	0	0	(2,897.1)	(721.8)	<0.1
Atlantic County	Longport borough	645.1	96.9	27.3	179.5	N/A	N/A	N/A	6,538.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(5.2)	37.8	<0.1
Atlantic County	Margate City city	4,523.4	1,054.7	286.8	1,775.7	N/A	N/A	N/A	16,024.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	312.1	(4.0)	<0.1
Atlantic County	Mullica township	2,099.8	369.1	141.2	788.8	N/A	N/A	N/A	81,741.1	N/A	N/A	2,467.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	90.1	65.4	357.2	0	2.1	(38,144.5)	(2,182.2)	24.6
Atlantic County	Northfield city	1,995.4	2,783.8	695.9	4,051.2	N/A	N/A	N/A	51,200.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0.8	0	0	(888.2)	(663.7)	0.2
Atlantic County	Pleasantville city	8,830.1	5,757.9	1,339.2	7,813.4	N/A	N/A	N/A	49,908.2	N/A	N/A	632.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(2,210.2)	(683.0)	0.3
Atlantic County	Port Republic city	320.6	40.8	14.8	120.2	N/A	N/A	N/A	34,739.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.9	4.4	8.5	0	0	(5,681.7)	(529.1)	1.5
Atlantic County	Somers Point city	3,235.5	6,430.5	1,047.5	6,023.9	N/A	N/A	N/A	61,762.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(2,065.8)	(461.5)	<0.1
Atlantic County	Ventnor City city	5,929.3	3,965.1	352.8	1,982.5	N/A	N/A	N/A	13,557.9	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(1,036.5)	(3.6)	<0.1
Atlantic County	Weymouth township	587.8	120.9	30.7	264.5	N/A	N/A	N/A	23,824.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	29.5	(7,186.3)	(760.0)	6.3
Cape May County	Avalon borough	2,012.2	688.6	262.7	2,915.2	N/A	N/A	N/A	9,894.5	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(5,187.0)	62.1	<0.1
Cape May County	Cape May city	964.8	2,964.9	1,008.2	11,006.9	N/A	N/A	N/A	8,323.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	552.3	(99.7)	<0.1
Cape May County	Cape May Point borough	111.0	75.9	32.2	370.2	N/A	N/A	N/A	980.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(62.4)	23.7	<0.1
Cape May County	Dennis township	2,332.7	924.8	371.3	4,553.6	N/A	N/A	N/A	111,439.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	76.3	414.3	318.2	0	10.8	(49,323.2)	(3,083.1)	8.3
Cape May County	Lower township	5,369.7	1,509.5	593.7	8,533.3	N/A	N/A	N/A	95,057.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	61.5	47.4	80.7	0	2,807.5	(16,117.8)	(2,187.7)	1.1
Cape May County	Middle township	5,683.7	5,826.0	2,117.0	24,195.3	N/A	N/A	N/A	279,876.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.9	40.4	209.9	0	6,547.5	(63,316.4)	(3,688.2)	5.0
Cape May County	North Wildwood city	2,101.3	1,003.8	258.8	3,129.4	N/A	N/A	N/A	12,927.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(213.1)	5.3	<0.1
Cape May County	Ocean City city	12,296.0	3,459.8	1,126.7	13,074.7	N/A	N/A	N/A	60,070.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	2,679.8	(7,519.5)	(18.9)	0
Cape May County	Sea Isle City city	1,376.6	635.0	234.6	2,694.7	N/A	N/A	N/A	9,753.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(2,018.4)	5.4	<0.1
Cape May County	Stone Harbor borough	629.1	655.9	182.1	2,015.4	N/A	N/A	N/A	4,605.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(1,082.4)	46.1	<0.1
Cape May County	Upper township	2,666.7	1,513.8	585.7	7,429.0	N/A	N/A	N/A	222,653.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.1	32.8	45.5	27,428.1	21.8	(56,230.7)	(3,771.0)	7.9
Cape May County	West Cape May borough	400.2	99.8	32.2	442.7	N/A	N/A	N/A	1,317.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.7	2.9	29.1	0	0	(445.8)	(112.4)	<0.1
Cape May County	West Wildwood borough	324.4	43.8	11.1	176.4	N/A	N/A	N/A	102.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(116.2)	21.4	<0.1
Cape May County	Wildwood city	2,722.3	2,583.8	710.3	8,016.8	N/A	N/A	N/A	5,695.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(12.8)	71.0	<0.1
Cape May County	Wildwood Crest borough	1,812.3	1,067.1	269.5	3,165.0	N/A	N/A	N/A	4,731.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(244.7)	57.7	<0.1
Cape May County	Woodbine borough	378.4	2,716.2	389.0	4,312.0	N/A	N/A	N/A	14,273.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	14.0	20.2	16.1	39,742.0	60.6	(2,906.6)	(375.8)	1.7
Cumberland County	Bridgeton city	12,139.7	6,036.2	5,527.4	13,110.1	N/A	N/A	N/A	49,711.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.9	0	8.3	1,686.1	3,552.1	(512.9)	(1,305.9)	4.0
Cumberland County	Commercial township	1,943.0	3,893.7	2,066.4	763.0	N/A	N/A	N/A	19,300.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	86.2	10.1	76.2	22,463.4	0	(32,278.8)	(895.2)	23.0
Cumberland County	Deerfield township	2,274.1	2,921.2	501.4	1,257.5	N/A	N/A	N/A	19,237.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	768.7	99.2	590.6	60,973.8	0	(2,884.3)	(720.1)	15.0
Cumberland County	Downe township	864.2	236.0	245.7	624.7	N/A	N/A	N/A	5,203.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	80.0	42.6	129.4	0	0	(47,937.1)	(335.0)	31.6
Cumberland County	Fairfield township	3,588.4	5,878.9	551.6	1,475.0	N/A	N/A	N/A	26,966.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	489.7	60.3	580.9	0	0	(30,874.6)	(2,377.6)	39.9
Cumberland County	Greenwich township	461.3	21.8	32.5	118.2	N/A	N/A	N/A	2,823.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	598.3	2.2	476.4	0	0	(12,128.7)	(221.0)	6.8
Cumberland County	Hopewell township	2,453.1	49.0	56.6	381.2	N/A	N/A	N/A	18,356.1	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,241.3	521.9	1,830.5	0	0	(6,817.7)	(1,349.9)	11.1
Cumberland County	Lawrence township	1,807.0	1,482.4	372.4	991.6	N/A	N/A	N/A	20,454.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	659.9	369.1	713.3	0	0.7	(22,772.3)	(957.6)	39.3
Cumberland County	Maurice River township	3,941.0	5,708.4	1,382.3	3,193.0	N/A	N/A	N/A	72,980.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	35.1	98.3	175.9	0	679.4	(70,253.7)	(1,111.3)	159.4
Cumberland County	Millville city	13,454.1	161,162.9	5,880.6	13,726.8	N/A	N/A	N/A	149,222.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	353.6	52.7	352.8	16,749.3	2,624.7	(11,716.4)	(3,785.3)	58.2
Cumberland County	Shiloh borough	448.5	95.3	47.5	133.5	N/A	N/A	N/A	16,624.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	186.0	6.4	90.9	0	0	37.1	(26.2)	<0.1
Cumberland County	Stow Creek township	874.5	119.8	175.5	464.3	N/A	N/A	N/A	7,358.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,397.3	179.4	937.8	0	0	(8,270.1)	(373.4)	10.4
Cumberland County	Upper Deerfield township	4,183.0	1,111.0	1,024.2	2,664.2	N/A	N/A	N/A	62,443.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,868.8	1,260.5	1,790.3	2,164.5	0	(819.5)	(1,695.8)	16.1
Cumberland County	Vineland city	20,690.9	185,939.8	37,622.9	38,651.5	N/A	N/A	N/A	438,919.4	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,247.1	182.2	828.1	51,946.7	6,467.8	(5,349.4)	(8,115.9)	69.2
Salem County	Alloway township	2,005.9	167.1	257.2	668.8	N/A	N/A	N/A	18,806.0	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,418.2	2,393.3	1,011.5	29,173.2	0	(8,782.7)	(1,444.1)	84.5
Salem County	Carneys Point township	4,450.1	1,453.2	1,499.7	3,450.9	N/A	N/A	N/A	74,803.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	926.6	80.4	481.1	1,419.9	1,382.4	(1,551.4)	(806.1)	20.6
Salem County	Elmer borough	426.8	557.3	2,061.8	1,719.6	N/A	N/A	N/A	8,178.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	24.2	0	16.0	252.4	0	79.2	(97.5)	0.2
Salem County	Elsinboro township	1,127.3	47.8	74.6	196.4	N/A	N/A	N/A	2,222.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	694.8	237.7	332.8	0	0	(1,551.0)	(132.2)	1.8
Salem County	Lower Alloways Creek township	1,727.6	313.5	479.9	1,088.2	N/A	N/A	N/A	31,233.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,136.4	624.9	838.3	0	42.5	(34,274.1)	(214.3)	33.1
Salem County	Mannington township	1,466.2	469.7	917.5	1,555.5	N/A	N/A	N/A	20,000.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3,711.2	1,831.1	1,927.1	0	0	(4,179.0)	(232.4)	32.0
Salem County	Oldmans township	583.2	5,064.1	3,672.4	613.6	N/A	N/A	N/A	50,462.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,365.5	235.7	738.7	0	37.2	(2,759.3)	(339.6)	17.4
Salem County	Penns Grove borough	2,742.7	557.9	548.9	1,356.6	N/A	N/A	N/A	7,241.7	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	556.2	57.5	11.7	<0.1
Salem County	Pennsville township	4,031.0	1,536.3	2,065.8	4,173.8	N/A	N/A	N/A	65,144.8	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	572.5	272.0	264.5	8,726.2	2,183.0	(210.7)	(949.6)	19.8
Salem County	Pilesgrove township	1,472.7	483.1	736.1	1,703.3	N/A	N/A	N/A	62,391.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3,125.0	5,775.7	1,910.6	14,612.6	0	(2,635.5)	(1,004.0)	34.9
Salem County	Pittsgrove township	3,360.7	609.0	827.3	2,097.3	N/A	N/A	N/A	59,267.3	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,105.4	700.9	1,255.7	0	2.4	(15,482.9)	(3,472.8)	140.2
Salem County	Quinton township	2,356.3	92.9	142.9	399.9	N/A	N/A	N/A	34,236.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,018.8	467.6	719.7	0	0	(9,181.8)	(745.0)	72.1
Salem County	Salem city	4,167.5	1,304.3	1,552.3	3,497.6	N/A	N/A	N/A	20,333.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	63.0	9.1	32.5	14,612.6	977.9	72.9	(222.7)	0.9
Salem County	Upper Pittsgrove township	1,217.8	216.6	338.2	843.4	N/A	N/A	N/A	49,113.6	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4,210.4	4,255.8	2,483.9	0	0	(5,038.0)	(683.2)	35.2
Salem County	Woodstown borough	1,004.8	676.1	925.2	2,100.0	N/A	N/A	N/A	11,163.2	N/A	N/A	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	26.8	0	12.4	0	459.6	(4.8)	(313.5)	0.9
Atlantic County	County Total	100,007.2	172,184.5	45,791.4	135,382.3	N/A	N/A	N/A	1,918,257.0	12,363.0	58,040.4	8,933.7	579.0	85,241.7	N/A	N/A	12,687.7	31.6	127,609.9	13.1	107,313.3	405.7	767.9	1,931.8	582.4	2,890.6	149,239.5	35,540.0	(344,494.6)	(34,372.5)	180.0
Cape May County	County Total	41,181.5	25,768.6	8,185.0	96,030.4	N/A	N/A	N/A	841,701.3	27,960.4	4,144.7	0	143.3	133,003.1	N/A	N/A	5,102.5	8.5	24,890.3	3.6	38,018.1	109.6	207.5	279.5	557.9	699.6	67,170.1	12,128.1	(204,244.6)	(13,044.1)	24.2
Cumberland County	County Total	69,123.0	374,656.3	55,487.1	77,554.5	N/A	N/A	N/A	909,601.4	100.3	5,560.0	0	111.6	59,013.9	N/A	N/A	6,678.3	71.8	278,410.1	29.9	61,326.9	922.7	1,746.6	10,022.8	2,885.0	8,581.5	155,983.8	13,324.7	(252,578.1)	(23,270.2)	484.3
Salem County	County Total	32,140.5	13,548.9	16,099.7	25,464.9	N/A	N/A	N/A	514,599.2	3,294.4	969.1	0	423.6	18,684.8	N/A	N/A	2,832.2	25.7	67,165.5	10.7	25,829.9	329.7	624.1	20,399.0	16,884.2	12,024.8	68,797.0	5,641.1	(85,441.7)	(10,645.3)	493.7
SJTPO	Region Total	242,452.2	586,158.4	125,563.2	334,432.1	N/A	N/A	N/A	4,184,158.8	43,718.0	68,714.1	8,933.7	1,257.5	295,943.6	N/A	N/A	27,300.6	137.6	498,075.8	57.3	232,488.2	1,767.8	3,346.2	32,633.1	20,909.6	24,196.6	441,190.4	66,633.9	(886,759.0)	(81,332.1)	1,182.2

[1] Emissions were calculated on a Direct basis, and no Consumption-Based emissions were prepared.
[2] Municipality-level emissions were not prepared.
[3] Energy cycle not included. These would include upstream emissions from production and transport of goods/materials, and can be very substantial.

Summer Season Direct GHG Emissions by Subsector (including energy cycle emissions where available)

CO_2e (metric tons)		RCI							Transportation						Industrial Processes[3]									Agriculture			Waste Management[3]		Land Use, Land Use Change, And Forestry		
		Fuel Use				Electricity																									
County	Municipality	Residential	Commercial	Industrial	Non-Road	Residential	Commercial	Industrial	On-Road	Non-Road[2]	Aviation[1,2]	Rail-Passenger[2]	Rail-Freight[2]	Marine[2]	Cement Use[2]	Iron and Steel Use[2]	Electric Power Transmission and Distribution[1,2]	Limestone and Dolomite Use[1,2]	Natural Gas Transmission and Distribution Loss[1,2]	Nitric Acid Production[1,2]	ODS Substitutes[1,2]	Semiconductor Manufacture[1,2]	Soda Ash Production and Use[1,2]	Crop Production[1]	Livestock Management[1]	Non-Road	Solid Waste	Wastewater	Forest Carbon[1]	Urban Forests[1]	Non-Road[1]
Atlantic County	Absecon city	254.8	384.6	177.7	N/A	N/A	N/A	N/A	40,683.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(811.9)	(270.2)	0.1
Atlantic County	Atlantic City city	1,045.9	12,266.9	3,126.7	N/A	N/A	N/A	N/A	100,112.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	6,298.4	20,946.0	(3,117.2)	(6.3)	<0.1
Atlantic County	Brigantine city	305.9	231.0	77.1	N/A	N/A	N/A	N/A	10,474.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(1,956.6)	(7.2)	<0.1
Atlantic County	Buena borough	73.3	371.7	79.6	N/A	N/A	N/A	N/A	16,105.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	102.2	5.7	77.3	0	142.2	(238.7)	(103.4)	0.3
Atlantic County	Buena Vista township	103.4	896.1	104.6	N/A	N/A	N/A	N/A	10,766.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	179.1	62.6	126.4	0	1.5	(4,455.0)	(571.9)	4.7
Atlantic County	Corbin City city	0.7	12.9	7.3	N/A	N/A	N/A	N/A	166.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.1	0	2.2	0	0	(3,086.0)	(37.3)	0.2
Atlantic County	Egg Harbor township	620.3	3,375.1	151.8	N/A	N/A	N/A	N/A	81,543.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	22,790.8	0	(2,083.0)	(116.5)	0.5
Atlantic County	Egg Harbor City city	63.7	1,442.3	697.6	N/A	N/A	N/A	N/A	43,370.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10.4	18.7	20.5	0	0	(4,619.6)	(2,097.3)	4.5
Atlantic County	Estell Manor city	0.4	20.4	11.6	N/A	N/A	N/A	N/A	6,405.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.8	2.5	17.1	0	0	(12,378.3)	(353.9)	6.1
Atlantic County	Folsom borough	22.4	521.1	45.2	N/A	N/A	N/A	N/A	16,902.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	9.3	0.7	9.6	0	0	(1,134.8)	(175.3)	0.9
Atlantic County	Galloway township	888.9	916.7	431.1	N/A	N/A	N/A	N/A	64,073.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	26.2	11.1	46.1	0	0	(16,534.0)	(2,050.1)	5.5
Atlantic County	Hamilton township	580.1	1,133.3	512.9	N/A	N/A	N/A	N/A	136,194.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	31.9	25.1	78.6	0	0	(17,068.1)	(828.3)	11.7
Atlantic County	Hammonton town	118.5	908.5	2,246.3	N/A	N/A	N/A	N/A	64,399.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	92.6	1.7	252.9	8,423.8	632.1	(3,689.7)	(482.5)	2.3
Atlantic County	Linwood city	110.0	246.2	135.8	N/A	N/A	N/A	N/A	9,855.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0.2	0	0	(724.3)	(180.5)	<0.1
Atlantic County	Longport borough	57.1	24.3	7.7	N/A	N/A	N/A	N/A	9,820.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(1.3)	9.5	<0.1
Atlantic County	Margate City city	353.8	172.7	81.4	N/A	N/A	N/A	N/A	15,124.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	78.0	(1.0)	<0.1
Atlantic County	Mullica township	36.8	57.3	31.2	N/A	N/A	N/A	N/A	29,339.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	22.5	16.3	89.3	0	1.0	(9,536.1)	(545.5)	6.1
Atlantic County	Northfield city	138.0	397.2	197.4	N/A	N/A	N/A	N/A	18,314.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0.2	0	0	(222.0)	(165.9)	<0.1
Atlantic County	Pleasantville city	527.4	1,267.4	374.1	N/A	N/A	N/A	N/A	16,677.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(552.6)	(170.8)	<0.1
Atlantic County	Port Republic city	<0.1	7.4	4.2	N/A	N/A	N/A	N/A	12,967.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.0	1.1	2.1	0	0	(1,420.4)	(132.3)	0.4
Atlantic County	Somers Point city	169.7	805.3	297.2	N/A	N/A	N/A	N/A	29,315.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(516.4)	(115.4)	<0.1
Atlantic County	Ventnor City city	472.9	342.3	84.4	N/A	N/A	N/A	N/A	8,676.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(259.1)	(0.9)	<0.1
Atlantic County	Weymouth township	24.4	17.0	8.7	N/A	N/A	N/A	N/A	10,086.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	14.1	(1,796.6)	(190.0)	1.6
Cape May County	Avalon borough	197.3	140.5	74.5	N/A	N/A	N/A	N/A	19,055.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(1,296.8)	15.5	<0.1
Cape May County	Cape May city	65.4	576.2	286.1	N/A	N/A	N/A	N/A	4,792.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	138.1	(24.9)	<0.1
Cape May County	Cape May Point borough	1.1	14.0	9.1	N/A	N/A	N/A	N/A	1,007.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(15.6)	5.9	<0.1
Cape May County	Dennis township	32.3	159.5	105.3	N/A	N/A	N/A	N/A	27,040.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	19.1	103.6	79.6	0	6.4	(12,330.8)	(770.8)	2.1
Cape May County	Lower township	195.8	285.0	168.4	N/A	N/A	N/A	N/A	32,215.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.4	11.8	20.2	0	1,675.8	(4,029.4)	(546.9)	0.3
Cape May County	Middle township	167.4	987.6	600.6	N/A	N/A	N/A	N/A	77,794.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25.7	10.1	52.5	0	3,908.3	(15,829.1)	(922.1)	1.3
Cape May County	North Wildwood city	227.7	252.5	73.1	N/A	N/A	N/A	N/A	13,637.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(53.3)	1.3	<0.1
Cape May County	Ocean City city	595.3	629.5	319.7	N/A	N/A	N/A	N/A	52,731.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	1,599.6	(1,879.9)	(4.7)	0
Cape May County	Sea Isle City city	102.8	134.9	66.6	N/A	N/A	N/A	N/A	15,057.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(504.6)	1.3	<0.1
Cape May County	Stone Harbor borough	59.3	191.0	51.7	N/A	N/A	N/A	N/A	8,080.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(270.6)	11.5	<0.1
Cape May County	Upper township	73.8	237.4	166.1	N/A	N/A	N/A	N/A	64,658.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.3	8.2	11.4	6,857.0	13.0	(14,057.7)	(942.7)	2.0
Cape May County	West Cape May borough	22.5	19.6	9.1	N/A	N/A	N/A	N/A	674.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.9	0.7	7.3	0	0	(111.4)	(28.1)	<0.1
Cape May County	West Wildwood borough	35.7	11.1	3.1	N/A	N/A	N/A	N/A	73.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(29.0)	5.3	<0.1
Cape May County	Wildwood city	256.7	633.9	200.9	N/A	N/A	N/A	N/A	3,585.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(3.2)	17.8	<0.1
Cape May County	Wildwood Crest borough	193.2	270.4	76.2	N/A	N/A	N/A	N/A	3,905.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	0	(61.2)	14.4	<0.1
Cape May County	Woodbine borough	3.8	464.7	110.4	N/A	N/A	N/A	N/A	3,378.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.5	5.1	4.0	10,078.5	36.2	(726.6)	(94.0)	0.4
Cumberland County	Bridgeton city	267.0	850.0	1,567.2	N/A	N/A	N/A	N/A	19,387.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.7	0	2.1	1,015.9	1,449.9	(128.2)	(326.5)	1.0
Cumberland County	Commercial township	68.0	907.6	579.4	N/A	N/A	N/A	N/A	7,524.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	21.6	2.5	19.1	5,615.9	0	(8,069.7)	(223.8)	5.8
Cumberland County	Deerfield township	37.6	610.9	141.4	N/A	N/A	N/A	N/A	7,511.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	192.2	24.8	147.6	15,243.5	0	(721.1)	(180.0)	3.8
Cumberland County	Downe township	8.5	45.7	69.7	N/A	N/A	N/A	N/A	2,027.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	20.0	10.7	32.4	0	0	(11,984.3)	(83.8)	7.9
Cumberland County	Fairfield township	43.1	1,088.3	156.2	N/A	N/A	N/A	N/A	10,520.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	122.4	15.1	145.2	0	0	(7,718.6)	(594.4)	10.0
Cumberland County	Greenwich township	0.2	3.9	9.2	N/A	N/A	N/A	N/A	1,100.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	149.6	0.5	119.1	0	0	(3,032.2)	(55.2)	1.7
Cumberland County	Hopewell township	22.6	7.7	16.1	N/A	N/A	N/A	N/A	7,158.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	560.3	130.5	457.6	0	0	(1,704.4)	(337.5)	2.8
Cumberland County	Lawrence township	17.5	335.7	105.2	N/A	N/A	N/A	N/A	7,974.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	165.0	92.3	178.3	0	0.3	(5,693.1)	(239.4)	9.8
Cumberland County	Maurice River township	28.5	1,294.0	389.7	N/A	N/A	N/A	N/A	28,636.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.8	24.6	44.0	0	277.3	(17,563.4)	(277.8)	39.9
Cumberland County	Millville city	508.2	37,791.5	1,607.3	N/A	N/A	N/A	N/A	58,268.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	88.4	13.2	88.2	4,187.3	1,071.3	(2,929.1)	(946.3)	14.6
Cumberland County	Shiloh borough	5.1	23.5	13.5	N/A	N/A	N/A	N/A	6,497.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	46.5	1.6	22.7	0	0	9.3	(6.5)	<0.1
Cumberland County	Stow Creek township	0.7	21.3	49.8	N/A	N/A	N/A	N/A	2,871.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	349.3	44.9	234.4	0	0	(2,067.5)	(93.4)	2.6
Cumberland County	Upper Deerfield township	52.2	181.1	290.4	N/A	N/A	N/A	N/A	24,392.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	467.2	315.1	447.6	541.1	0	(204.9)	(423.9)	4.0
Cumberland County	Vineland city	960.1	41,293.8	9,935.2	N/A	N/A	N/A	N/A	171,331.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	311.8	45.6	207.0	12,986.7	2,639.9	(1,337.4)	(2,029.0)	17.3
Salem County	Alloway township	2.2	29.8	73.0	N/A	N/A	N/A	N/A	7,234.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	354.6	598.3	252.9	7,326.7	0	(2,195.7)	(361.0)	21.1
Salem County	Carneys Point township	96.2	195.0	425.5	N/A	N/A	N/A	N/A	28,708.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	231.6	20.1	120.3	355.0	568.5	(387.9)	(201.5)	5.1
Salem County	Elmer borough	9.2	94.9	581.2	N/A	N/A	N/A	N/A	3,152.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.1	0	4.0	118.6	0	19.8	(24.4)	<0.1
Salem County	Elsinboro township	0.6	8.6	21.2	N/A	N/A	N/A	N/A	853.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	173.7	59.4	83.2	0	0	(387.8)	(33.0)	0.4
Salem County	Lower Alloways Creek township	2.8	55.9	136.2	N/A	N/A	N/A	N/A	11,995.1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	284.1	156.2	209.6	0	17.5	(8,568.5)	(53.6)	8.3
Salem County	Mannington township	5.0	82.4	259.7	N/A	N/A	N/A	N/A	7,681.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	927.8	457.8	481.8	0	0	(1,044.7)	(58.1)	8.0
Salem County	Oldmans township	5.6	3,113.9	1,031.8	N/A	N/A	N/A	N/A	19,348.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	341.4	58.9	184.7	0	15.3	(689.8)	(84.9)	4.3
Salem County	Penns Grove borough	68.1	73.1	155.7	N/A	N/A	N/A	N/A	2,777.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0	0	228.7	14.4	2.9	<0.1
Salem County	Pennsville township	80.6	246.6	585.1	N/A	N/A	N/A	N/A	24,992.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	143.1	68.0	66.1	2,181.6	897.7	(52.7)	(237.4)	5.0
Salem County	Pilesgrove township	5.8	84.9	208.8	N/A	N/A	N/A	N/A	24,000.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	781.3	1,443.9	477.6	3,653.2	0	(658.9)	(251.0)	8.7
Salem County	Pittsgrove township	47.3	107.8	234.6	N/A	N/A	N/A	N/A	22,808.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	526.4	175.2	313.9	0	1.0	(3,870.7)	(868.2)	35.1
Salem County	Quinton township	2.2	16.6	40.6	N/A	N/A	N/A	N/A	13,176.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	254.7	116.9	179.9	0	0	(2,295.5)	(186.2)	18.0
Salem County	Salem city	84.7	206.7	440.4	N/A	N/A	N/A	N/A	7,814.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	15.8	2.3	8.1	3,653.2	402.1	18.2	(55.7)	0.2
Salem County	Upper Pittsgrove township	6.5	38.9	95.7	N/A	N/A	N/A	N/A	18,917.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1,052.6	1,064.0	621.0	0	0	(1,259.5)	(170.8)	8.8
Salem County	Woodstown borough	21.9	108.7	262.5	N/A	N/A	N/A	N/A	4,294.9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	6.7	0	3.1	0	189.0	(1.2)	(78.4)	0.2
Atlantic County	County Total	5,968.3	25,817.6	8,891.5	N/A	N/A	N/A	N/A	751,373.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	482.9	145.6	722.7	37,513.0	21,736.9	(86,123.6)	(8,593.1)	45.0
Cape May County	County Total	2,230.0	5,007.7	2,320.9	N/A	N/A	N/A	N/A	327,690.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	69.9	139.5	174.9	16,935.5	7,239.3	(51,061.2)	(3,261.0)	6.0
Cumberland County	County Total	2,019.4	84,455.1	14,930.2	N/A	N/A	N/A	N/A	355,204.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2,505.7	721.3	2,145.4	39,590.3	5,438.7	(63,144.5)	(5,817.6)	121.1
Salem County	County Total	438.6	4,463.9	4,552.0	N/A	N/A	N/A	N/A	197,754.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	5,099.8	4,221.1	3,006.2	17,288.2	2,319.7	(21,360.4)	(2,661.3)	123.4
SJTPO	Region Total	10,656.2	119,744.3	30,694.7	N/A	N/A	N/A	N/A	1,632,022.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8,158.3	5,227.4	6,049.1	111,327.1	36,734.7	(221,689.7)	(20,333.0)	295.6

[1] Emissions were calculated on a Direct basis, and no Consumption-Based emissions were prepared.
[2] Municipality-level emissions were not prepared.
[3] Seasonal Estimates were not prepared.
[4] Energy cycle not included. These would include upstream emissions from production and transport of goods/materials, and can be very substantial.

Appendix B

Additional Results

APPENDIX B: ADDITIONAL RESULTS

Appendix B includes additional results by sector. While the results presented in the inventory report (usually consumption-based) generally represent the most appropriate basis for evaluating the potential effects of mitigation strategies, in some cases both consumption-based and direct results were analyzed because both methods may provide useful information depending on the type of mitigation pursued. The additional direct results and discussion comparing the two methods are presented below.

Transportation

Direct based emissions are discussed below. Consumption-based emissions from the Transportation sector are present within the chapter. Direct based emissions are estimated for all sub-sectors. For the recreational marine and recreational vehicle (off-road) sub-sectors, the direct emissions inventory is assumed to be equivalent to the consumption based inventory approach. For aviation and commercial marine, direct is the only inventory method conducted. The transportation sector inventory includes 2010 annual GHG emissions from the following transportation sources:

1. On-road mobile sources—all passenger vehicles including transit buses and commercial vehicles (light, medium, and heavy-duty commercial trucks);
2. Aviation;
3. Marine (recreational and commercial vessels);
4. Rail (passenger rail and freight rail); and
5. Non-road vehicles.

The direct based emissions inventory allocates emissions based on where the transportation activity occurs, not where it originates from or is destined to (as in the consumption based emission inventory approach). **Figure 1** presents the allocation of direct and energy cycle emissions by county. For the direct-based inventory, Atlantic County has the largest share of emissions, at 45% of the regional total, with Cape May County at 22%, Cumberland County at 21%, and Salem County at 12%. These shares are comparable to the population shares for Atlantic and Salem Counties, but are different for Cape May and Cumberland Counties. Cape May County share of regional emissions exceeds its population share (22% compared to 16%) and Cumberland County emissions share is below its population share (21% compared to 26%). The explanation for the difference in Cape May County is the significant seasonal variation in population (approximately a 3.2x increase in household population) and the associated transportation activity associated with this influx of residents.

Figure 2 presents the share of direct-based transportation sector GHG emissions by transportation sub-sector. Direct GHG emissions from the transportation sector in the region are dominated by on-road vehicles, with passenger vehicles (passenger cars and trucks) and commercial vehicles (medium and heavy-duty trucks and buses) representing 90.9% of total transportation sector emissions (66.8% passenger vehicle emissions, 24.1% commercial vehicle emissions).

Figure 1
Transportation Sector Emissions by County

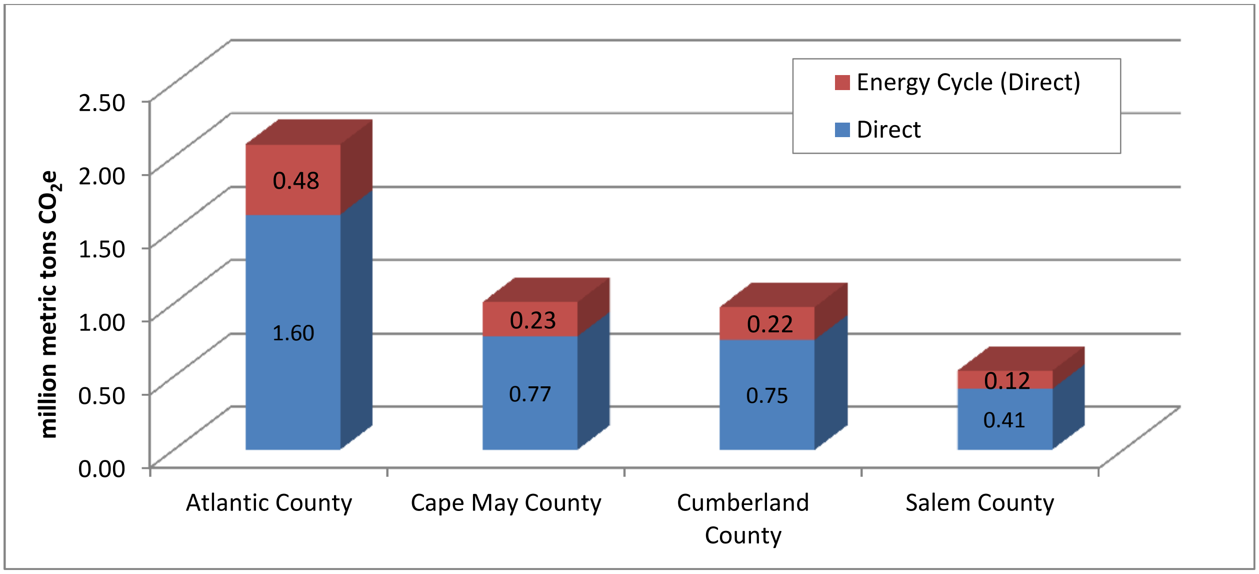
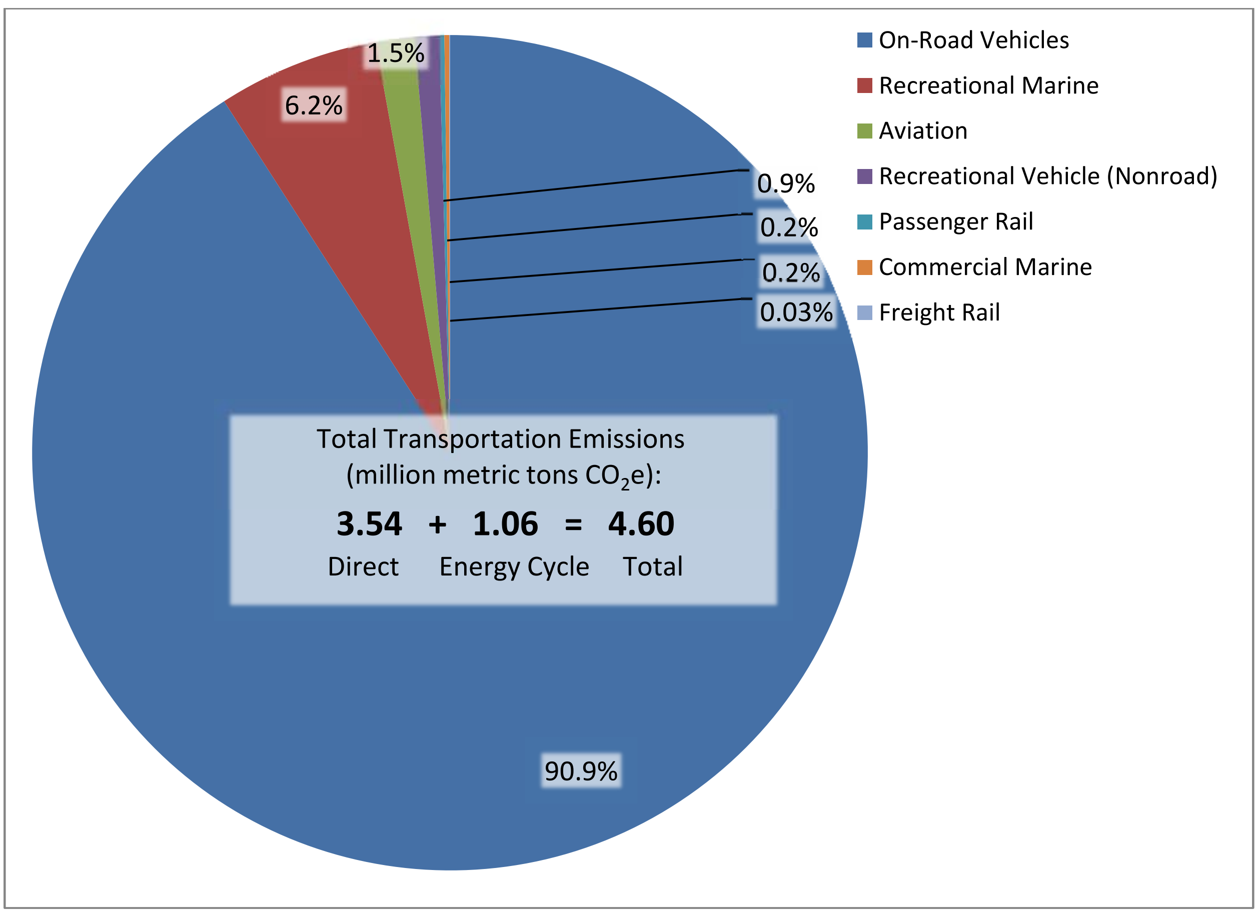


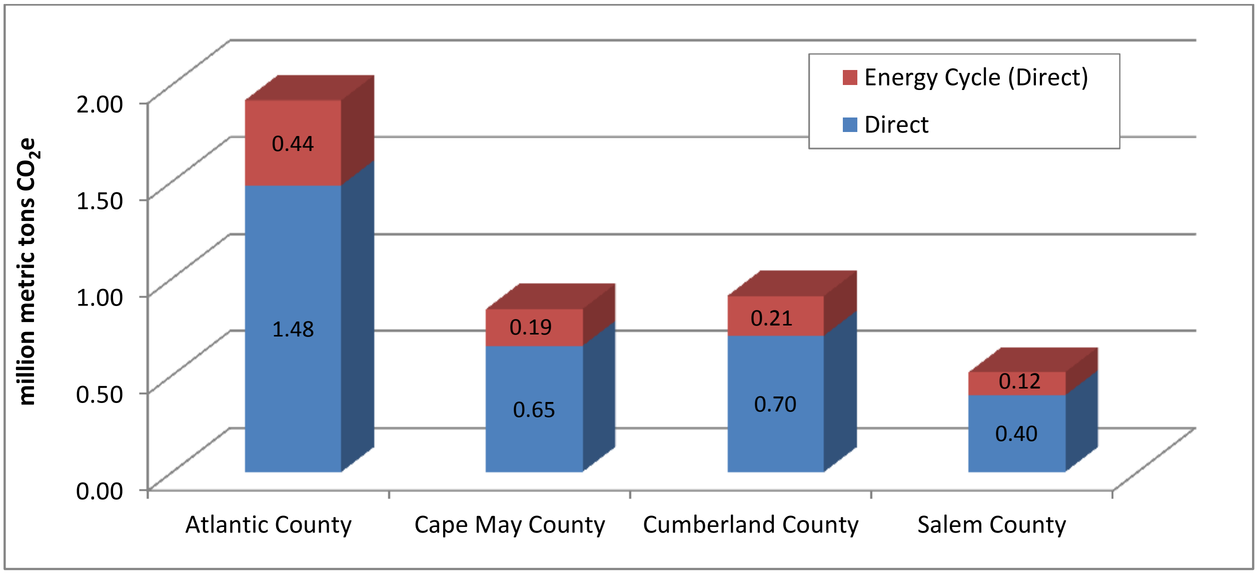
Figure 2
Transportation Sector Emissions by Subsector



ON-ROAD VEHICLES

On-road activity for direct-based GHG emissions is estimated based on total vehicle miles of travel (VMT) by vehicle type and average speed on roadways within each county and municipality. The primary difference between the two approaches within the region is the accounting of emissions from trips with an origin and/or destination outside the region (e.g., the direct approach does not account for emission outside the region, but does include emissions from through trips). **Figure 3** presents the allocation of direct-based emissions by county for the on-road sector.

Figure 3
2010 SJTPO On-Road Vehicle GHG Emissions by County
(direct, $MMtCO_2e$)



Emissions are also allocated to the municipal level for both the consumption and direct-based inventories. Because the consumption-based inventory excludes through-trips, it is a more useful approach for comparing emissions at the municipality scale. For example, when comparing consumption to direct-based GHG emissions per capita for the six municipalities presented in **Table 1**, emissions significantly decrease in the consumption approach. In all of these municipalities the consumption approach excludes emissions from through passenger traffic on the Garden State Parkway, therefore emissions per capita for the direct approach are significantly higher.

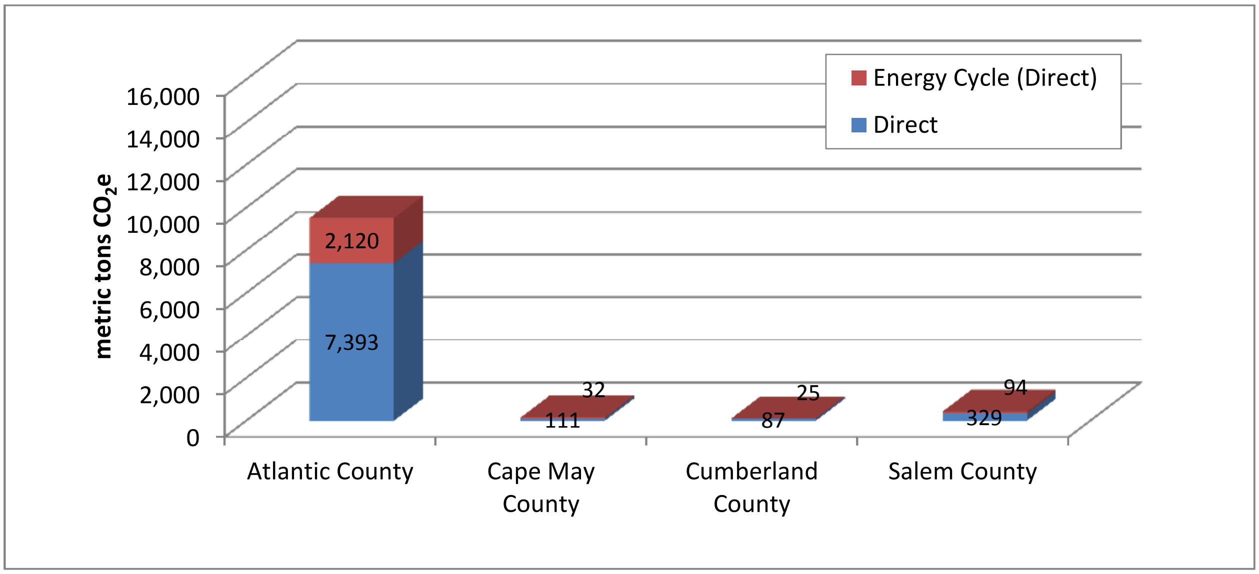
Table 1
Comparison of Consumption to Direct GHG Emissions per Capita

Location	Consumption $mtCO_2e$/capita	Direct $mtCO_2e$/capita
Atlantic County	2.8	4.0
Folsom Borough	3.6	13.6
Port Republic City	1.3	21.6
Cape May County	2.6	4.8
Upper Township	3.1	8.9
Middle Township	3.1	8.1

RAIL

Direct emissions from passenger and freight rail allocates emissions based on the actual miles travelled by the locomotive within each jurisdiction. For the rail sub-sector the emission results have more to do with the length of the rail line in the jurisdiction than the actual passenger or freight activity generated by the location. As presented in **Figure 4**, Atlantic County dominates direct-based rail emissions as the majority of freight rail activity passes through Atlantic County before accessing Cumberland or Cape May County, and Atlantic County contains the only passenger rail service in the region. Salem County shows a much smaller allocation than the consumption approach as emissions are only estimated based on activity within the county. Also, the total emission inventory for freight rail is much lower, as emissions from external trips are not included (eg. 977 MtCO_2e direct, compared to 19,299 MtCO_2e consumption).

Figure 4
2010 SJTPO Rail GHG Emissions by County (direct, MtCO2e)



Direct emissions from passenger rail are also allocated to the municipality level. In the consumption based inventory, emissions are only allocated to municipalities with stations on the Atlantic City rail line (Hammonton, Egg Harbor City, Absecon, and Atlantic City), with the majority allocated to Atlantic City (72% of total emissions due to this station having the highest total annual boardings and alightings on the Atlantic City rail line). In the direct based inventory, emissions are allocated to where they occur, therefore, emissions are allocated to municipalities without a station, including Galloway Township, Mullica Township, and Pleasantville City. For example, 63% of total direct based passenger rail emissions are allocated to these three municipalities without stations.

Industrial Processes and Fossil Fuel Industry

CEMENT, IRON, AND STEEL PRODUCTION

While cement, iron, and steel production are not found in the SJTPO region, production emissions attributed to the use of these materials have also been calculated under an alternative consumption-based accounting approach. Emissions from limestone and dolomite use (*e.g.*, flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and use, nitric acid production, and semiconductor manufacture are presented within the report as well as the use and release of fluorinated compounds including ozone depleting substance (ODS) substitutes used for cooling and refrigeration equipment and aerosols, solvents, fire protection, electric power transmission and distribution, and natural gas released from transmission and distribution.

County-level consumption of cement, iron, and steel estimates based on statewide tonnage shipped to New Jersey for cement and base metals from the US Geological Survey (USGS) *Materials Yearbook*[1] and the Freight Analysis Framework (FAF)[2], respectively. Allocation of cement consumption to individual counties was based strictly on county-level construction activity. However, iron and steel consumption would occur within both manufacturing and construction. Therefore, county-level construction activity, construction employment, and manufacturing employment were used in order to allocate iron and steel consumption to individual counties. **Table 2** summarizes the consumption of raw materials within the SJTPO region.

Table 2
SJTPO Annual Cement, Iron, and Steel Consumption

County	Cement (metric ton)	Base Metals (metric ton)
Atlantic	26.6	125,873
Cape May	7.2	64,913
Cumberland	60.5	185,525
Salem	21.6	63,173
SJTPO Region Total	115.8	437,485

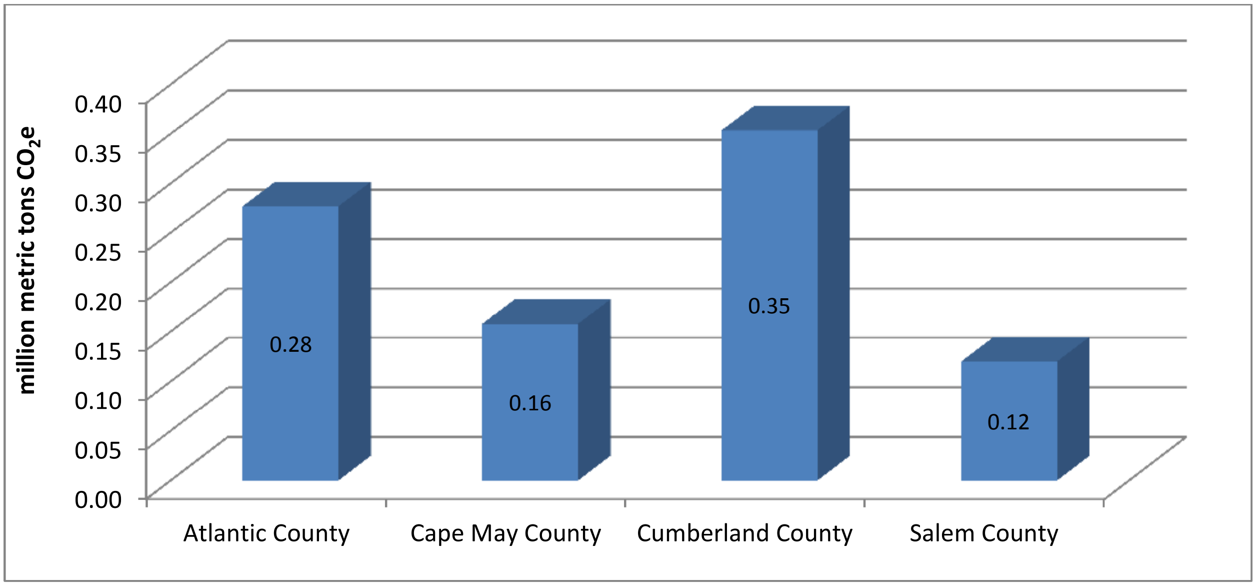
Sources: AKRF, based on USGS and FAF[3] data

Total emissions in the IP sector from the consumption of cement, iron, and steel in 2010 are estimated at 0.91 $MMTCO_2e$— more than the direct emissions from the entire IP&FF sector in the SJTPO region. The geographic distribution of emissions in the region is presented in **Figure 5**. The distribution of emissions from the various source types is presented in **Figure 6**.

[1] USGS, *Mineral Yearbook Volume I.—Metals and Minerals*, Table (: Cement Shipments to Final Customer by Destination and Origin

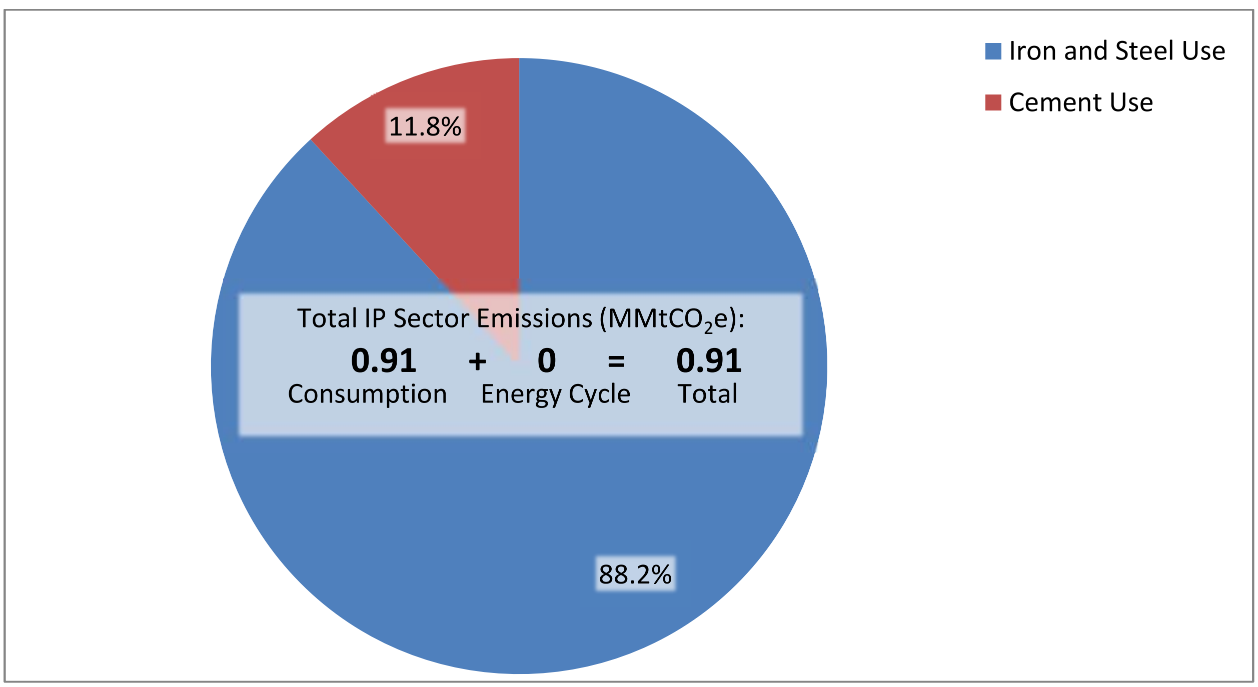
[2] FAF, *FAF version 3 (FAF*[3]*)*, Freight Analysis Framework Data Tabulation Tool http://faf.ornl.gov/fafweb/Extraction1.aspx

Figure 5
SJTPO Cement, Iron, and Steel Consumption
GHG Emissions by County, 2010



Note: Energy cycle emissions are not relevant to the IP sector since it does not include any fuel-based emissions.

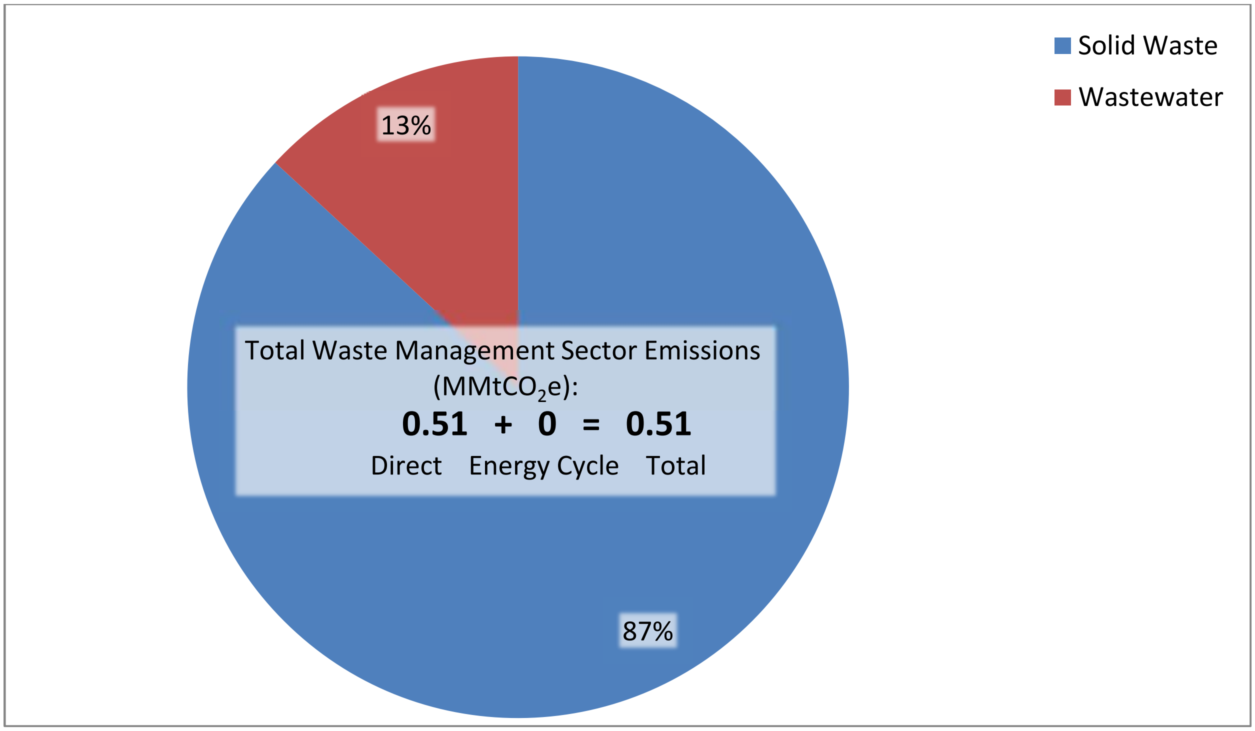
Figure 6
SJTPO Industrial Processes and Fossil Fuel Industry
Consumption Based GHG Emissions of Select Sources, 2010



Waste Management

Figure 7 below shows the total sector emissions on a direct emissions basis. On a direct basis, the emissions shown (0.51 $MMtCO_2e$) are greater than those estimated on a consumption basis (0.19 $MMtCO_2e$). Most of the difference relates to the way in which landfill methane emissions were calculated for the solid waste subsector as described below.

Figure 7
SJTPO Waste Management Direct GHG Emissions by Subsector, 2010



SOLID WASTE

For the direct estimates, we adopted NJDEP emission estimates.[3] While NJDEP used similar modeling methods (the first order decay equation as embodied within EPA's LandGEM), the waste emplacement history was developed differently than for the consumption-based estimates described below. For NJDEP's estimates, we presume that total waste in place was first estimated, and then the known or assumed number of operating years for the site was used to estimate annual average waste emplacement (the same average waste emplacement was then used as input to estimate methane generation in each year).

For consumption-based estimates, we used the landfill values in the waste management profiles constructed for each county as input to LandGEM. These produced much different disposal histories than those in the NJDEP approach as shown in **Table 3** below. According to data provided by NJDEP for the landfilled solid waste emplacement used to calculate direct emissions, in 1985 all of the SJTPO counties had more than one open landfill. Between 1985 and the early 1990s, most of the counties consolidated their landfills leaving only one landfill open per county; Salem County is the only exception with two Landfills open from 1981 to

[3] S. Jenks, NJDEP, personal communication and data file to S. Roe, CCS, January 10, 2014.

2010[4]. From 1991 to 1997, Atlantic County stopped disposing household MSW into Atlantic County landfills, due to issues with birds. During this time Atlantic County exported all of their MSW out of county, thus explaining, in the above table, why there is no waste emplaced into Atlantic County landfills in 1995[5]. It is unclear from the gathered data whether or not the counties imported large amounts of wastes during the 1980s and 1990s. Some explanations for the variation between the direct and consumption emplaced landfilled tonnage might include: data gaps (lack of imported MSW data); inflated direct emplacement data from using an average amount of waste emplaced over a period of time rather than using the actual amounts emplaced each year; and/or data gaps resulting from landfills opening and closing.

Table 3
Direct vs. Consumption-Based Landfill Emplacement Estimates (short tons)

	1985		1990		1995		2000		2005		2010	
	Direct	**Cnspt.**	**Direct**	**Cnspt.**	**Direct**	**Cnspt.**	**Direct**	**Cnspt.**	**Direct**	**Cnspt.**	**Direct**	**Cnspt.**
Atlantic County	544,311	176,050	435,449	199,377	0*	222,704	362,186	246,031	362,186	295,808	362,186	202,090
Cape May County	289,098	65,600	235,574	76,896	235,574	88,192	235,574	100,728	235,574	111,047	235,574	95,844
Cumberland County	513,965	43,876	273,561	63,333	273,561	82,790	273,561	116,573	273,561	124,039	273,561	111,230
Salem County	236,847	73,188	123,449	80,481	123,449	87,774	123,449	94,815	123,449	99,416	123,449	126,298

Notes:
Cnspt. = Consumption
Underlined text indicates back-casted consumption based emplacement estimates.
* From the data provided by NJDEP for direct landfill emplacement, there were no landfills open in Atlantic County from 1990 to 1997

For comparison, direct landfill emissions for the SJTPO region are 0.38 MMtCO_2e, while consumption-based estimates are 0.19 MMtCO_2e. Recall that consumption-based estimates are meant to address the emissions associated with the waste generated within each county, regardless of where it is managed. Direct emissions are those from waste management activities located in the county, regardless of where the waste was generated. As described in the Protocol (see separate appendix), consumption-based estimates are most useful for GHG mitigation planning but ideally would be augmented with full energy-cycle emissions, so that a full understanding of the benefits of source reduction, recycling and re-use is conveyed.

WASTEWATER TREATMENT

For wastewater treatment, there are no regional to county differences in emissions. The differences will be seen at the municipal level. The detailed municipal level emissions data in Appendix A will show these differences between accounting approaches. Direct emissions are attributed to the locations of treatment plants or the Atlantic City biosolids incineration facility;

[4] S. Jenks, NJDEP, personal communication to S. Roe, CCS, January 10, 2014; file name: "NJDEPlandfillspreadsheet_SJTPO_calcs.xlsx.

[5] G. Conover, ACUA, Personal Communication to L. Bauer, CCS, April 29, 2014.

while the consumption-based emissions are allocated back to each municipality based on population. Improvements to this allocation procedure are possible, if estimates of wastewater generation by residents versus commercial/institutional establishments were available. **Table 4** below provides an example of this allocation of emissions for Atlantic County.

Table 4
Atlantic County Wastewater Treatment GHG Emissions by Accounting Method, 2010

Municipality	Direct Emissions				Consumption-Based Emissions			
	tCO_2e	tCO_2	tCH_4	tN_2O	tCO_2e	tCO_2	tCH_4	tN_2O
Absecon city	-	-	-	-	1,030	-	37	0.83
Atlantic City	33,887	-	1,165	30.4	5,110	-	184	4.05
Brigantine city	-	-	-	-	1,505	-	55	1.15
Buena borough	297	-	14	0.01	550	-	20	0.41
Buena Vista township	3	-	0	0.00	909	-	33	0.69
Corbin City	-	-	-	-	60	-	2	0.05
Egg Harbor township	-	-	-	-	5,128	-	187	3.89
Egg Harbor City	-	-	-	-	521	-	19	0.41
Estell Manor	-	-	-	-	205	-	8	0.15
Folsom borough	-	-	-	-	222	-	8	0.16
Galloway township	-	-	-	-	4,443	-	161	3.42
Hamilton township	-	-	-	-	3,144	-	115	2.36
Hammonton town	1,321	-	62	0.06	1,760	-	64	1.33
Linwood city	-	-	-	-	844	-	31	0.63
Longport borough	-		-	-	196		7	0.15
Margate City	-		-	-	1,076		39	0.82
Mullica township	2		0	0.00	723		27	0.53
Northfield	-		-	-	1,017		37	0.76
Pleasantville	-		-	-	2,344		86	1.74
Port Republic	-		-	-	133		5	0.10
Somers Point	-		-	-	1,392		51	1.06
Ventnor City	-		-	-	1,521		55	1.15
Weymouth township	30		1	0.00	334		12	0.25

✷

Appendix C

Additional Sector Details

APPENDIX C: ADDITIONAL SECTOR DETAILS

Appendix C includes additional details regarding methodology and reference data for some sectors (note that the complete methodology as developed prior to preparation of the inventory can be found in **Appendix D)**. Complete calculation details are found in the inventory calculation sheets for each sector. Inventory calculation sheets are available upon request,

Energy-Cycle Emissions

The energy-cycle GHG emission factors used in this project are shown in **Table 1** below. These emission factors represent the additional emissions associated with the upstream production and transport of each fuel to the point of distribution ("well to pump"). In all cases, a single emission factor in total carbon dioxide equivalents (CO_2e) is provided, since the source data do not usually provide specific emission factors for each greenhouse gas.

Table 1
Fuel Energy-Cycle GHG Emission Factors

Fuel	Energy-Cycle Emissions Factor	Units
Baseline Gasoline	2.695	metric tons CO_2e/1000 gallon
Compressed Natural Gas	18.61	metric tons CO_2e/MMcf
Liquefied Natural Gas	0.01747	metric tons CO_2e/MMBtu
Pipeline Natural Gas	0.00425	metric tons CO_2e/MMBtu
Liquefied Petroleum Gas	1.59	metric tons CO_2e/1000 gallon
Ethanol, Corn	(0.479)	metric tons CO_2e/1000 gallon
Conventional and LS Diesel	2.95	metric tons CO_2e/1000 gallon
Soybean-based BD100	(7.10)	metric tons CO_2e/1000 gallon
Coal Combustion	0.00494	metric tons CO_2e/MMBtu
Wood	0.111	metric tons CO_2e/ metric ton
Residual Oil	2.07	metric tons CO_2e/1000 gallon
Jet Fuel	3.064	metric tons CO_2e/1000 gallon

The primary source of data was the Argonne National Laboratory's GREET Model.[1] Output from GREET Model version GREET1_2013 was used. GREET defaults for US fuel supplies were used to derive the estimates for all fuels supported by GREET. Notably, ethanol production is all sourced from corn through 2020 (GHG emissions from land use change are included). Note that there is also a new separate GREET Life Cycle Analysis tool that runs on a web-based platform. Values for some additional fuels (stationary combustion) that were not included in the spreadsheet version of GREET were taken from the web-based version.

[1] GREET Model website: http://greet.es.anl.gov/.

Since GREET was originally designed to support analysis of transportation fuels, it does not support all fuel types. Additional notes on the development of the upstream emission factors follow:

- *Coal Combustion*: this is a GREET upstream pathway emission factor (EF) average for coal use in power plants. There is no specific pathway for other coal use (e.g., industrial use). Since this is not a transportation fuel, GREET does not estimate separate values for the historical years, so the same value is assumed for all years.
- *Pipeline Natural Gas:* Not a GREET transportation fuel, so a complete annual series of values is not calculated by GREET. However, the GREET default US pipeline natural gas pathway emission factors for CO_2, CH_4, and N_2O were used to generate an upstream CO_2e emission factor. This is based on the current mix of 23% shale gas and 77% conventional gas.
- *Wood Combustion*: GREET does not provide this EF. Upstream emissions are based on an Ontario study of the Life Cycle Impacts of Wood vs Coal production (Tables S-1 and S-2).[2] The value used here is for pelletized wood fuel.
- *Heating Oil:* the value for residual oil was used as a proxy for heating oil. This value was taken from the new GREET 2013 Net (web-based) tool.
- *Jet Fuel:* this value was taken from the new GREET Net tool. "Ultra-low sulfur jet fuel from crude oil" was the only relevant pathway available.
- *Aviation Gasoline:* this was not available from GREET. The EF for conventional gasoline was used as a proxy.

Negative values for ethanol and biodiesel occur as a result of the accounting procedures used to account for the effects of co-products. For ethanol, this includes dried distillers grains and for biodiesel, it includes soy meal. Both can be used for animal feed or other uses, which displace the need to source these feed materials from other crops (which reduces the energy and emissions that would have occurred to produce them). Other accounting procedures may not credit emission reductions for these co-products. Note that emissions that occur as a result of land use change are also included in these estimates.

Energy-cycle emissions rates for the generation of electricity were derived using the GREET model along with a resource mix obtained from the eGRID[3] database for the RFCE region instead of the GREET Model's default resource mix (as shown in **Table 2**). Energy-cycle GHG emissions factors represent the difference between the GREET Life-Cycle emissions factors, and consumption-based emission factors obtained from the eGRID database. Energy-cycle GHG emission factors used for the generation of electricity within the SJTPO region are shown in **Table 3** below.

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[2] http://pubs.acs.org/doi/suppl/10.1021/es902555a/suppl_file/es902555a_si_001.pdf.

[3] USEPA, eGRID 9th edition version 1.0, http://epa.gov/cleanenergy/energy-resources/egrid/index.html

Table 2
eGRID RFCE Region Resource Mix

Fuel	Generation Percentage
Coal	35.27%
Oil	0.55%
Gas	20.62%
Fossil	0.69%
Biomass	1.28%
Other Hydro	1.01%
Nuclear	39.91%
Wind	0.67%
Solar	0.01%
Geothermal	0.00%
Unknown/Purchased Fuel	0.00%

Source: eGRID2012 Table SRL10

Table 3
SJTPO Electricity Generation Emission Factors

	Energy-Cycle Emission Factors
CO_2 (metric tons/MWh)	0.0445
CH_4 (metric tons/GWh)	0.8335
N_2O (metric tons/GWh)	2.643×10^{-5}
CO_2e (metric tons/MWh)	0.0621

Transportation

AVIATION

The approach for aviation emission estimates was to develop GHG emission estimates based on the estimated fuel used during the landing-takeoff (LTO) cycle (emissions occurring below 3,000 feet) using the Federal Aviation Administration's (FAA) Emissions and Dispersion Modeling System (EDMS)[4]. GHG emissions were inventoried in accordance with Airport Cooperative Research Program (ACRP) *Guidebook on Preparing Airport Greenhouse Gas Emission Inventories* (*ACRP Report 11*).[5] Fuel usage per LTO cycle or touch and go (TGO) were calculated using fuel flow rates for each operating mode for each specific aircraft engine combined with the typical period of time the aircraft is within the operating mode. A LTO cycle

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4 EDMS is available from the Federal Aviation Administration at the following website: http://www.faa.gov/about/office_org/headquarters_offices/apl/research/models/edms_model/.

5 Airport Cooperative Research Program, Report 11, Project 02-06, *Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories*, http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_011.pdf.

consists of aircraft operating modes of approach, taxi in, engine startup, taxi out, takeoff, and climbout.[6] A TGO is an aircraft operation where the pilot lands on a runway and takes off again without coming to a full stop. Estimating the airport emissions by capturing the LTO activity up to 3,000 feet is preferable for assigning emissions to particular airports, and in keeping track of changes to operations at those airports that change with time.

Table 4 presents the baseline year (2010) annual operations by aircraft category (i.e., air carrier, air taxi, general aviation, and military)[7] for the nine airports within the SJTPO. For general aviation, both LTO and TGO were included. Aircraft activity levels were based on FAA's Terminal Area Forecasts (TAF), FAA's OPSNET, and Airport IQ5010™ Airport Master Records.

Table 4
Annual Airport Operations by Aircraft Category—Baseline Year

Airport	Air Carrier	Air Taxi	General Aviation (TGO)	General Aviation (LTO)	Military (TGO)	Military (LTO)
Atlantic City International	12,630	5,607	9,944	23,010	33,294	22,765
Bucks	0	0	1,150	50	0	0
Cape May County	0	0	8,000	22,000	0	200
Hammonton Municipal	0	0	8,400	7,500	0	0
Kroelinger	0	0	150	20	0	0
Millville Municipal	0	0	30,000	27,000	0	3,000
Ocean City Municipal	0	0	8,060	12,098	0	0
Spitfire Aerodrome	0	0	12,720	4,243	0	0
Woodbine Municipal	0	0	8,044	4,331	0	0

Source: Airport IQ5010™ Airport Master Records and Reports, http://www.gcr1.com/5010web/, Federal Aviation Administration Terminal Area Forecast (TAF), http://aspm.faa.gov/main/taf.asp, and Federal Aviation Administration Operations Network (OPSNET), https://aspm.faa.gov/opsnet/sys/Default.asp.

[6] An LTO cycle consists of the following operational modes:

- "Taxi/idle" includes the time an aircraft taxis between the runway and a terminal, and all ground-based delay incurred through the aircraft route. The taxi/idle-delay mode includes the landing roll, which is the movement of an aircraft from touchdown through deceleration to taxi speed or full stop.
- "Approach" begins when an aircraft descends below the atmospheric mixing height and ends when an aircraft touches down on a runway.
- "Takeoff" begins when full power is applied to an aircraft and ends when an aircraft reaches approximately 500 to 1,000 feet. At this altitude, pilots typically power back for a gradual ascent.
- "Climb out" begins when an aircraft powers back from the takeoff mode and ascends above the atmospheric mixing height.

[7] Commercial aircraft include those used for transporting passengers, freight, or both. Commercial aircraft tend to be larger aircraft powered with jet engines. Air Taxis carry passengers, freight, or both, but usually are smaller aircraft and operate on a more limited basis than the commercial aircraft. General Aviation includes most other aircraft used for recreational flying and personal transportation. Finally, military aircraft are associated with military purposes, and they sometimes have activity at non-military airports.

Application of this method requires that data on LTOs from each of the airports in the region by aircraft/engine type be determined. This critical detail about the aircraft focuses on whether each aircraft is turbine- or piston-driven, which allows the emissions estimation model to assign the fuel used, jet fuel, or aviation gas, respectively. The fraction of turbine- and piston-driven aircraft were either assumed for air taxi and general aviation operation per Environmental Protection Agency (EPA) estimates. Specifically, EPA assumes that 72.5 percent of general aviation and 23.1 percent of all air taxi activity are powered by piston-powered aircraft, while the remainder is powered by turbine aircraft.

Representative aircraft/engine combinations for each aircraft category were developed based on EPA's 2011 National Emissions Inventory (NEI), Official Airline Guide (OAG) Aviation Database, the JP Airline-Fleets International Database (JP Fleets), or other appropriate sources. A detailed air carrier aircraft fleet mix for Atlantic City International Airport was also developed. For air taxi, general aviation, and military operations, a representative aircraft were assigned (e.g., Cessna 172 with O-360-B engine was assigned as a representative piston-driven general aviation aircraft).

Table 5 presents the aircraft fleet mix and operations for the baseline year for Atlantic City International Airport. **Table 6** presents the aircraft fleet mix for the eight general aviation airports.

International Civil Aviation Organization (ICAO) operating times were used to estimate fuel usage within each aircraft operating mode: approach, taxi in, engine startup, taxi out, takeoff, and climbout. The ground-based taxi time and queue delay used in the air quality assessment are shown in **Table 7.** The taxi-delay and queue time is a function of the aircraft type.

Fuel usage within the aircraft engine startup mode was estimated based on published guidance for the engine startup fuel flow rate.[8] Based on the number of non-piston aircraft operations and the estimated fuel flow rate, the engine startup fuel usage was determined and with the use of the aircraft GHG emission factors GHG emissions were developed.

The fuel usage from each aircraft category was added and converted to GHG emissions based on appropriate CO_2, N_2O, and CH_4 emission factors (for Jet A and aviation gasoline) and GWP values. **Table 8** presents the GHG emission factors to be used for aviation fuels.

In addition to aircraft emissions, GHG emissions from auxiliary power units (APUs)[9] and ground support equipment (GSE)[10], such as aircraft refueling vehicles, baggage handling vehicles, and

8 ICAO/CAEP Working Group 3, May 5, 2006, Engine Starting Emissions.

9 Auxiliary power units (APU) are small turbine engines used by many commercial jet aircraft to start the main engines; provide electrical power to aircraft radios, lights, and other equipment; and to power the onboard air conditioning (heating and cooling) system. When an aircraft arrives at a terminal gate, the pilot has the option of shutting off power to the main jet engines and operating the onboard APU, which is fueled by the aircraft's jet fuel. Alternately, an aircraft can receive 400 Hertz (Hz) gate power and pre-conditioned air (PCA) from mobile ground power unit (GPU) and air conditioning equipment, or receive electrical power and PCA from connections at the gate. In most cases, gate power connections are built into the passenger loading bridge used to connect the terminal building to the aircraft for loading and unloading passengers. EDMS assigns default APU based on aircraft assignments and also includes criteria pollutant emission factors corresponding to the horsepower for each unit.

10 Ground support equipment (GSE) is a term used to describe the vehicles that service aircraft after arrival and before departure at an airport. Emissions from these sources are based on the number and type of equipment used to service each aircraft along with the amount of time the equipment is in use per aircraft landing-takeoff cycle and the fuel type. The types of GSE includes aircraft tugs, baggage tugs, belt loaders, fuel trucks, food trucks, cargo trailers, hydrant carts, lavatory trucks, cabin service, and cargo loaders as well as deicers, forklifts, and ground power units. Emissions resulting from the operation of GSE vary depending on the type of equipment, fuel type (i.e., gasoline, diesel, propane, electric, etc.) and the duration of equipment operation

equipment, aircraft towing vehicles, and passenger buses, were also included in the aviation sector. These emissions were based on assigned aircraft and default operating conditions within the EDMS. **Table 9** presents the GHG emission factors used for non-road equipment and vehicles.

Table 5
Annual Operations by Aircraft Type—Baseline Year for Atlantic City International Airport

Aircraft	Engine	LTO	TGO
Boeing DC-9-30 Series	JT8D-11	2	
Boeing DC-9-50 Series	JT8D-17	766	
Boeing MD-82	JT8D-217C	99	
Boeing MD-87	JT8D-217C	1	
Bombardier CRJ-200	CF34-3B	1	
Embraer ERJ145	AE3007A1E	1	
Embraer ERJ170	CF34-8E5	1	
Embraer ERJ190	CF34-10E	12	
Gulfstream G500	BR700-710A1-10	1	
Airbus A319-100 Series	CFM56-5B6/P	3,713	
Airbus A320-200 Series	V2527-A5	717	
Airbus A321-100 Series	V2530-A5	180	
Airbus A330-200 Series	PW4156	9	
Boeing 737-100 Series	JT8D-15	793	
Boeing 737-400 Series	CFM56-3-B1	6	
Boeing 737-800 Series	CFM56-7B26	9	
Boeing 757-200 Series	RB211-535C	3	
Boeing 767-300 ER	PW4060	2	
Boeing DC-3	R-1820	648	
Embraer EMB120 Brasilia	PW118B	2,156	
Cessna 172 Skyhawk	IO-360-B	8,341	7,209
Bombardier Learjet 35	TFE731-2-2B	3,164	2,735
Lockheed Martin F-16 Fighting Falcon	F100-PW-229 (w/AB)	11,383	33,294

Source: United States Environmental Protection Agency, 2011 National Emission Inventory, http://www.epa.gov/ttn/chief/net/2011inventory.html, Federal Aviation Administration Terminal Area Forecast (TAF), http://aspm.faa.gov/main/taf.asp, and Federal Aviation Administration Operations Network (OPSNET), https://aspm.faa.gov/opsnet/sys/Default.asp,

(engine run time). The type of GSE used depends on the aircraft type and the designated category of an aircraft operation (i.e., passenger, cargo, etc.).

Table 6
Aircraft Fleet Mix for General Aviation Airports

Aircraft	Engine
Boeing DC-3	R-1820
Embraer EMB120 Brasilia	PW118B
Cessna 172 Skyhawk	IO-360-B
Bombardier Learjet 35	TFE731-2-2B
Fairchild A-10A Thunderbolt II	TF34-GE-100-100A
Cessna 414	TIO-540-J2B2

Source: United States Environmental Protection Agency, 2011 National Emission Inventory, http://www.epa.gov/ttn/chief/net/2011inventory.html and Airport IQ5010™ Airport Master Records and Reports, http://www.gcr1.com/5010web/.

Table 7
Aircraft Taxi Times

Aircraft Category	Taxi In	Taxi Out
Commercial		
Jet	7.0	19.0
Turboprop	7.0	19.0
Piston	6.5	6.5
General Aviation		
Business Jet	6.5	6.5
Turboprop	7.0	19.0
Piston	4.0	12.0
Helicopter	3.5	3.5
Military		
Combat (USAF)	11.3	18.5
Trainer	4.4	6.8
Transport	6.7	9.2

Source: Federal Aviation Administration EDMS, 2013 and United States Environmental Protection Agency, Compilation of Air Pollutant Emission Factors.

Table 8
Aviation Fuel Emission Factors

Fuel	CO_2	N_2O	CH_4	Units
Jet A	21.50	0.00068	0.00060	lb/gallon
Avgas	18.32	0.00024	0.01554	lb/gallon

Source: The Climate Registry's 2013 Default Emission Factors.

Table 9
Ground Support Equipment Fuel Emission Factors

Fuel	CO_2	N_2O	CH_4	Units
Diesel	22.51	0.00057	0.00163	lb/gallon
Gasoline	19.36	0.00086	0.00013	lb/gallon

Source: The Climate Registry's 2013 Default Emission Factors.

Direct aviation GHG emissions by airport for the baseline year are summarized in **Table 10**. Of note, Atlantic City and Hammonton Airports are in Atlantic County; Cape May, Ocean City and Woodbine Airports are in Cape May County; Bucks, Kroelinger, and Millville Airports are in Cumberland County; and Spitfire Aerodrome is in Salem County. A majority (83 percent) of the direct GHG emissions occur within the Atlantic City International Airport. Approximately 90 percent of the aviation GHG emissions are related to aircraft and the remaining 10 percent are related to GSE operations.

Table 10
Direct Aviation Emissions by Airport

Airport	CO_2e (metric ton)
Atlantic City International Airport	43,593
Bucks Airport	50
Cape May County Airport	1,539
Hammonton Municipal Airport	729
Kroelinger Airport	8
Millville Municipal Airport	4,186
Ocean City Municipal Airport	1,054
Spitfire Aerodrome	739
Woodbine Municipal Airport	569
Total	**52,468**

Source: Federal Aviation Administration EDMS, 2013 and KB Environmental Sciences, 2014.

The GHG energy-cycle emissions are the emissions associated with upstream activities, including fuel extraction or production, processing, and transport. The energy-cycle emissions are important for accounting for the differences between various fuels, including biofuels and standard fuels. Measuring GHG emissions by using this method provides a more complete picture of where GHGs are being emitted and provides additional guidance on what type of GHG mitigation measures may be pursued.

The Argonne National Laboratory's GHG, Regulated Emissions and Energy use in Transport (GREET) model[11] was used to determine the energy-cycle emission factors (in metric ton of CO_{2e} per fuel usage) for each aviation fuel type (i.e., aviation gasoline, diesel, and jet fuel) for the baseline year. The GREET model does not have an energy-cycle emission factor specifically for aviation gasoline, so motor gasoline fuel was used as a surrogate. Conventional and low-sulfur diesel fuels were used for diesel fuel. Aviation fuel consumption (in gallons) for

[11] The GREET Model is available from the Argonne National Laboratory of the U.S. Department of Energy at the following website: http://greet.es.anl.gov/.

aircraft, APU, and GSE for the nine airports within the SJTPO were derived using FAA's EDMS for the baseline year. Energy-cycle GHG emissions by airport for the baseline year are summarized in **Table 11**. A majority (83 percent) of the energy-cycle GHG emissions occur within the Atlantic City International Airport. The energy-cycle GHG emissions represent approximately 30 percent of the total direct GHG emissions for aviation.

Table 11
SJTPO Regional Energy-Cycle Emissions from Transportation - Aviation

Airport	2010 CO_2e (metric ton)
Atlantic City International Airport	13,492
Bucks Airport	16
Cape May County Airport	477
Hammonton Municipal Airport	227
Kroelinger Airport	3
Millville Municipal Airport	1,297
Ocean City Municipal Airport	327
Spitfire Aerodrome	230
Woodbine Municipal Airport	177
Total	**16,245**

Source: Federal Aviation Administration EDMS, 2013 and KB Environmental Sciences, 2014.

NON-ROAD RECREATIONAL VEHICLES

Non-road engines include mobile vehicles and engines (including non-vehicle engines such as movable generators). This section describes the emissions associated with non-road recreational vehicles, including snowmobiles, off-road vehicles, golf carts, and other specialty vehicles. Note that other non-road engines, such as agricultural, industrial, commercial, lawn and garden, recreational marine, construction, airport ground support, mining, oilfield, and railway maintenance engines are included with their respective subsectors.

This approach differs from EPA's approach in the Inventory of U.S. GHG Emissions and Sinks where all mobile-source energy consumption (including both on- and off-road) and stationary source emissions are included in the energy sector.[12] For the SJTPO inventory, emissions only from on- and off-road mobile sources supporting transportation were included in the transportation sector (including non-road recreational vehicles, recreational marine vessels, airport ground support equipment, and railway maintenance engines).

The general methods described in this section for non-road engines apply to all sectors, but the emissions are included with each sector as appropriate. Since the emissions are all local, the consumption-based and the direct emissions from these sources is the same.

The latest version of EPA's NONROAD model (NONROAD2008a)[13] was used to calculate CO_2 emissions and fuel consumption for non-road recreational vehicles. NONROAD provides the

[12] http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Chapter-3-Energy.pdf

[13] NONROAD2008a is available from the Environmental Protection Agency at the following website: http://www.epa.gov/otaq/nonrdmdl.htm#model.

best estimate available for emissions down to the county level. GHGs other than CO_2 (i.e., N_2O and CH_4) were calculated based on fuel consumption for each fuel type (i.e., diesel, gasoline, compressed natural gas, and propane), as described for highway fuels. Upstream emissions were calculated as well for the energy-cycle analysis, based on fuel consumption, as described for highway vehicles.

NONROAD includes emissions from the following categories: recreational vehicles, construction equipment, industrial equipment, lawn and garden equipment, agricultural equipment, light commercial equipment, logging equipment, and marine equipment. Some of these emissions were then allocated to the applicable sectors including rail (railway support equipment), recreational marine (recreational), agriculture, forestry, and marine. **Table 12** presents the GHG emission factors used for non-road equipment and vehicles.

Table 12
Nonroad Equipment and Vehicles Fuel Emission Factors

Fuel	CO_2	N_2O	CH_4	Units
Diesel	22.51	0.00057	0.00128	lb/gallon
Gasoline	19.36	0.00049	0.00110	lb/gallon
CNG	119.95	0.00218	0.00231	lb/1000 ft^3
Propane	12.32	0.00090	0.00020	lb/gallon

Source: The Climate Registry's 2013 Default Emission Factors.

The model was run according to the latest procedures and assumptions used by the New Jersey Department of Environmental Protection (NJDEP) in State Implementation Plan (SIP) preparation, in consultation with NJDEP. These parameters are summarized in **Table 13**. The model includes estimates of all equipment type used, equipment size (horsepower), load factors, and hours of operation for the various equipment and vehicles and fuel types for multiple sectors.

Table 13
NONROAD Emission Model Input Parameters

Parameter	Baseline	Future
Reid Vapor Pressure	9.84	
Fuel Oxygen Weight Percentage	3.45	
Gasoline Sulfur Percentage	0.0387	
Diesel Sulfur Percentage	0.0165	0.0011
Marine Diesel Sulfur Percentage	0.0319	0.0055
LPG/CNG Sulfur Percentage	0.0030	
Minimum Temperature	48.4	
Maximum Temperature	68.1	
Average Temperature	58.3	
Stage II Control Percentage		
EtOH Blend Percentage	100.00	
EtOH Volume Percentage	9.87	

Source: Email from Jim Koroniades, NJDEP to Hillel Hammer, November 25, 2013, EPA, Suggested Nationwide Average Fuel Properties, April 2003, and Local Climatological Data, Annual Summary with Comparative Data, Atlantic City Airport, Department of Commerce, National Oceanic and Atmospheric Administration.

As with other transportation sub-sectors, energy-cycle emissions were based on results of the GREET model. Energy-cycle emission factors for each non-road equipment categories fuel types (i.e., gasoline, diesel, propane, and compressed natural gas) for the baseline year and forecasted years were based on results of the GREET model. Fuel consumption (in gallons) for the non-road equipment categories and counties (i.e., Atlantic, Cape May, Cumberland, and Salem counties) within the SJTPO for the baseline year was derived using EPA's NONROAD Model

Waste Management

SOLID WASTE

Consumption-based Emissions

To develop these estimates, the Team conducted surveys of municipal solid waste (MSW) management agencies to gain an understanding of the waste management practices conducted in each county. Through these surveys and additional information with NJDEP staff, the Team determined that landfill disposal is the most prominent method for MSW management. In addition to landfill disposal, recycling and composting are conducted within each county. No waste incineration or open burning are conducted in the SJTPO counties and no other forms of MSW management were identified (e.g. anaerobic digestion).

Figures 1 through 4 depict the historical waste management profiles based on the county-level surveys. Available data varied by county, and in order to develop an adequate history so that landfill methane emissions could be modeled, the Team had to conduct some back-casting of waste management by each mode. This back-casting was generally performed using trend analysis.

Consumption-based solid waste emissions are generated from solid waste landfill disposal (excluding imports), composting, and in-county waste transportation activities. These activities create CH_4 from landfill disposal; CO_2, N_2O, and CH_4 from transportation of the waste, compostable materials and recyclables to landfills, composting and recycling facilities; and CH_4, and N_2O emissions from composting. Total 2010 emissions for the solid waste subsector are 120,528 metric tons of CO_2e on a consumption-basis.

To calculate CH_4 generation from landfilling, the Environmental Protection Agency's (EPA's) LandGEM model was used.[14] The team used the same LandGEM modeling inputs as those used by NJDEP to generate their landfill gas emissions as described under Direct Emissions below. These inputs include the default assumptions for the methane generation potential of landfilled waste and the methane generation constant.[15] NJDEP uses standard assumptions regarding collection and control of landfill gas. This includes a combined 75 percent collection and control efficiency for CH_4 and a ten percent oxidation of CH_4 within the landfill's cover soil. To calculate consumption-based landfilling emissions, the team input landfilled MSW data provided by each county into LandGEM, and then applied the same standard collection and control assumptions. For uncontrolled landfills, only the 10% oxidation factor was applied to landfill CH_4 generation to estimate emissions.

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[14] EPA Landfill Gas Emissions Model (LandGEM) Manual: http://www.epa.gov/ttn/catc/dir1/landgem-v302-guide.pdf.

[15] J. Davis, NJDEP, personal communication to L. Bauer, CCS, March 18, 2014; S. Jenks, NJDEP, personal communication to S. Roe, CCS, January 10, 2014.

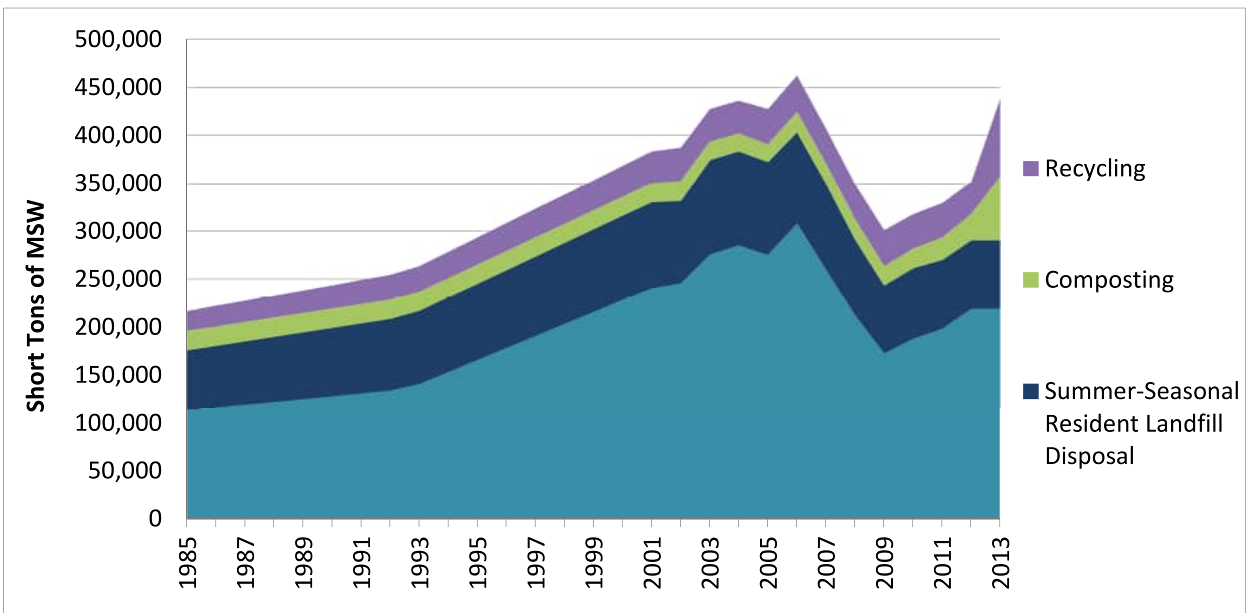
Compost feedstock data for 2010 reported by each county were used to calculate the CH_4 and N_2O emissions from the composting process. The emission factors applied were 7.89×10^{-4} tCH_4 per ton of compost feed stock[16] and 4.74×10^{-5} tN_2O per ton of compost feedstock.[17]

For the consumption-based estimates, the team also calculated emissions resulting from the transportation of landfilled, composted and recycled solid waste generated within each county. To calculate these emissions, the team used EPA's default Waste Reduction Model (WARM) multiplier of 2.81×10^{-3} tCO_2e per ton of waste transported.[18]

Summer-seasonal and year round resident emission estimates were also produced for Atlantic and Cape May Counties, due to the increase of population in the summer from vacationers or other seasonal residents. The summer season is considered to be the months of June-August. To estimate landfill waste emplacement by each type of resident (year-round vs. seasonal), the team first assumed that solid waste generation rates were the same for each resident type. Then total person-days for each resident type were calculated from the SJTPO population data and forecast. The annual person-day estimates were back-casted to 1985 using trend analysis based on .the 2010-2030 data

The amount of waste emplaced into the county landfills was then broken out between summer-seasonal and year-round residents based on total person-days. These estimates indicate that, for Cape May County, about half of the waste emplacement (and subsequent GHG emissions) could be attributed to seasonal populations. In Atlantic County, the potential contribution by seasonal residents was over one-third of the annual total. As mentioned above, the EPA's LandGEM model was used to calculate methane emissions for all counties.

Figure 1
Solid Waste Management Profile for Atlantic County



[16] Roe *et al.* 2004. "Estimating Ammonia Emissions from Anthropogenic Nonagricultural Sources." Available at: http://www.epa.gov/ttnchie1/eiip/techreport/volume03/eiip_areasourcesnh3.pdf.

[17] UNFCCC. 2005. "Approved Baseline Methodology AM0025; Avoided emissions from organic waste composting at landfill sites." Available at: http://cdm.unfccc.int/EB/021/eb21repan15.pdf.

[18] EPA WARM Model: http://epa.gov/epawaste/conserve/tools/warm/pdfs/Composting_Overview.pdf

Figure 2
Solid Waste Management Profile for Cape May County

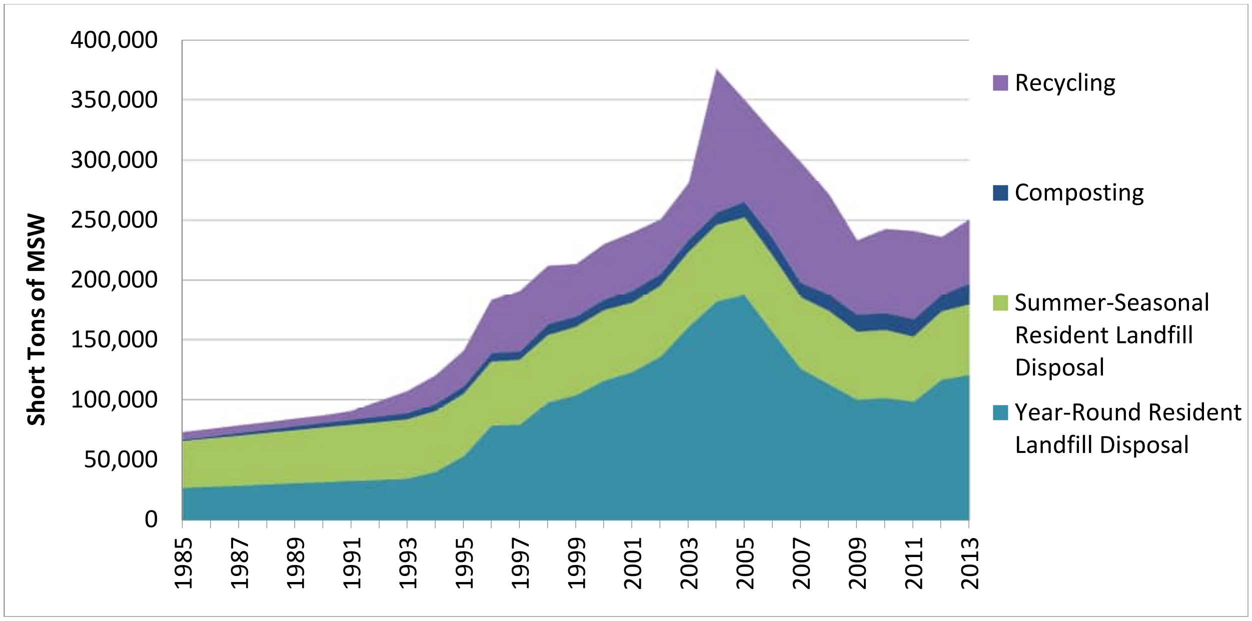


Figure 3
Solid Waste Management Profile for Cumberland County

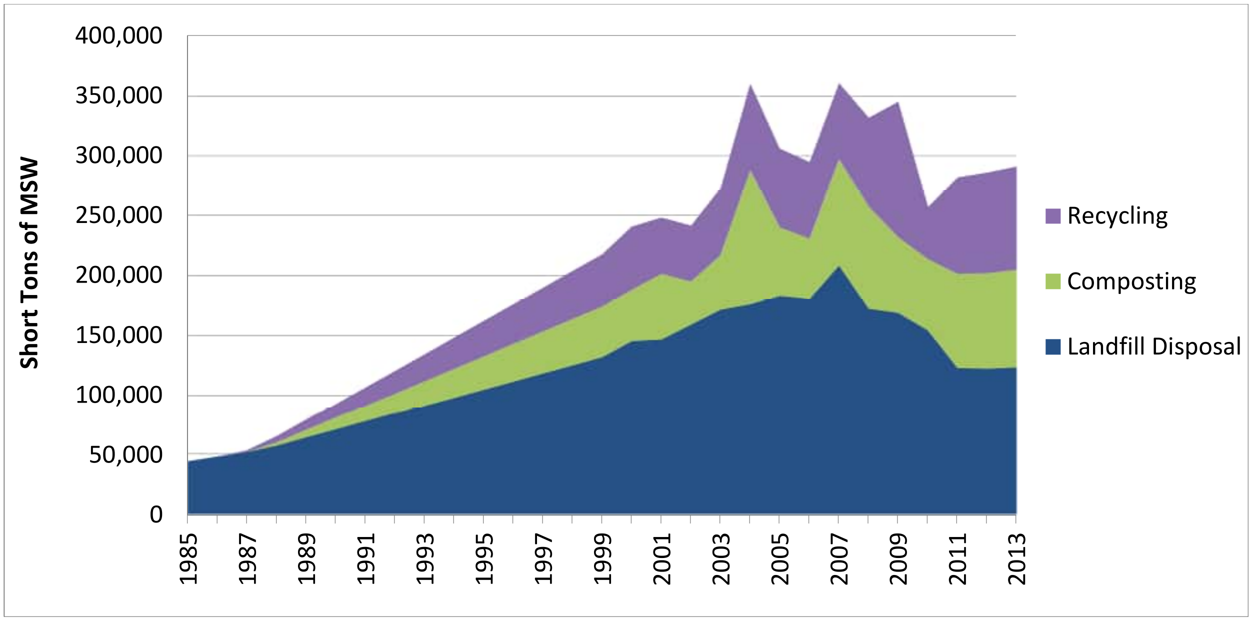
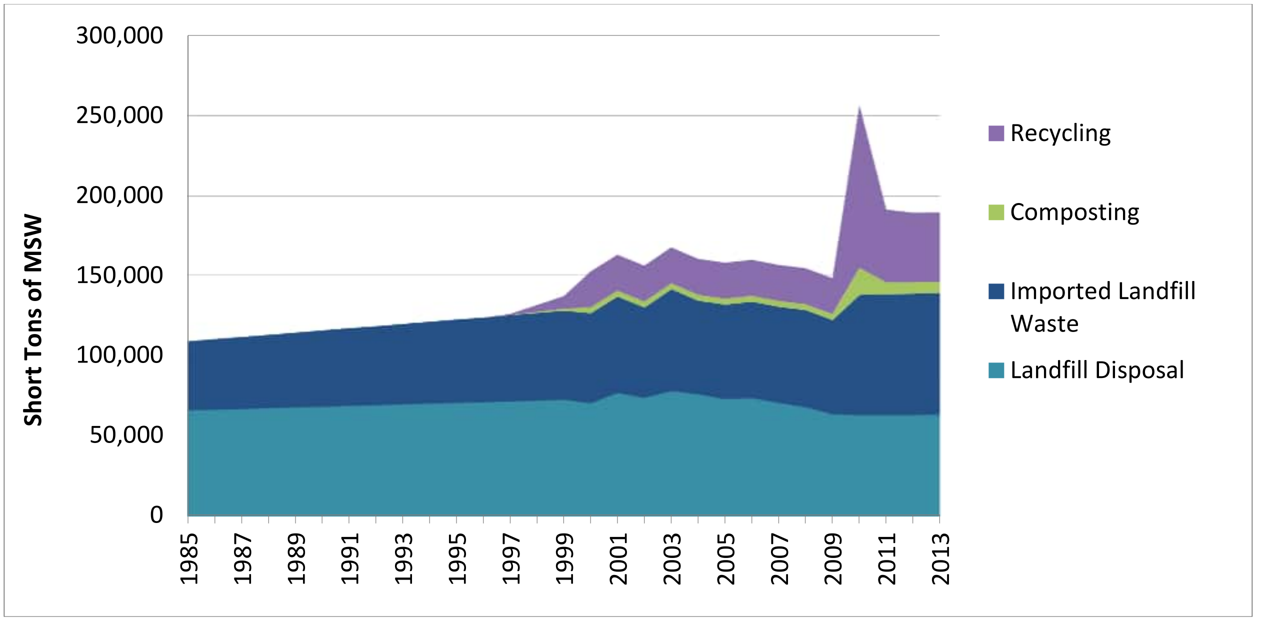


Figure 4
Solid Waste Management Profile for Salem County



Direct Emissions

These include landfill CH_4 and composting CH_4 and N_2O. For landfill methane emissions, the Team adopted estimates provided directly by NJDEP.[19] These estimates cover large and/or currently operating landfills in the region, but exclude small, old, and closed sites. As discussed in the Protocol, those sites would be excluded from the inventory due to their expected very small contributions to CH_4 emissions.[20] Landfills with methane emission estimates from NJDEP are provided in **Table 14** below. Total regional CH_4 emissions are 20,872 metric tons or 438,312 tCO_2e. Direct emissions are allocated to the municipality where the landfill is located. In cases where the landfill straddles two different municipalities, the emissions were split evenly between them.

Composting activity in the SJTPO region for 2010 is summarized in **Table 15** below. These data were gathered from the county-level surveys described above. In all cases, these operations composted food and yard waste. Emission factors for CH_4 and N_2O were taken from literature sources.[21] Emissions were allocated to the municipality where the composting took place. SJTPO regional emissions for composting totaled 2,942 tCO_2e in 2010.

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[19] S. Jenks, NJDEP, personal communication to S. Roe, CCS, January 10, 2014; file name: "NJDEPlandfillspreadsheet_SJTPO_calcs.xlsx.

[20] There are about 135 total landfills identified by NJDEP in the SJTPO region. Most of these are less than 30 acres in size and ceased operations before 1990. Any remaining methane emissions would therefore be considered fairly small.

[21] CH_4 Emission Factor: Roe et al. 2004. *Estimating Ammonia Emissions from Anthropogenic Nonagricultural Sources*. Available at: http://www.epa.gov/ttnchie1/eiip/techreport/volume03/eiip_areasourcesnh3.pdf. N_2O Emission Factor: UNFCCC. 2005. "Approved Baseline Methodology AM0025; Avoided emissions from organic waste composting at landfill sites." Available at: http://cdm.unfccc.int/EB/021/eb21repan15.pdf.

Table 14
2010 SJTPO Landfill Data from NJDEP

County/ Municipality	Landfill	Controls[a]	Year Opened/ Closed	tCH_4 Generated	tCH_4 Emitted[b]
Atlantic/Egg Harbor Twp.	Atlantic Co. Util. Authority	EG	1997 - Present	10,959	2,466
Atlantic/Egg Harbor Twp.	Pinelands Park	Flare	~1950/1990	8,040	1,809
Atlantic/Atlantic City	Atlantic City	None	~1920/1975	1,333	1,200
Atlantic/Hammonton	Hammonton	None	~1944/1987	1,783	1,605
Cape May/Upper Twp. & Woodbine	Cape May Co.	Gas and EG	1983 - Present	11,610	2,612
Cape May/Woodbine	F&S	None	1971/1985	630	567
Cumberland/Deerfield Twp.	Cumberland Co.	EG	1985 - Present	12,905	2,904
Cumberland/Millville City	Millville City	None; PV	~1936/1983	886	798
Cumberland/Vineland City	Vineland City	None; PV	~1944/1987	2,749	2,474
Cumberland/Commercial Twp.	Commercial Twp.	None	~1944/1987	1,189	1,070
Cumberland/Upper Deerfield Twp.	Seabrook Farms	None	~1924/1977	115	103
Salem/Alloway Twp.	Salem Co.	Flare	1981 - Present	6,174	1,389
Salem/Salem City	Salem City	None; PV	~1946/1988	773	696
Salem/Pennsville & Carney's Point	DuPont A&B	None	1981 – Present	150	135
Salem/Pennsville	Pennsville	None	~1946/1988	387	348
Salem/Pilesgrove	Woodstown-Pilesgrove	None	~1946/1988	773	696
			Totals	60,456	20,872

[a] EG – electricity generation; PV – passive vents; Gas – direct use of landfill gas.

[b] For all sites with methane collection and control, NJDEP assumes 75% collection/control efficiency and 10% oxidation of methane through the soil cover.

Table 15
2010 SJTPO Composting Activity

County/Municipality	Feedstock Processed (metric tons)	Methane Emissions (tCH_4)	Nitrous Oxide Emissions (tN_2O)	Notes
Atlantic/ Egg Harbor Twp.	20,320	14.5	0.87	Clean wood; vegetative waste
Cape May/ Woodbine	14,303	10.2	0.62	Leaves; grass clippings; brush, tree branches/limbs; stumps; Christmas trees
Cumberland/ Bridgeton	59,449	43	2.6	Brush/tree parts; grass clippings; leaves; food waste
Salem/ Elmer	8,899	6.4	0.38	Brush/tree parts; grass clippings; leaves; food waste
Totals	**102,971**	**74.1**	**4.47**	

WASTEWATER TREATMENT

Consumption-based Emissions

For wastewater processing, CH_4 and N_2O emissions were estimated using the default methods from the EPA 2010 Draft Regional Guidance. These are population-based methods that employ the following emission factors: 3.20 kg CH_4/person/yr; 3.16 g N_2O/person/yr.[22] Municipal population data for 2010 were used to estimate non-summer seasonal emissions separate from those for the summer season.

For emissions from biosolids management, data were obtained from NJDEP on municipal-level biosolids management by mode.[23] The different management modes include incineration, beneficial use (typically land application), out of state disposal, landfill cover, and application to reed beds. The most prominent modes in the SJTPO region in 2010 were incineration and beneficial use. For beneficial use, the Team assumed that these were all land applied to crop lands within the county that the biosolids were generated in. These values then served as inputs to nitrogen application within the agriculture sector. Emissions for other biosolids management modes are presumed to be negligible for 2010.[24]

Atlantic City operates the only biosolids incinerator in the region and has indicated that also has handled incineration for other SJTPO counties in the past.[25] Emission factors for CH_4 and N_2O were taken from the Intergovernmental Panel on Climate Change (IPCC) Guidelines.[26] Emissions were then estimated at the county-level based on the amount of biosolids

[22] Note that more accurate GHG estimates could be derived if municipal-level data were obtained for the fraction of the population on septic systems. Then separate estimates would be made for households served by centralized systems versus septic systems.

[23] http://www.nj.gov/dep/dwq/pdf/2010_statewide_sewage_sludge_production.pdf.

[24] This includes 109 dry tons sent out of state for disposal and 2 dry tons applied to reed beds/other.

[25] B. Carlson, Atlantic County Utilities Authority, personal communication with S. Roe, CCS, April 7, 2014.

[26] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_5_Ch5_IOB.pdf.

incinerated. It isn't possible to determine how much wastewater biosolids is generated by the population of each municipality. This is because while the location of sewage treatment plants is known, the location of the populations served by each plant is not known (meaning a plant could provide service for some households in adjoining municipalities). Therefore, for the consumption-based emissions, the team allocated the county-level emissions based on population. Separate estimates were made for non-summer seasonal and summer seasonal populations.

Direct Emissions

For the direct emission estimates, the county-level wastewater treatment processing emissions described above were allocated to each municipality based on the flows of wastewater through treatment plants in each municipality. Data on plant level flows were provided by NJDEP.[27] For biosolids management, all incineration regional emissions were allocated to Atlantic City, since this is the only incinerator in the region, and as indicated above, sources indicated that this facility also serves the other counties. As mentioned above, land applied biosolids emissions were allocated to the agriculture sector and are assumed to supply a portion of the nitrogen requirements for crop production in the region.

Land Use, Land Use Change, and Forestry (LULUCF)

FORESTED LAND USE

Forested area for each municipality was estimated using the 2002 and 2007 NJDEP acreage estimates. The total forest land for 2010 and amount of forested land that was lost or gained from 2009 to 2010 for each municipality was estimated using the percent annual change from 2002 to 2007. The detailed land use categories used in the NJDEP data were classified as forest, forested wetland, non-forested wetland, or tidal marsh with input from NJDEP.[28] **Table 16** presents a county-level summary of the acreages for forests, forested wetlands, and tidal marshes, used in the forest sequestration estimates. Also presented is the estimated loss of forestland, which was used to estimate carbon losses due to land use change.

Table 16
Estimated 2010 Forest and Wetland Acreages for South Jersey Counties

	Estimated 2010 Acreage			Estimated 2009-2010 change in acres (forest and forested wetlands only)
County	Forest	Forested Wetland	Tidal Marsh	
Atlantic County	133,871	74,266	39,680	-875
Cape May County	33,215	35,588	40,294	-338
Cumberland County	95,995	42,819	38,712	-684
Salem County	33,460	28,906	10,786	-262
SJTPO	**296,542**	**181,579**	**129,473**	**-2,159**

[27] S. Jenks, NJDEP email communication with S. Roe, CCS, November 7, 2013; M. Dillon, NJDEP, email communication with S. Roe, CCS, February 21, 2014.

[28] Craig Courtros, NJDEP; personal communication with H. Lindquist, CCS, March 23, 2014.

Initial draft estimates of the changes in forest density were prepared using forest carbon data from the U.S. Forest Service (USFS) Forest Inventory and Analysis (FIA) EVALIDator tool.[29] County-level forest densities for 2004-2008 and 2008-2012 were calculated using the forest carbon and forest acreage values from EVALIDator. However, the FIA data show that the forest carbon density in the SJTPO counties to be relatively stable. Differences in carbon density between time periods were significantly less than the sampling error for the carbon values from FIA surveys.[30] Therefore, an alternative method for estimating sequestration rates was developed.

Sequestration rates were still estimated from FIA forest carbon data obtained from the EVALIDator tool. Estimates of total forest carbon (including all 5 forest carbon pools) and forest area by physiographic class and stand[31] age were obtained for New Jersey, Maryland, and Delaware. Data for two neighboring states were used in addition to New Jersey to provide a larger sample size (and lower sampling error). The physiographic classes were divided into two classifications[32]: forest or forested wetlands, and the overall carbon densities for each age range were calculated for each of these two forest types. The annual change in carbon density was then estimated by taking the difference between carbon densities for each 20-year age range and dividing by 20 years. The density change values were weighted by the area of forestland in each age range present in SJTPO counties, and summed to produce the estimated sequestration rates of 0.35 metric tons C per acre per year for forests and 0.45 metric tons C per acre per year for forested wetlands. These values are shown in **Table 17**.

For Tidal Marshes, a sequestration of 0.97 metric tons C per acre per year was used. This value, taken from a national study, was used in the state GHG inventory.[33] The carbon sequestration rates were applied to the 2010 acreage values for forests, forested wetlands, and tidal marshes for each municipality.

A recent Rutgers study indicates that the Inner and Outer coastal plain forests, which cover South Jersey, are close to their peak in terms of forest carbon density.[34] As shown in **Figure 5**, developed from the carbon density data in **Table 17**, after a forest stand reaches peak density, the amount of carbon stored starts to decline as the stand matures and thins. Therefore, the potential for South Jersey forests to continue to sequester carbon at current rates is likely to decline in the near future (65% of the region's forest are over 60 years old).

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[29] Miles, P.D. Mon Mar 17 18:08:11 CDT 2014. Forest Inventory EVALIDator web-application version 1.5.1.06. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. [Available only on internet: http://apps.fs.fed.us/Evalidator/evalidator.jsp]

[30] Christopher Woodall, USDA Forest Service, personal communication with H. Lindquist, CCS; March 17, 2014; COLE data is a reasonable source for estimating changes in forest density, if the differences in density between time periods are greater than the data sampling error.

[31] A forest stand is a contiguous community of trees sufficiently uniform in composition, structure, age and size class distribution, spatial arrangement, site quality, condition, or location to distinguish it from adjacent communities.

[32] The physiographic classes assigned to forests include dry tops, dry slopes, deep sands, flatwoods, and rolling uplands. The classes assigned to wetlands include moist slopes and coves, narrow floodplains/bottomlands, broad floodplains/bottomlands, other mesic, swamps/bogs, small drains, and other hydric.

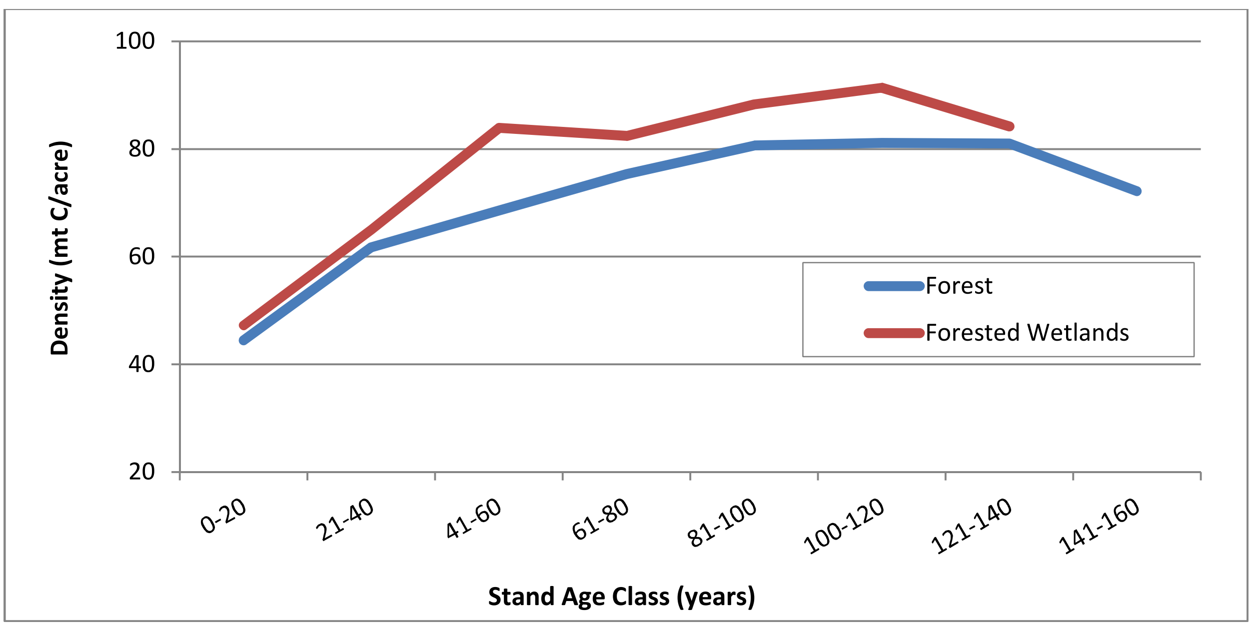
[33] Jorge Reyes, NJDEP; Midwest Regional Carbon Sequestration Partnership Phase II, Assessment of Terrestrial Sequestration Potential in New Jersey. Prepared for Battelle & The U.S. Department of Energy, NETL; April 29, 2011, http://www.mrcsp.org/userdata/phase_II_reports/mrcsp_njdep_tsfinalrptweb.pdf.

[34] Lathrop, G. et al., *Assessing the Potential for New Jersey Forests to Sequester Carbon and Contribute to Greenhouse Gas Emissions Avoidance*; Rutgers, NJDEP, March 2011, http://crssa.rutgers.edu/projects/carbon/RU_Forest_Carbon_final.pdf.

Table 17
Development of Sequestration Rates for SJTPO Forests

Stand Age (years)	Carbon Density (metric tons/acre)		Change in Density per year (mt/acre/year)		% of Total Forest Land in SJTPO Counties		Sequestration Rates (mt/acre/year)	
	Forest	Forested Wetlands	Forest	Forested Wetlands	Forest	Forested Wetlands	Forest	Forested Wetlands
0-20	44.5	47.3	2.22	2.36	0.01	0.12	0.020	0.282
21-40	61.7	65.0	0.86	0.89	0.08	0.04	0.067	0.032
41-60	68.6	83.9	0.34	0.94	0.25	0.13	0.086	0.118
61-80	75.4	82.4	0.34	-0.07	0.34	0.36	0.116	-0.026
81-100	80.6	88.3	0.26	0.29	0.22	0.16	0.058	0.048
100-120	81.1	91.4	0.02	0.15	0.07	0.13	0.002	0.020
121-140	81.0	84.2	-0.01	-0.36	0.02	0.07	0.000	-0.025
141-160	72.1	NA	-0.44	NA	0.00	0.00	0.000	0.000
Total					**1.00**	**1.00**	**0.35**	**0.45**

Figure 5
Carbon Density by Stand Age for Forests and Forested Wetlands



We also investigated whether data existed to quantify the net carbon flux in non-forested wetlands based on recent research in NJ. While wetlands are known to store large amounts of carbon (and to release large amounts of CO_2 when drained), net GHG emissions have always been highly uncertain due to methane emissions and the extent to which these counter-act carbon sequestration. New Jersey researchers provided a recent study on CH_4 flux; however, currently available information is still insufficient to model net GHG emissions.[35] It should be noted that CH_4 emissions still remain a sizable uncertainty (data gap) in developing net GHG impacts for forested wetlands, as well. Future assessment of net GHG emissions for non-forested wetlands will require information on methane emissions as well as annual carbon accumulation and detailed estimates of land use change (e.g. drainage and conversion of wetland acreage to some other land use).

In forested areas, to estimate carbon flux resulting from land use change, the estimated change in municipal forested land in acres was multiplied by the forest density (metric tons carbon per acre), obtained from the US Forest Service (USFS) and National Council for Air and Stream Improvement (NCASI) Carbon On-Line Estimator (COLE).[36] The carbon density values in COLE, shown in **Table 18**, are based on FIA measurements taken from 2008-2012. All above-ground carbon was assumed to be lost due to land use change. No change was assumed for below ground carbon storage, since it is not known to what extent these pools would be affected by the change to a new land use.

Table 18
Above Ground Carbon Density from COLE

County	Metric tons per hectare	Metric tons per acre
Atlantic County	72.2	29.2
Cape May County	80.5	32.6
Cumberland County	79.3	32.1
Salem County	120	48.5

Wood harvests for 2010 were estimated based on the trend in the 3 years of available data in the TPO database. The wood harvests volumes (thousand cubic feet) were converted to metric tons of carbon using specific gravity values[37] and the assumption that 50% of the dry weight of wood is carbon. The wood harvest carbon was allocated to municipalities based on the 2010 forest area estimated from the NJDEP land use data.

URBAN FORESTS

The area of urban forest was estimated by multiplying the total urban area for each municipality by the urban tree canopy percentage. The urban forest area was then applied to a region-specific urban forest carbon sequestration rate. The region-specific urban forest carbon sequestration rate was estimated by averaging sequestration rates for cities in New Jersey and

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[35] Karina Schäfer, Rutgers University personal communication with S. Roe, CCS, January 23, 2014. Recent paper on CH_4 fluxes in wetlands and marshes: "M. C. Reid, R. Tripathee, K. V. R. Schäfer, and P. R. Jaffé ,*Tidal marsh methane dynamics*: Difference in seasonal lags in emissions driven by storage in vegetated versus unvegetated sediments", *Journal of Geophysical Research: Biogeosciences,* VOL. 118, 1802–1813, 2013. More on CH_4 dynamics on wetlands is expected to be published later this year.

[36] Van Deusen, P., and L.S. Heath. YEAR. COLE web applications suite. NCASI and USDA Forest Service, Northern Research Station. Available only on internet: http://www.ncasi2.org/COLE/ (Accessed March, 2014)

[37] Miles, D, W. Smith. *Specific Gravity and Other Properties of Wood and Bark for 156 Tree Species Found in North America*, USDA Forest Service, http://www.nrs.fs.fed.us/pubs/rn/rn_nrs38.pdf

surrounding states from a recent study of urban forest sequestration.[38] These sequestration rates are shown in **Table 19.**

Table 19
Urban Tree Carbon Sequestration Rates

City/State	kg carbon/m²/yr
Freehold, NJ	0.314
Jersey City, NJ	0.183
Moorestown, NJ	0.320
Woodbridge, NJ	0.285
Baltimore, MD	0.282
Boston, MA	0.231
Hartford, CT	0.329
New York, NY	0.230
Philadelphia, PA	0.206
Roanoke, VA	0.399
Scranton, PA	0.399
Washington, DC	0.263
Average	**0.287**

Municipal-level non-farm fertilizer application was estimated by allocating state-level estimates from EPA SIT using municipal-level USFS data on urban area available green space (non-tree canopy green space).[39]

NONROAD FUEL COMBUSTION

Emission factors from the EPA NONROAD model were used along with the NONROAD fuel consumption data to develop GHG emission estimates. County-level fuel consumption and emissions were allocated to each municipality based on 2010 forest area estimated from the NJDEP land use data.

Agriculture

CROP PRODUCTION.

As discussed in the Inventory Protocol, the team was interested in preparing emissions estimates using as much bottom-up data as possible, rather than allocating state-level emissions. Ideally, bottom-up data would begin with municipal-level estimates of livestock populations and cultivated crop area.

The NJ Department of Agriculture & Natural Resources (NJDANR) provided a valuable dataset from the State's Farmland Assessment Program (FAP) that includes municipal-level data on

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[38] Nowak, D., et al. "Carbon storage and sequestration by trees in urban and community areas of the United States". *Environmental Pollution* 178 (2013) 229-236. http://www.fs.fed.us/nrs/pubs/jrnl/2013/nrs_2013_nowak_001.pdf.

[39] Urban Forest Data for New Jersey, U.S. Department of Agriculture Forest Service, State Summary Report, Table 5. Tree canopy and impervious surface cover characteristics by community. http://www.nrs.fs.fed.us/data/urban/state/?state=NJ.

crop production and livestock management for operations that qualify for the program.[40] Since potentially not all agricultural activity might be covered in the FAP data, comparisons were first made to NJDEP land use data to assess the coverage. **Tables 20 through 23** provide these comparisons for each county.

Table 20
Atlantic County Crop Area

Atlantic County Ag Land Use Data Comparison	2007 NJDEP Land Use	2010 Farm Land Assesment Data	Difference
Total Ag Area (Acres)	**23,422**	**25,430**	**(2,008)**
CROPLAND AND PASTURELAND	14,104	8,183	5,921
ORCHARDS/VINEYARDS/ NURSERIES/HORTICULTURAL AREAS	7,170	16,819	(9,649)
OTHER AGRICULTURE	2,148	428	1,720

Table 21
Cape May County Crop Area

Cape May County Ag Land Use Data Comparison	2007 NJDEP Land Use	2010 Farm Land Assesment Data	Difference
Total Ag Land (Acres)	**5,822**	**3,905**	**1,917**
CROPLAND AND PASTURELAND	4,099	1,823	2,276
ORCHARDS/VINEYARDS/ NURSERIES/HORTICULTURAL AREAS	1,098	1,449	(351)
OTHER AGRICULTURE	624	633	(9)

Table 22
Cumberland County Crop Area

Cumberland County Ag Land Use Data Comparison	2007 NJDEP Land Use	2010 Farm Land Assesment Data	Difference
Total Ag Land (Acres)	**59,147**	**55,243**	**3,904**
CROPLAND AND PASTURELAND	43,162	37,969	5,193
ORCHARDS/VINEYARDS/ NURSERIES/HORTICULTURAL AREAS	13,575	13,869	-294
OTHER AGRICULTURE	2,409	3,405	-996

Table 23
Salem County Crop Area

Salem County Ag Land Use Data Comparison	2007 NJDEP Land Use	2010 Farm Land Assesment Data	Difference
Total Ag Land (Acres)	**79,532**	**77,729**	**-1,803**
CROPLAND AND PASTURELAND	72,973	71,577	-1,396
ORCHARDS/VINEYARDS/ NURSERIES/HORTICULTURAL AREAS	3,678	5,273	1,595
OTHER AGRICULTURE	2,881	879	-2,002

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[40] M. Purcell, NJDANR, personal communication with S. Roe, CCS, February 10, 2014 and subsequent database on compact disc. The farm must be 5 acres or greater in size and generate gross sales of products from the land of at least $500/year for the first 5 acres + $5 per acre ($.50 for woodland/wetland) for each additional acre.

Unfortunately, 2010 land use data from NJDEP won't be available until later this year, so the comparisons are made against 2007 data. With the exception of Cape May County, there is reasonable agreement between the two data sets (<10% difference in overall agricultural area). It isn't possible to determine whether the differences are related to actual changes in area between 2007 and 2010 (FAP data were not available for 2007), differences in land use classification, or some other reason. Given the value of the municipal-level FAP data, these were selected for primary inputs into estimating GHG emissions.

Emission factors were developed based on the methods used in the EPA's State Inventory Tool (SIT) – Agriculture Module. Use of these procedures retains consistency with the NJ state inventory, as well as other regional inventory efforts. Sources addressed are N_2O emissions that occur as a result of nitrogen (N) inputs to crop soils:

- Crop residues
- Nitrogen fixing crops
- Application of synthetic fertilizers
- Application of organic fertilizers: including manure and sewage treatment plant (STP) biosolids

Default data for New Jersey within SIT were used to develop N inputs per acre for each of the crops grown in the SJTPO region to address crop residues and N-fixing crops. For fertilizer additions (both synthetic and organic), the first step was to develop crop N requirements based on literature sources (most came from NJ Agricultural Extension Fact Sheets; citations are provided in the Agriculture workbook). In each case, the mid-point of any specified range was selected to represent the additional N requirement (i.e., the incremental amount above that provided by crop residues and N-fixing crops) as shown in **Table 24**. Total manure N was calculated for each county based on SIT values for total Kjeldahl-N produced for each animal. The manure N generated in each county was assumed to be applied in that county. Biosolids N was taken from NJDEP county summaries.[41] Class A and B biosolids were assumed to be applied to crop fields.[42] Total organic N available was then calculated as the sum of manure N and biosolids N. From these estimates of total organic N available, the regional fraction of organic N fertilizer applied (15%) versus synthetic fertilizer N applied (85%) was determined.[43]

[41] http://www.nj.gov/dep/dwq/pdf/2010_statewide_sewage_sludge_production.pdf.

[42] This could be over-estimated, since biosolids could be beneficially applied to other lands, e.g. road medians.

[43] This organic vs. synthetic split was calculated at the regional level, since for Cape May County, the available organic N exceeded the overall N requirement for the County.

Table 24
Crop Nitrogen Requirements

Crop	Nitrogen Application Requirements		Notes
Alfalfa	0.000	t N/Ha	0 is assumed; due to N fixation
Barley	0.073	t N/Ha	65 lb N/acre
Corn	0.140	t N/Ha	125 lb N/acre
Oats	0.062	t N/Ha	55 lb N/acre
Rye	0.062	t N/Ha	55 lb N/acre
Sorghum	0.101	t N/Ha	90 lb N/acre:
Soybeans	0.000	t N/Ha	0 is assumed; due to N fixation
Wheat	0.073	t N/Ha	65 lb N/acre
Lima Beans	0.084	t N/Ha	75 lb N/acre
Snap Beans	0.067	t N/Ha	60 lb N/acre
Dry Edible Peas	0.067	t N/Ha	61 lb N/acre
All Other Vegetables	0.120	t N/Ha	107 lb N/acre; average of 7 vegetables most grown in SJTPO (other than those above)

Sources: NJ Ag Extension Fact Sheets, except where other sources are noted; mid-points of ranges specified were selected.
[a] http://www.hort.purdue.edu/newcrop/afcm/sorghum.html

Other sources of GHG emissions for crop production that were not addressed, include:

- Crop residue burning: NJ has a ban on open burning and none of this is practiced in the State;[44]
- Liming of soils: limestone and dolomite are applied to acidic soils; however, bottom-up information as to where, crop type, and amounts were not identified. It should be noted that the IP sector has estimates for CO_2 emissions from limestone/dolomite use that include all state-level consumption of these materials (both for industrial processes and agricultural use). However, information from local agricultural experts would be needed in order to break-out agriculture sector use from industrial use.
- Urea application: while the N_2O emissions from N application are addressed, the decomposition of urea also emits CO_2. These emissions could be estimated with some local information on the fraction of total synthetic N supplied by urea fertilizers.
- Land use/cover change: terrestrial carbon gains/losses occur during shifts from one land cover to another (e.g., woodlands to agriculture), or when crop cultivation practices change (e.g., change from a pasture to annual crops). Very detailed land use and management change data would be needed to assess these net carbon fluxes, along with above and below-ground carbon density data. Currently these data are lacking, not only at the SJTPO regional level, but for the U.S. generally.

[44] D. Kluchinski, Assistant Director of Extension, Department of Agricultural and Resource Management Agents, Rutgers Cooperative Extension, personal communication with S. Roe, 3/12/2014.

LIVESTOCK MANAGEMENT.

For livestock, animal populations are the primary input for estimating emissions. A similar comparison as above for crop acreage was attempted using the 2010 FAP livestock data and US Department of Agriculture National Agricultural Statistics Service (USDA NASS) livestock populations. However, the same problem was encountered in that the most recent USDA NASS data are for 2007. In terms of GHG emissions contribution for the livestock management subsector, the most important livestock types are cattle, swine, and poultry. Poultry operations become important in areas where very large operations are present (e.g. flocks of 10's of thousands or more).

The comparisons are summarized in **Table 25**. Reasonable agreement was found in most cases, given the difference in the years covered, and the fact that population estimates can vary considerably depending on the time of year that the data are collected. Key exceptions were for the number of layers (egg chickens) in the FAP database for Cumberland County as compared with the USDA data (in this case, the USDA estimate for layers is taken from the previous 2002 census, since 2007 data were withheld); poultry estimates in Salem County (USDA withheld data for layers in both 2002 and 2007); and swine estimates in Atlantic County. On balance, there was no reason to believe that the FAP data did not provide reasonable coverage of livestock populations in the SJTPO region. In addition to cattle, swine and poultry, FAP population estimates for sheep, goats, and horses were also used to generate GHG emission estimates.

Table 25
SJTPO Livestock Data

County	Cattle		Swine		Poultry	
	2007 USDA	2010 FAP	2007 USDA	2010 FAP	2007 USDA	2010 FAP
Atlantic	167	158	285	33	2,290	1,294
Cape May	60	56	1,066	1,293	1,219	1,056
Cumberland	1,307	877	1,315	794	2,677	42,569
Salem	8,000	6,277	204	398	684	4,251
Notes: poultry include chickens (broilers, layers and pullets) and turkeys.						

These emissions address CH_4 from enteric fermentation and CH_4 & N_2O from manure management (prior to field application). As with the crop production subsector, a set of emission factors were derived from the EPA SIT Agriculture Module to apply to the municipal-level livestock populations. Emission factors are provided in the Agriculture workbook for the project. An uncertainty encountered by the team in applying these emission factors concerns the fraction of beef cattle located on feedlots. The State has relatively few feedlot cattle, and we were unable to find any information on feedlots located in the SJTPO region. As a result, the emission estimates presume that all beef cattle are managed on pasture/range, rather than on feedlots, which results in much lower manure management emissions.

NONROAD FUEL COMBUSTION.

County-level fuel consumption estimates from the EPA Nonroad Model served as the primary input to these emission estimates.

Emission factors from the EPA NONROAD model were used along with the NONROAD fuel consumption data to develop GHG emission estimates. County-level fuel consumption and emissions were allocated to each municipality based on harvested cropland acres from the

2010 FAP data. In future work, more accuracy could be achieved if data can be identified on the fuel use intensity for different crop types (e.g., gallons diesel/acre). In that case, the nonroad fuel consumption estimates could be derived from the bottom-up, like the crop production and livestock management emission estimates. ✷

Appendix D

Inventory Protocol

Prepared for

SJTPO Region Greenhouse Gas Emissions Inventory

Protocol

January 31, 2014
(revised April 2014)

Prepared by

with

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TABLE OF CONTENTS

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ACRONYMS

ACRP	Airport Cooperative Research Program
BTU	British thermal unit
CCS	Center for Climate Strategies
CH_4	Methane
CMAQ	Congestion Mitigation and Air Quality
CMV	Commercial marine vessel
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
COLE	Carbon On-Line Estimator
DBE	Disadvantaged Business Enterprise
DOE	U.S. Department of Energy
DOT	Department of Transportation
DVRPC	Delaware Valley Regional Planning Commission
EDMS	Emissions and Dispersion Modeling System
eGRID	Emissions & Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
FIA	USFS Forest Inventory & Analysis program
GHG	Greenhouse gas
GIS	Geographic information systems
GREET	GHG, Regulated Emissions, and Energy use in Transportation (model)
GWP	Global warming potential
GWRA	*Global Warming Response Act*
HCFC	Hydrochlorofluorocarbon
HFCs	Hydrofluorocarbons
I&F	Inventory & Forecast
IPCC	Intergovernmental Panel on Climate Change
LandGEM	EPA's Landfill Gas Emissions Model
$MMtCO_2e$	Million metric tons of carbon dioxide equivalent
MOBILE6.2	EPA's Motor Vehicle Emission Factor Model
MOVES	EPA's Motor Vehicle Emission Simulator
MPO	Metropolitan Planning Organization
MSW	Municipal solid waste
N_2O	Nitrous oxide
NAICS	North American Industry Classification System
NCASI	National Council for Air and Stream Improvement
NJDEP	New Jersey Department of Environmental Protection
NJDOT	New Jersey Department of Transportation
NYSDOT	New York State Department of Transportation
NYSERDA	New York State Energy Research and Development Authority
ODS	Ozone depleting substances

PFCs	Perfluorocarbons
RCI	Residential, commercial, and industrial
RTP	Regional Transportation Plan
SF_6	Sulfur hexafluoride
SIP	State Implementation Plan
SIT	EPA's State Inventory Tool
SJTPO	South Jersey Transportation Planning Organization
TAC	Technical Advisory Committee
USFS	U.S. Forest Service
VMT	Vehicle miles traveled
WARM	Waste Reduction Model
WMA	Watershed management area

GLOSSARY OF TECHNICAL TERMS AS USED IN THE PROTOCOL

Carbon sequestration (agriculture and forestry): the process through which carbon dioxide (CO_2) from the atmosphere is absorbed by trees, plants and crops through photosynthesis, and stored as carbon in biomass (tree trunks, branches, foliage, and roots) and soils.

Carbon dioxide equivalent (CO_2e): a sum that includes the quantity of each greenhouse gas (GHG) weighted by a factor of its effectiveness as a GHG, using CO_2 as a reference. This is achieved by multiplying the quantity of each GHG by a factor called global warming potential (GWP), specific to each GHG, where the GWP for CO_2 is 1.

Combustion emissions: emissions resulting from fossil fuel consumption.

Consumption-based accounting: considers all the emissions that result from energy consumed, waste generated, and transportation trips generated in an area, even if the emissions occur outside of the boundaries of the geographic area considered. Consumption-based accounting is useful to policy makers wishing to reduce emissions by affecting activities they have control over.

Direct emissions: emissions occurring at the emission source; for example exhaust from the vehicle tailpipe or power plant stack.

Emission factor: an indication of the average amount of a pollutant emitted into the atmosphere from a specific activity per amount of fuel used, industrial product manufactured, electricity produced, miles driven, or other usage measure.

Energy-cycle emissions: GHG emissions covering the fuel-cycle (see below), but also addressing electricity consumption (*i.e.*, the fuel-cycle emissions of primary fuels used in producing electricity). Energy-cycle emissions are also referred to as “embedded emissions”.

Enteric fermentation: CH_4-generating process that takes place in the digestive systems of ruminant animals. Most of the CH_4 byproduct is belched by the animal; however, a small percentage is also produced in the large intestine and passed out as gas.

Fuel-cycle emissions: GHG emissions associated with the extraction, transport, processing, distribution, and usage of fuels.

Global Warming Potential (GWP): a weighing factor indicating the effectiveness of a specific GHG in contributing to global warming, as compared with CO_2. GWPs account for the lifetime and the influence on the global energy balance of each chemical over a period of 100 years (*e.g.*, CO_2 has a much shorter atmospheric lifetime than SF_6, and, therefore, has a much lower GWP).

Lifecycle emissions: involves a cradle-to-grave view of GHG emissions associated with an activity (*e.g.*, driving) or use of product (*e.g.*, plastic bottle). Such an assessment includes the extraction and transport of raw materials, manufacture, packaging, freight, usage, and finally disposal.

Load factor: an indication of the power that an engine is operating at on average, as compared with the maximum (rated) power that the engine is designed to produce. Engines typically operate at a variety of speeds and loads, and operation at rated power for extended periods is rare. To take into account the operation of the engine at less than maximum power (partial load), as well as transient operation, a load factor is developed to indicate the average proportion of rated power used.

Nonattainment area: an area defined by EPA as in exceedance of the National Ambient Air Quality Standards, or contributing to air pollution in a nearby area that fails to meet standards, as defined by the Clean Air Act.

ODS substitutes: chemicals (primarily hydrofluorocarbons [HFCs] and perfluorocarbons [PFCs]) intended to replace substances that deplete the ozone layer. Ozone depleting substances (ODS) are being phased out, in accordance with the Montreal Protocol. However ODS substitutes are a concern due to their role as GHGs.

Process emissions: GHG emissions resulting from chemical reactions needed to manufacture certain products. For example, in cement production, limestone is heated to a high temperature to start a chemical reaction that makes lime. The byproduct of that chemical reaction is CO_2, a GHG.

Renewable energy: energy from sources that are perpetual or that are replenished more quickly than they are used up. Renewable energy includes solar, wind, wave, tidal, geothermal, landfill gas, anaerobic digestion, and certain other forms of biomass and hydro power.

Ruminant animals: animals having four stomachs, including cows, sheep, and goats.

Ton-mile: a unit of freight transportation equivalent to a ton of freight moved one mile.

Upstream emissions: Emissions that occur before a product is used for its intended purpose; for example drilling, refining, and transportation of oil to be used as vehicle fuel; emissions during manufacturing of a product (metal can, glass bottle, steel beam, etc.). This term is sometimes applied to energy-cycle emissions or lifecycle emissions as defined above.

INTRODUCTION

The SJTPO region consists of four New Jersey counties—Atlantic, Cape May, Cumberland, and Salem—and 68 municipalities. There is broad scientific consensus that human-caused greenhouse gas (GHG) emissions are impacting the earth's climate, and that increasing atmospheric GHG concentrations will result in very significant adverse global, regional, and local environmental impacts.[1] Projected effects of climate change include sea level rise, increased frequency and severity of storms, increased storm surge, and temperature rise, all of which could affect the region and require consideration in planning for the future. The GHG inventory for the SJTPO region, developed under this protocol, will be a basis for local and regional efforts to reduce emissions, and this protocol is designed to facilitate that future use of the inventory data.

Efforts to quantify and reduce GHG emissions and to plan for resilience to climate change have been ongoing at the State, regional, and local levels. New Jersey's Global Warming Response Act (GWRA) calls for a reduction in GHG emissions to 1990 levels by 2020, approximately a 20% reduction below estimated 2020 business-as-usual emissions, followed by a further reduction of emissions to 80% below 2006 levels by 2050. Some of the emission reduction programs within the SJTPO counties include the development of the landfill gas-to-energy plant in Deerfield Township, the Pilesgrove Township solar farm, as well as numerous smaller scale solar panel installations facilitated by New Jersey's Solar Energy Advancement and Fair Competition Act, the anti-idling education campaign undertaken by Cape May City, the conversion of coal and oil burning plants to natural gas, and many others. The region's resources make many areas a summer destination, and therefore this inventory will need to address GHG emissions associated with the seasonal population.

This region-wide GHG inventory is part of a larger, long-range climate change initiative at SJTPO, which will include a forecast of the inventory, and may include mitigation and adaptation research and planning, undertaking an inventory of climate vulnerable facilities within the region, and the creation of a framework for incorporating climate impacts into evaluation criteria for programs and project selection and prioritization. The SJTPO inventory will be consistent with similar efforts in the neighboring Metropolitan Planning Organizations (MPOs)—North Jersey Transportation Planning Authority (NJTPA) and Delaware Valley Regional Planning Commission (DVRPC), as well as available guidance for developing regional GHG inventories (*e.g.*, the U.S. Environmental Protection Agency's (EPA's) Draft Regional Guidance).

The inventory will serve as the basis for formulating and evaluating GHG reduction policies and action plans, at the regional, county, and municipal levels. This protocol has been designed to not only produce a quality inventory, but to also set the foundation and begin to define the approach for those future efforts by addressing emissions in a format most useful for that future work and specific to SJTPO. The inventory will present GHG emissions from fuel combustion and electricity consumption in the residential, commercial, and industrial sectors; on-road, non-road, aviation, marine, and rail transportation sectors; industrial processes; agricultural sources, including soils, manure, and livestock; solid waste and wastewater management; and land use, land use change, and forestry. Emissions will be analyzed for a baseline year, 2010, reported for the entire SJTPO region and by county and municipality to the extent practicable, and a methodology for forecasting to future years will be developed.

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[1] Intergovernmental Panel on Climate Change, Climate Change 2007: Synthesis Report, Summary for Policymakers, Fourth Assessment Report, November 2007.

REVIEW OF OTHER GHG INVENTORY EFFORTS

A literature review of GHG inventory and forecast (I&F) projects was conducted to inform the approaches to be adopted for the SJTPO GHG inventory. I&F projects at the municipal, regional, and state levels were reviewed. The literature review summary presented below includes examples of the many municipal GHG I&F projects available in the literature, including two MPOs in New Jersey and the state of New Jersey's inventory and forecast. A summary of this literature review is presented below and implications for this project are presented.

Municipal GHG Inventories and Forecasts

A large number of cities have developed GHG I&Fs as part of their commitments under the Cities for Climate Protection Campaign headed up by the International Council on Local Environmental Initiatives (ICLEI). Two examples are cited in the footnote below.[2] The common framework for these inventories is as follows:

- *Two separate inventories prepared to serve differing objectives:*
    - a community-scale inventory representing direct GHG emissions and indirect GHG emissions (electricity or steam consumption) occurring within the geographic boundaries of the municipality to inform community-based approaches to GHG mitigation; and
    - a municipal operations GHG inventory that provides emission estimates specific to the city's operation of buildings, vehicle fleets, and other sources of direct emissions (*e.g.*, landfills, wastewater treatment plants) and indirect emissions (from electricity or steam consumption). The city operations GHG estimates are inherently captured within the community-scale inventory. However, the municipal operations inventory provides details (sometimes for specific buildings/facilities) on energy consumption and emissions for use in developing approaches for GHG mitigation/energy savings/ other environmental goals specific to city-owned or operated sources.
- *Focus on direct GHG and indirect GHG from electricity consumption:* these inventories typically do not include lifecycle GHG estimates associated with fuels consumed or solid waste management. In some of the more recent inventories, however, lifecycle emissions for solid waste are being addressed, since the benefits of source reduction, reuse and recycling cannot be fully quantified without them. Also, varying the allocation of emissions to more closely represent the drivers of GHG emitting activities is not done in these inventories (*e.g.*, assigning mobile source emissions between an origin and destination; origin of the waste generator to assign solid waste management emissions, including landfill methane or product lifecycle GHG).

In addition to participation in the Cities for Climate Protection Campaign, some cities and counties have begun to publicly report their municipal operations inventories to voluntary registries like The Climate Registry[3] or its predecessor, the California Climate Action Registry.[4]

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[2] City of Somerville, MA, GHG Inventory & Forecast, Summer 2001, http://www.somervillema.gov/CoS_Content/documents/Somerville_GHG_Inventory%20Report.pdf;

City of New York, NY, GHG Inventory and Forecast, September, 2009, http://www.nyc.gov/html/planyc2030/downloads/pdf/greenhousegas_2009.pdf.

[3] http://www.theclimateregistry.org/.

[4] http://www.climateregistry.org/.

To develop these inventories, municipalities are required to use the general reporting protocol of the registry and the Local Government Operations Protocol (LGOP).[5] It is important to understand that the LGOP was designed to support organizational emissions reporting to a registry, not necessarily GHG mitigation planning for a community. Hence, unlike the approach mentioned above by cities using ICLEI's tools and procedures, the LGOP covers only the sources owned/operated by the city (*e.g.*, police, fire department, and other municipal fleets; city owned/leased buildings; city-owned/operated landfills or wastewater treatment plants, etc.). Since emissions for the community at-large are not included, these "entity-level" inventories cannot be used for regional planning purposes.

Consideration of appropriate boundaries and the applicable GHG accounting method for inventory and forecast development is critical to a successful mitigation planning project. A focus strictly on direct GHG emissions (*e.g.*, fuel consumption) and indirect GHG emissions from electricity consumption can lead to missed opportunities for GHG abatement. A municipal inventory based only on application of the LGOP would not capture emissions associated with solid waste management, except for landfills. Nor would the inventory capture emissions for wastewater treatment, unless the plant(s) was owned or operated by the City. Other sources/sinks, including urban forests, are also missed. As further exemplified in Section 2.0, solid waste management, in particular, produces significant GHG inventory contributions when considered on a lifecycle basis (inclusion of emissions from raw material extraction, production, and transport, in addition to end-of-life waste management).

MPOs: NJTPA, DVRPC, and MWCOG

NORTH JERSEY TRANSPORTATION PLANNING AUTHORITY (NJTPA)

NJTPA GHG Emissions Inventory was developed based on two accounting approaches: a direct approach, and a consumption-based approach. The direct approach presents emissions at the location from which they are emitted and allocated to the municipality where the activity occurs. Consumption-based emissions associate the emissions with the activity or consumption leading to those emissions and allocated to location where the consumption activity occurred. For the consumption-based method, emissions associated with energy, production, and transport, *i.e.*, energy-cycle emissions, were also included.

CO_2, CH_4, N_2O, SF_6, and HFCs and PFCs were included to the extent practicable. Emissions were allocated to the extent practicable down to the County and municipality level. Details by sector are provided below.

Electricity

The NJTPA Inventory for electricity sector was prepared using both the direct and consumption/energy-cycle approach method. The most significant GHG emitted is CO_2; CH_4 and N_2O are emitted as well.

For direct emissions, the NJDEP point source inventory was used in developing the emissions in the NJTPA region. EPA's Clean Air Markets Database (CAMD) and Emissions and Generation Resource Integrated Database (eGRID) information were used to determine facility locations and verify fuel type and consumption. The emission factors by fuel type were based on factors recommended by The Climate Registry.

[5] http://www.theclimateregistry.org/resources/protocols/local-government-operations-protocol/.

The consumption/energy-cycle inventory considered all emissions used in the NJTPA region including emissions from electricity generated within the region and the emissions imported into it. Inventory was developed using annual consumption data by geographic area (MCD or zip code) and customer type (residential, commercial, and industrial) provided by the major power suppliers within the region. Emission factors were taken from eGRID2007 database, for the RFCE subregion, adjusted to include emissions from energy lost through transmission and distribution (which is about 6.41%).

The energy-cycle emissions accounted for emissions associated with fossil fuel production and transport with consumed electricity. The electricity module of the GREET model was used to develop a factor which accounts for energy cycle emissions.

Fuel Use (Residential, Commercial, and Industrial)

Most commonly used fuel in Residential, Commercial, and Industrial (RCI) sector is pipeline natural gas. Other fuels include fuel oil, kerosene, liquefied petroleum gas and wood. Fuels used for non-road engines were also included.

The direct emissions and consumption-based emissions are the same for fuel use in the RCI sector. The inventory includes the CO_2, CH_4 and N_2O emitted through fuel combustion. Three utility companies provide pipeline natural gas to NJTPA region. Annual consumption of natural gas by zip code of the metered location or by MCD was obtained from the utility companies for each customer type (residential, commercial and industrial). Commercial and Industrial consumption of fuels other than natural gas was based on the NJDEP point source inventory and EIA data for New Jersey. Residential use of other fuels was based on 2000 Census data and the American Community Survey (2006-2008) using estimates of number of households in a geographic area using each fuel type. Emission factors by fuel type were taken from The Climate Registry General Reporting Protocol.

The energy-cycle emissions including upstream emissions for all fuels were developed using the GREET model.

Transportation

On-Road Vehicles

CO_2 is the main GHG emitted from the on-road vehicles, CH_4 and N_2O are also emitted and all three pollutants were included in the direct, consumption-based and energy-cycle inventory.

On-road direct emissions were estimated from all privately and publicly owned vehicles and commercial trucking. Link based vehicle miles of travel (VMT) by vehicle type was estimated using NJTPA's North Jersey Regional Transportation Model-Enhanced (NJTRM-E). Emission factors were estimated using EPA's Motor Vehicle Emission Simulator (MOVES 2010) model.

Consumption-based emissions were expressed at MCD level and not broken down by road type or vehicle type. The estimates were calculated for each origin-to-destination trip in the region and then allocated to the origins and destinations which produced those trips.

Energy-cycle emissions associated with the production, refining and transport of fuel were estimated using the GREET model.

The on-road transportation emissions inventory was updated in March 2013, as part of the NJTPA Regional Greenhouse Gas Mitigation Plan to incorporate updates to the vehicle miles traveled forecast and vehicle emission rates. The revised emissions were estimated using updated EPA MOVES 2010a model and new travel activity data from NJTPA's regional travel model (NJTRM-E) associated with the August 2011 amendments to the Plan 2035.

Aviation

Aircraft emission estimates were developed based on PANYNJ GHG emissions inventory for Newark and Teterboro airports, and EPA 2008 National Emissions Inventory (NEI) landing-takeoff (LTO) data for other applicable airports. Estimates were based on fuel combusted during an LTO cycle. Emissions were allocated to county level. Consumption-based emissions were not estimated.

The energy-cycle emissions were estimated using the GREET model and using diesel fuel as a surrogate.

Marine Vessels

Emissions from fuel used in marine vessels were estimated for both in the main engines for propulsion and in the secondary engines for electrical power onboard. The commercial marine vessels (CMV) activity data was obtained from the Port Authority sponsored study which evaluated vessel study in New York City Harbor. Energy-Cycle emissions were estimated using the GREET model.

Nonroad Engines

EPA's NONROAD model (NONROAD2008a) was used to calculate CO_2 emissions and fuel consumption for nonroad engines. Energy-Cycle emissions were estimated using the GREET model.

Rail

The GHGs CO_2, CH_4, and N_2O are primarily from combustion of diesel fuel and consumption of electricity. Direct emissions included only diesel emissions and consumption-based emissions included both diesel and electric. Energy-cycle emissions were also estimated. Detailed ridership, energy, and fuel consumption data was obtained to estimate emissions.

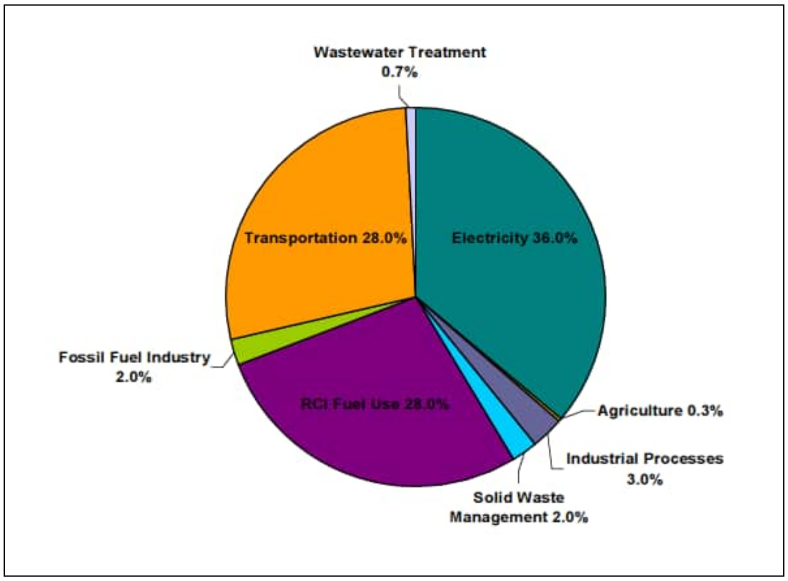
Other Sectors

Industrial process emissions included CO_2, CH_4, SF_6, HFCs, PFCs, and N_2O released from industrial activities such as nitric acid production, semiconductor manufacturing, consumption of limestone and soda ash, and electric power transmission and distribution. The consumption-based approach estimated emissions associated with cement and steel production. Crude oil refining emissions associated with the fossil fuel industry in the NJTPA region were also accounted for in the GHG inventory. Agriculture sector included emissions associated with production of crops, livestock management, and emissions from agricultural nonroad engines. Land use and Forestry sector included emissions from fuel combustion in nonroad engines for forestry sector and included net CO_2 flux from forested lands and urban forests. Solid Waste and Wastewater sector included emissions for the Municipal sector alone due to limited data availability on the industrial sector.

The 2006 GHG emissions were estimated at 86 million metric tons CO_2 equivalent ($MMtCO_2e$) using the direct GHG emissions approach for all sources except electricity. As summarized in **Figure A**, emissions from the electricity, RCI fuel use and transportation sector contribute to 92% of the greenhouse gas emissions in the region. Other sectors contribute small amounts.

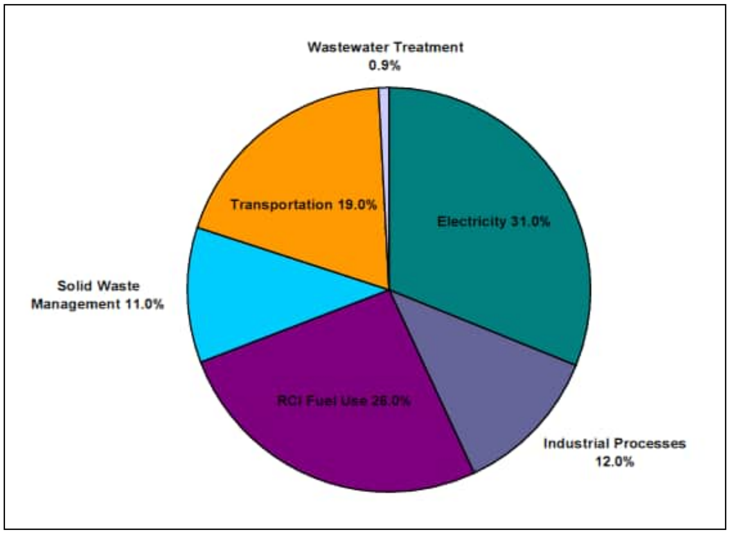
However, when considering emissions on a consumption basis and including the upstream GHG emissions in the energy-cycle, emissions in the NJTPA region exceeded 107 $MMtCO_2e$ in 2006. The three sectors mentioned earlier still accounted for majority (76%) of emissions, but emissions from other sectors (solid waste and industrial processes) became more prevalent as summarized in **Figure B.**

Figure A
2006 NJTPA Regional Inventory of Direct GHG Emissions
(86 MMtCO2e)



Source: NJTPA Regional Greenhouse Gas Emissions Inventory and Forecast, Final Report 2011

Figure B
2006 NJTPA Regional Inventory of
Consumption-Based + Energy-Cycle GHG Emissions
(107 MMtCO2e)



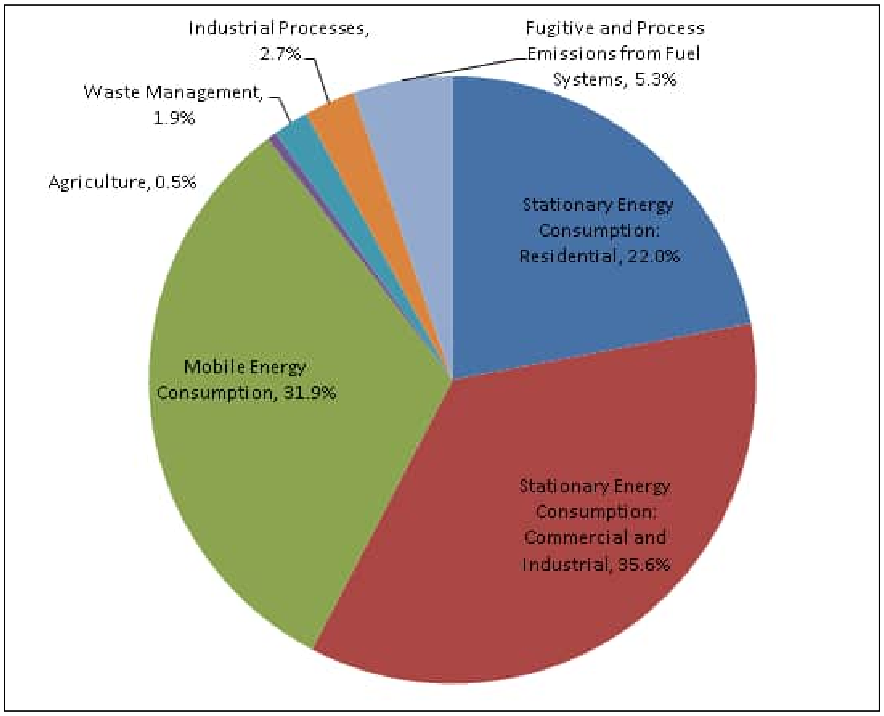
Source: NJTPA Regional Greenhouse Gas Emissions Inventory and Forecast, Final Report 2011

DELAWARE VALLEY REGIONAL PLANNING COMMISSION (DVRPC)

A GHG Inventory was developed by the Delaware Valley Regional Planning Commission (DVRPC) to support regional GHG mitigation planning.[6] Like the MWCOG inventory, the DVRPC regional inventory was developed largely on direct emissions basis, with the notable exceptions of the electricity sector, where the emissions are based on the GHG emissions associated with the power consumed in the region, and on-road transportation, where external trips were included, and through trips excluded. The DVRPC effort involved allocating emissions to the municipal and county level to make the data more meaningful to local planners. Some new methods were developed to carry out this allocation, notably, for on-road transportation, where DVRPC's travel demand model was employed to allocate emissions equally to the municipality of trip destination and trip origin. This provides useful information for planners to assess actions related to reducing trip generation, carpooling and mass transit. While lifecycle emissions were largely not the focus of this effort, some lifecycle components were included.

The GHG inventory was initially prepared for a baseline year of 2005, and emissions totaled 87.5 MMtCO2e. DVRPC released its 2010 GHG Emissions and Energy Use Inventory in late 2013.[7] The 2010 Inventory incorporates updated data as well as updated emission factors for electricity. In addition, a few other analytical improvements were made. The 2010 GHG estimates for DVRPC are summarized in **Figure C.** Emissions from the RCI (includes both fossil fuel and electricity consumption) and transportation sectors contribute 89.5% of the regional total.

Figure C
2010 Regional GHG Emissions for the DVRPC (81.6 MMtCO_2e)



Source: Delaware Valley Regional Planning Commission (DVRPC), 2013, http://www.dvrpc.org/energyclimate/inventory.htm

[6] DVRPC Regional Greenhouse Gas Inventory, March 2009, http://www.dvrpc.org/energyclimate/Inventory.htm.

[7] Regional Energy Use and Greenhouse Gas Inventory, http://www.dvrpc.org/EnergyClimate/Inventory.htm

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS

A GHG I&F was developed for the Metropolitan Washington Council of Governments' (MWCOG's) Climate Change Report[8] to support regional GHG mitigation planning. The MWCOG I&F uses 2005 as a baseline and forecasts out to 2050. With the exception of the electricity sector, all estimates were developed on a direct emissions accounting basis. Details by sector are provided below.

Electricity

GHG based on consumption data from local utilities appears to be limited to CO_2; CO_2 emission factors for local utilities taken from US EPA Clean Air Markets Division; imported power emission factors based on US Department of Energy, Energy Information Administration regional estimates;

Fuel Use (stationary sources, non-electrical generation)

These also appear to be limited to CO_2; cover natural gas, distillate oil and residual oil consumption; State-level consumption data allocated to the region based on population;

Transportation

Emission factors for on-road vehicles based on the EPA MOBILE6.2 model and local vehicle registration data; vehicle-miles traveled (VMT) data taken from long range transportation plans for the region; CO_2 emissions for aviation developed by allocating national aviation emissions to the region based on the region's total flight miles;

Other sectors

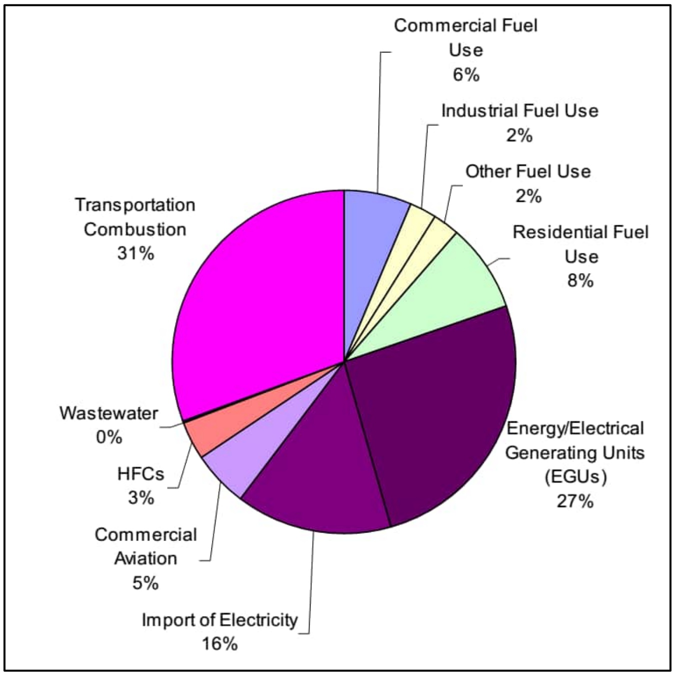
Details are limited in the appendix to the Climate Change Report cited above, however, landfill methane, wastewater treatment (*e.g.*, N_2O), and HFC use are covered.

Based on the available documentation, the MWCOG emissions were not allocated down below the regional level [*i.e.*, to counties or municipal civil divisions (MCDs)]. However, the 2005 base year inventory was developed using a variety of bottom-up and top-down data. For example, local utilities provided electricity consumption data that could be used to develop bottom-up estimates (*e.g.*, MCD-level). Also, the on-road transportation inventory was based on bottom-up activity data (vehicle-miles traveled or VMT) from regional transportation models and local registration data. On the other hand, non-electricity sector stationary source fuel consumption estimates were scaled based on population to the region from state-level estimates.

As shown in **Figure D** below, taken from the draft technical memorandum, 74% of the regional emissions were contributed by electricity consumption and transportation (on-road sources only). When emissions from fuel combustion in the residential, commercial, and industrial (RCI) sectors are added, this yields 92% of the estimated emissions. Notably, wastewater treatment and solid waste management are either zero or not shown in this figure; however, they are mentioned as sources in the Climate Change Report appendix.

[8] National Capital Region, Climate Change Report, prepared by the Climate Change Steering Committee for the MWCOG Board of Directors, adopted November 12, 2008, downloaded from: http://www.mwcog.org/uploads/pub-documents/zldXXg20081203113034.pdf. A draft I&F memo is located here: http://www.mwcog.org/uploads/committee-documents/tVZXWls20071126113742.pdf.

Figure D
2005 Regional GHG Emissions for the MWCOG
(74.2 MMtCO2e)



Source: MWCOG, DRAFT November 2007 *Draft Greenhouse Gas InventoryProjection for the Washington, DC-MD-VA Region*.

State of New Jersey GHG I&F

NJDEP's inventory[9] and forecast for the state is developed on a direct emissions accounting basis with a structure similar to US EPA's national inventory and used by other states.[10] The exception is for the electricity sector, where both direct ("production-basis" in the report) and consumption-based emissions are presented. NJDEP also recently issued an update to the 2008 I&F, which addresses revisions made to 2005-2007 GHG estimates in several sectors.[11]

Similar to the direct accounting-based municipal and regional inventories mentioned above, the state I&F shows only minor contributions from the waste management sector. However, these represent only the direct emissions associated with solid waste landfilling and wastewater treatment.

The state GHG inventory of emissions associated with electricity differs from the NJTPA and DVRPC methods in its accounting method: NJDEP assumes that NJ as a state, as a net importer of electricity, consumes all of the electricity produced in the state, and uses the emissions associated with those sources weighted added to the net import fraction of the

[9] NJDEP, *New Jersey Greenhouse Gas Inventory and Reference Case Projections, 1990-2020,* November 2008, http://www.nj.gov/globalwarming/home/documents/pdf/20081031inventory-report.pdf. Annual updates can be found at http://www.nj.gov/dep/sage/ce-ggi.html.

[10] EPA, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2011, EPA 430-R-13-001, April 12, 2013.

[11] NJDEP, *November 9, 2009 NJDEP GHG I&F Update*, http://www.nj.gov/dep/oce/inventory-05-06-07.pdf.

emissions from out-of-state sources as a basis for calculating electricity emission factors. The MPO analyses applied a weighted emission factor from the larger multi-state region for the electricity consumption, since the grid is shared across the region. In the case of the State, since it is focused on power production which it has some control over via regulation, this is appropriate. For the MPOs, which have no control over power production, it would be a very large effort to attempt to evaluate the specific generation profiles for each municipality and county and would not provide a benefit in terms of evaluating mitigation efforts. Therefore, SJTPO methodology will be consistent with method used by the other New Jersey MPOs.

SJTPO project team members have been involved in the development or validation of state-level inventories and forecasts for over 30 states/provinces in the US, Canada, and Mexico.[12] Each of these I&Fs have had a similar structure to the New Jersey I&F in that they are direct emissions based (with the exception of electricity consumption), and that they are designed to adhere to the structural conventions of the US and international requirements for inventorying national emissions (*i.e.*, based on Intergovernmental Panel on Climate Change (IPCC) requirements). More recent efforts, such as the state of Oregon inventory,[13] are developing consumption-based GHG inventory and forecast that are attempting to quantify all upstream/downstream GHGs associated with goods and services consumed within the state.

Conclusions & Recommendations

In addition to the findings from the literature search conducted above, the SJTPO's project team's experiences from facilitating GHG mitigation planning suggest that a standard direct emissions-based approach to I&F development does not fully address the needs of mitigation planners. In particular, at the municipal- to regional-scale, opportunities for implementing policies directed at mitigating emissions within the transportation, land use, waste management, and wastewater treatment sectors are much more apparent. These include smart development, car-pooling or any other VMT-reducing measure, waste reduction, re-use and recycling, energy efficiency improvements, and others. Relying only on a direct emissions based approach can often downplay the importance of some of these options or target areas where the emissions generating activity is not as important (*e.g.*, areas that attract vehicle trips, generate waste, etc.).

A full consumption-based approach where upstream and downstream GHG emissions are quantified for all goods and services consumed in the region is arguably the most useful for GHG planners. Such an I&F would capture emissions from upstream fuel production/transport, upstream manufacturing/transport of goods, downstream management of all wastes, and the provision of all services. Unfortunately a full consumption-based approach is not possible due to both project resource limitations and methods/data availability. However, the approach presented, captures important inventory data needed by planners to more fully understand the relative benefits of mitigation actions under consideration. We suggest that, if possible, some additional analyses may be added in the future (*e.g.*, energy cycle analyses in the waste sector), but have selected the most appropriate analysis approaches by sector where possible, and provide sufficient data and consistency with the other New Jersey MPOs in this protocol.

SJTPO has also met with stakeholders, including DVRPC, NJTPA, and NJDEP to review the protocol and identify the most appropriate methods for this inventory when differences were identified, and to ensure consistency to the extent practicable with these other inventories.

[12] Links to many of the state-level GHG I&Fs can be found at the Center for Climate Strategies website: www.clmatestrategies.us. The I&Fs support each of the climate action plans developed by each state.

[13] ODEQ/ODOE/ODOT, Oregon's Greenhouse Gas Emissions Through 2010, July 18, 2013/

INVENTORY APPROACH

Guiding Principles and Accounting Methods

SJTPO has developed the technical approach delineated below, designed to anticipate and meet future planning and evaluation needs of SJTPO, its counties, and municipalities based on the following guiding principles:

- The level of effort is focused on achieving a higher level of detail for sectors directly under the influence of SJTPO, as well as sectors that can be addressed by the region's counties and municipalities. The transportation sector has high priority, as do other sectors influenced by regional and local planning, such as fuel and electricity consumption, and solid waste management.
- The results of this process will help facilitate SJTPO's larger, long-range climate change initiative. Since the baseline and forecast emissions will be the basis for making decisions regarding potential mitigation actions, the inventory methodology was designed to—
    - provide data that are useful to future analyses of mitigation actions at all levels (MPO, counties, municipalities). For example, the on-road analysis will include energy use, speed, vehicle-miles traveled data, and emissions by vehicle type; solid waste management emissions will be detailed by process (recycling, composting, landfilling, combustion). Where available, the data will include physical units (*e.g.*, fuel, electricity).
    - provide detail to the extent practicable on contributions to energy use and GHG emissions from seasonal residents and seasonal weekend visitors.
    - present both direct and consumption-based approaches for some sectors, and full energy-cycle emissions for all sectors other than waste[14] so the full benefit of potential mitigation actions can be evaluated and compared by data users, as summarized in **Table 1** (and discussed in further detail below).
- The protocol is based on commonly accepted guidance and existing similar efforts, while improving on those where practicable and where meaningful enhancement would result.
- Data used will be the most reliable, recent, and relevant available. To that end, priority will be given to government sources such as the U.S. Department of Energy (DOE), Energy Information Administration (EIA) energy data, U.S. Census data specific to the region, as well as local detailed data, such as energy consumption data from local utilities, waste management data from NJDEP, and modeled transportation data from SJTPO.
    - Stakeholder involvement is crucial to achieving a quality product, ensuring compatibility with similar efforts, and facilitating future related work. This includes coordinating closely with entities providing data for the inventory, planners who will be using the results, and other interested parties involved in similar and related efforts. This protocol was developed by SJTPO in consultation with the Technical Advisory Committee formed for this purpose, and will notify the stakeholders of progress and seek out comments and collaboration.

[14] Energy-cycle emissions related to fuel use in the waste sector is included as is transport within the region (as part of the transportation sector inventory) but upstream emissions associated with materials extraction, production, and transport outside the region are not included.

- The inventory documentation will also provide information that addresses:
  - data, methodologies, laws, and regulations that need to be tracked to inform future updates; and
  - procedures and timelines for future updates.
- The forecast methodology, to be developed along with the inventory, will follow the same principals and be consistent with the inventory methodology.

Table 1: Approach Summary by Sector

Sector	**Accounting Method / Component**		
	Direct	**Consumption**	**Energy-Cycle**
Residential, Commercial, and Industrial Fuel Use and Electricity Consumption			
Electricity		√	√
Fuel Use (including RCI non-road engines)	√	√	√
Transportation			
On-Road	√	√	√
Non-Road Recreational Vehicles	√	√	√
Aviation (including non-road engines)	√		√
Rail—Passenger		√	√
Rail—Freight	√	√	√
Marine	√		√
Industrial Processes	√	√[1]	√[1]
Agriculture (including non-road engines)	√		√[2]
Waste Management			
Solid Waste	√	√	[3]
Wastewater	√	√	[3]
Land Use, Land Use Change, And Forestry (including non-road engines)	√		√[2]

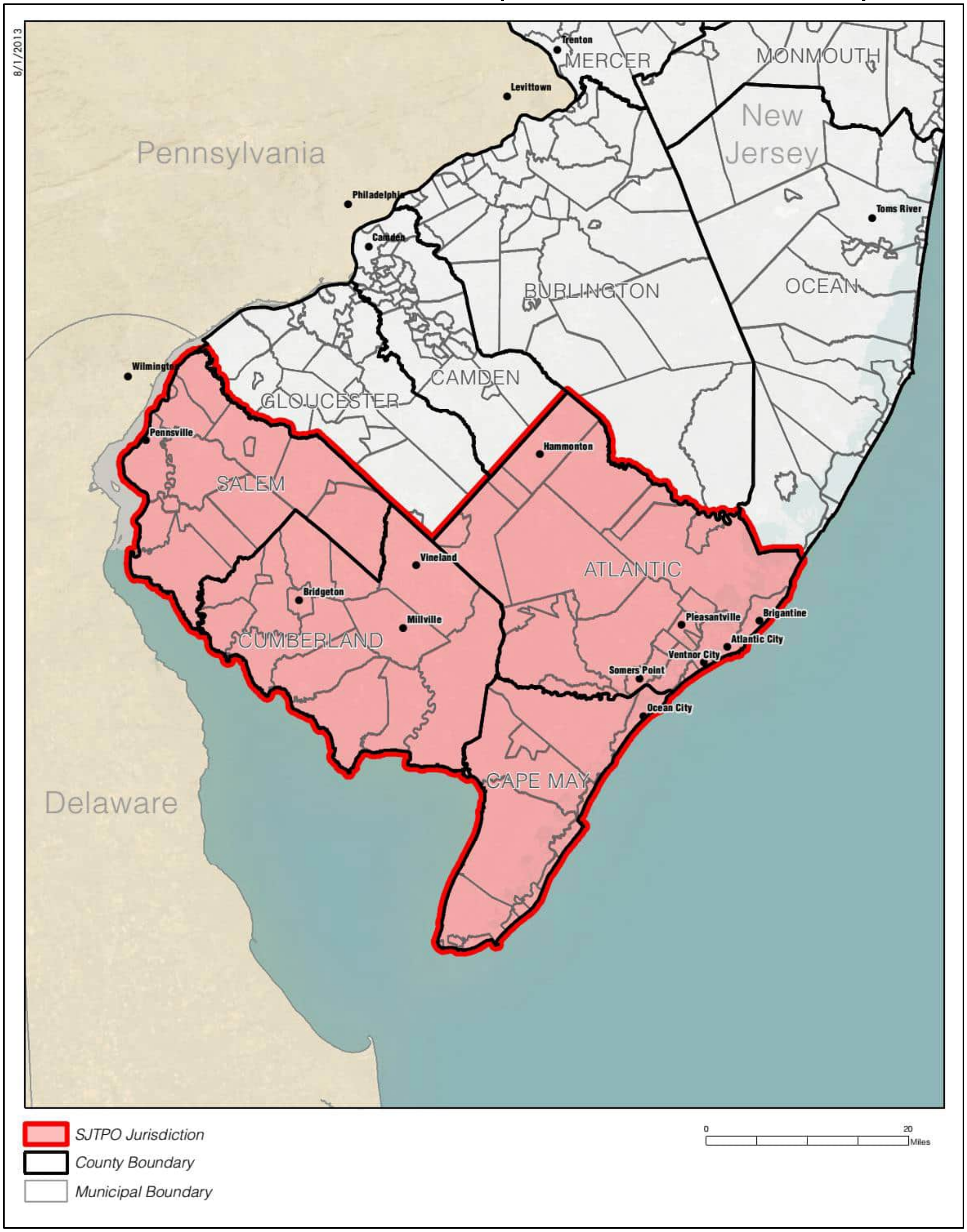
Notes:

1. Includes only consumption of cement and steel if consumption data is available, and energy cycle for those components. These include both energy and non-energy emissions for those commodities.
2. For non-road engine fuel combustion in these sectors; excludes upstream fertilizer production emissions.
3. Fuel consumption and energy-cycle emissions associated with fuel consumption will be included in the Residential, Commercial, and Industrial Fuel Use and Electricity Consumption sector emissions.

Boundaries

Boundaries for the direct emissions-based accounting estimates will be the geographic boundaries of the MPO, counties, and municipalities, presented in **Figure 1**. Consumption-based analyses will include activity as it would be *influenced* by planning in each geographic unit. Thus, using the on-road vehicle sector as an example, half of the emissions from each on-

Figure 1
Map of SJTPO Counties and Municipalities



road trip would be allocated to the origin county/municipality and half to the destination county/municipality, which is similar to the approach used for allocation in the NJTPA and DVRPC inventories. This differs from the New Jersey I&F, which is strictly based on direct emissions within the State's boundaries. Energy-cycle components will be allocated to the time and place of the associated consumption.

Scope

The scope of emission sectors will be comprehensive, including the sectors/sub-sectors listed in **Table 1**, above. The level of detail for each sector/sub-sectors will differ and is tailored to meet regional, county, and municipal-scale GHG planning needs. The inventory report will list emission sources not included and discuss the future efforts that would be required to add such sources.

Base Year

The base year for the inventory will be 2010. The selection of 2010 as base year was based on the latest regional transportation modeling, and consistency with DVRPC and NJTPA efforts and updates. It should be noted that data availability may vary by sector, in which case extrapolation of some data may be necessary to obtain a single base year for the inventory in all sectors.

Gases Included

The report will include all GHGs identified by the Intergovernmental Panel on Climate Change (IPCC) unless otherwise explicitly excluded and explained. For example, in cases where negligible quantities are expected and considerable effort would be required to estimate a certain GHG, this will be explained. These include carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons.[15] Emissions of the various GHGs will be added together and presented as carbon dioxide equivalent (CO_2e) emissions—a sum which includes the quantity of each GHG weighted by a factor of its effectiveness as a GHG, using CO_2 as a reference. This is achieved by multiplying the quantity of each GHG emitted by its global warming potential (GWP)—a factor representing each gas's impact on the atmospheric energy balance—where the GWP for CO_2 is 1. The GWP accounts for the atmospheric lifetime and the radiative forcing of each gas over a period of 100 years. Following standard protocol for GHG inventories, and consistent with the US GHG inventory, the GWP factors from IPCC's Second Assessment Report (1996) will be used. These GWP factors are specified for use for national GHG inventories under the Kyoto Protocol.

Guidance

As detailed below for each sector, the methods will be based on existing international and national guidance, and will build on existing work done at the national, state, and municipal level. This includes the *Draft Regional GHG Inventory Guidance Report* from the EPA (referred to in this proposal as the "*EPA's GHG Inventory Guidance Report*" or "EPA guidance"). Although not yet published as a draft, relevant guidance from the most recent draft (June 2010) has been factored into the approach below. The EPA guidance document is mostly based on the DVRPC and the Metropolitan Washington Council of Governments (MWCOG) experience

[15] For the Industrial Processes sector, it is possible that a seventh gas recently added to national reporting requirements by the IPCC, nitrogen trifluoride could also be emitted (*e.g.*, electronics manufacturing). If so, it will also be added to the inventory.

and has not been updated to account for the more advanced methods used by NJTPA, which are also applied here.

Geographic Allocation

Emissions will be allocated to the extent practicable down to the county and municipality level (see the methodology for each sector for details)**;** while all emissions will be allocated to the county level, in some instances, such as rail freight, allocating further to the municipal level may require a large effort and not provide additional useful data. In general, emissions will be either calculated 'bottom-up' (based on specific data that are already geographically allocated), or 'top-down' (based on national-, county-, or state-level data) and then allocated geographically based on other metrics such as population or consumption. In some cases—where considerable effort would be required, where detailed data are not readily available, and/or where limited mitigation would be available at the municipal level—allocation may be performed only to the subregion level.

In cases where allocation is undertaken using population as a metric, the effect of seasonal population, which more than doubles in the SJTPO region in the summer, will be accounted for.

Accounting Methods

As indicated in **Table 1** above, the inventory will selectively include two accounting methods (varies by sector) as well as an energy-cycle component. These have been selected to provide the accounting method best suited for relevant mitigation efforts in each sector, to the extent practicable and with the above guiding principles in mind, and in some cases more than one method.

Most GHG inventory protocols or guidance used for planning purposes use a *direct (production–based) emission* accounting approach, which provide emissions estimates directly tied to the geographic and temporal location of a source, based on the fuels consumed and other GHG emitting processes. For example, the U.S. inventory calculates transportation emissions based on the transportation fuels consumed in the U.S. in a given year. This approach is useful in accounting for all emissions directly, within defined geographic borders, and enables clear accounting for emissions trading and comprehensive regulation such as would occur within a federal or international system.

However, many GHG mitigation actions are designed to reduce consumption (travel, energy, fuel use, materials that become waste) as a way to indirectly reduce GHG emissions. Also, actions taken to reduce emissions within a jurisdiction may have mitigation effects that occur outside of the jurisdiction. As one proceeds down the hierarchy of planning jurisdictions (from nation to state to county to municipality), these issues become more magnified, to the extent that GHG mitigation becomes primarily an effort to reduce consumption.

Consider electricity consumption as an example: At the level of a nation or state, authority exists to effect the way in which electricity is produced and delivered to consumers (*e.g.*, via renewable portfolio standards, emissions standards, etc.). The effect of these programs on power plants can be measured against the direct emissions produced by the power plants involved. However, for counties and municipalities, authority likely does not exist to affect the way in which power is produced, so reduction in electricity consumption is the primary mitigation response. As a result, a GHG accounting system using consumption-based methods has become the standard for community-scale planning purposes. Similar examples exist for other sectors, including on-road transportation (*e.g.*, fuel economy standards or renewable fuel standards aren't enacted by local jurisdictions).

In addition to the authority that local jurisdictions may have to effect GHG emissions, another issue that impacts mitigation planning concerns the underlying drivers for GHG emissions and that these may occur within a jurisdiction, but some or all of the emissions occur outside of the jurisdiction. Key examples include transportation and solid waste management. For transportation, trip attractors may exist within a jurisdiction but a portion of the emissions occur outside of the jurisdiction. When assessing mitigation actions directed at reducing travel (*e.g.*, via mode shift or ride-sharing programs), an accounting system that captures the emissions for the entire trip will provide more meaningful results. Solid waste is often exported for management outside of the local jurisdiction in which it was generated. Therefore, an accounting system that captures GHG emissions for all waste generated in an area, regardless of where it is managed, is needed to determine the benefits of source reduction, recycling, composting, and other waste management programs. In response, planning inventories can be constructed to provide the best information to assess the benefits of reduced consumption.

To date, the only sector for which a *consumption-based* emission accounting approach has been used is the electricity sector. Most inventories provide GHG estimates based on the electricity consumed in a region and the carbon intensity of that electricity. The estimated carbon intensity takes into account both locally-produced power and imported power used to meet local demand.

In addition to the two accounting methods (consumption-based and direct), the inventory will include *energy-cycle emissions* as a separate (additive) component. Energy-cycle emissions are calculated so as to include all of the emissions associated with an activity. For example, if the activity is vehicle use, in addition to the direct emissions from fuel consumed, there are upstream emissions from the extraction, refining, transportation, and distribution of that fuel.[16]

Planning organizations, such as MPOs and municipalities, typically wish to affect change at different levels and are inevitably interested in comparing the overall emission reduction benefits at the level they are affecting. When reducing travel, reducing home electricity use, selecting a fuel for use, increasing recycling, constructing a new high speed rail system, or shifting freight from truck to rail, the entity making the decisions inevitably will want to compare the complete benefits of such actions, including the energy-cycle emissions, against a business-as-usual scenario.

In some cases, ignoring energy-cycle emissions can result in misleading conclusions:

- All biofuels (and even “cleaner” fossil fuels) are not created equally in terms of their embedded carbon content: cellulosic ethanol has much lower energy-cycle emissions than common starch-based (corn) ethanol; natural gas derived from conventional drilling will have lower upstream emissions than that derived from hydraulic fracturing. The true benefits of biofuels can only be accounted for if energy-cycle emissions are included.

- Ignoring the impact of construction will attribute less GHG emissions to any project requiring construction, since there are significant emissions associated with the

[16] If the action could result in reduction in vehicles purchased, the emissions associated with vehicle production could be reduced as well. In some mitigation analyses, these additional reductions outside of the energy-cycle might be included. This document considers all of these additional emissions (vehicle production, building the manufacturing facility) to be part of the *life-cycle* emissions of vehicle use, and do not propose to develop life-cycle emission estimates for any sector of the SJTPO inventory. As provided in our definitions of terms, “fuel-cycle” can be thought of as a subset of “energy-cycle” emissions. We use the latter term more commonly, since it allows for extension to electricity consumption and the capture of upstream GHG emissions associated with the extraction, processing, and transport of primary fuels used in electricity production.

production of cement and steel, the transport of the materials, and, to a lesser degree, the use of construction equipment.

- Direct emissions from solid waste disposal may be a small fraction of the total inventory, but after accounting for the upstream emissions of the waste materials, lifecycle analysis shows that source reduction efforts (reduced packaging, other purchasing policies) and recycling, can have tremendous GHG implications. Waste sector emissions including energy-cycle emissions, capturing the upstream GHGs in consumed goods and packaging, are comparable with other large sectors, such as fuel use in the residential, commercial, and industrial (RCI) sector. While including the energy-cycle component for solid waste is important, the effort required for that component is beyond the scope of the current analysis.

Emission Factors

Wherever possible, as detailed in the sector-specific methodologies below, the inventory will be developed using a 'bottom-up' approach, which means that a given consumption metric (*e.g.*, quantity of fuel used, amount of nitrogen added to soils) is multiplied by an emission factor representing the quantity emitted per consumption unit. For general fuel use that is not included in models such as EPA's MOVES, GREET, or NONROAD models, the most recent emission factors provided by The Climate Registry[17] will be applied. The Climate Registry's emission factors are provided in detail in Attachment A. Other emission factors are detailed below for each sector or subsector.

Development of Energy-Cycle Emission Estimates

The upstream component of the energy-cycle emission estimates will be developed using the latest version of the Argonne National Laboratory's GREET Model.[18] The current version is GREET 1 2013. This model allows a user to develop fuel-specific estimates of embedded energy and GHG emissions for each of the fuels that we will encounter in this project with a few exceptions (heating oil, pipeline natural gas, coal, and wood). For these other fuels, upstream emission factors developed for use in other recent projects, which will serve as starting points. New literature searches will be conducted to determine whether any newer information is available to update our existing estimates.

These upstream energy-cycle emissions will always be presented separately from the direct emissions, and clearly identify any instances where there may be a potential for double-counting of emissions (*e.g.*, in cases where a fuel is extracted or processed in the same area that it is consumed).

Emissions Forecasting

Emissions forecasting will be undertaken in the next phase of this effort, and will provide estimates of future emissions in 5-year increments out to 2050. The methods would need to be reviewed again when the forecasting is undertaken to ensure that the best and most recent data sources are identified and used. In general, future emissions will be based on forecast growth (*e.g.*, population, employment, etc.) as well as any specific growth projected to occur based on other current plans if known at the time (*e.g.*, if large scale changes are expected in the region

[17] The Climate Registry. 2014 Climate Registry Default Emission Factors. January 10, 2014.

[18] http://greet.es.anl.gov/.

which would shift freight modes or electricity production fuel sources). Where relevant, these are discussed under the methodology section for each sector. The projected demographics for the region would be taken from the *SJTPO Regional Transportation Plan (RTP) 2040*. The RTP includes data for 2010, 2020, 2030, and 2040. Intermediate years will be interpolated from this data and extrapolated out to 2050. The precise method for interpolation and extrapolation will be determined when the data is analyzed in preparation for forecasting.

One issue somewhat unique to the SJTPO region, which will be important when developing the forecast, is seasonal population. According to the SJTPO *Regional Profile* (January 2013), the SJTPO region population more than doubles in the summer, from 600 thousand 1.3 million and summer weekdays and over 1.6 million on summer weekends. The seasonal population will need to be accounted for when developing population-dependent forecasts to account for the differences in consumption rates and growth rates of the seasonal and permanent population, and to correctly correlate the population metric with emissions and growth. Since the RTP also includes projections of summer population (weekday and weekend) out to 2040, the summer inventory and the total annual inventory for sectors where growth is population-dependent will be forecast while accounting for that population growth separately from the general population growth. The approach for each sector is detailed in the sector specific methodology, below.

INVENTORY METHODOLOGY BY SECTOR

Residential, Commercial, and Industrial Fuel Use and Electricity Consumption

DIRECT AND CONSUMPTION-BASED FUEL USE INVENTORY

Direct emissions and consumption-based emissions associated with fuel use in the RCI sector are the same because the fuel is used and combusted at the same location. For example, fuel oil used for home heating and hot water is both consumed and combusted within the residence.

As part of the stakeholder outreach effort, we will contact the utilities serving the SJTPO area. According to the New Jersey GHG Inventory, the fuel most commonly used by the Residential, Commercial, and Industrial (RCI) sector for space and water heating and for industrial processes is pipeline natural gas. The major company supplying natural gas to the region is South Jersey Gas. Typically, utilities have information on energy delivered to consumers, by municipality or zip code and by consumer sector (residential, commercial, and industrial). Data on natural gas consumption obtained from utilities will be aggregated, if needed, by municipality using GIS tools and data from the Census Bureau that indicates the proportion of households using natural gas in each municipality.[19] The US weighted average heat content of 1,028 Btu/scf, as reported by The Climate Registry will be assumed, unless South Jersey Gas provides a specific heat value for natural gas delivered to their South Jersey customers. The natural gas emission factors will be obtained from The Climate Registry, considering the natural gas heat value and sector (residential / commercial / industrial).

Detailed information on the RCI consumption of oil and other fuels is typically not easy to obtain. Therefore, an alternative method, which was also used to develop the NJTPA GHG emissions inventory, will be applied. For the residential sector, 2008-2012 data from the Census Bureau includes an estimate of the fraction of households within a municipality using each fuel type.[18] Assuming the fuel type use distribution reported by the Census Bureau, the residential use of fuels other than natural gas may be estimated using these fractions along with the data on natural gas consumption, as reported by the utilities. The amount of fuel use for home heating is

[19] U.S. Census Bureau, 2008-2012 American Community Survey

more a function of the floor area heated and the type of housing unit (for example single-family vs. multifamily), than of the number of residents. Assuming that housing unit types in a given municipality are similar and estimating the amount of oil and other fuel use based on the amount of gas use within the same municipality may therefore be a better approach than allocating state-wide data to municipalities based on population. Therefore, utility natural gas data and Census Bureau information on the fractions of households using various types of fuel for heating would be used to determine total heating energy data (in BTU) by municipality, and the amount of heat used by fuel type. Emission estimates for household heating arrived at using this method will be compared to the emission estimates obtained using the EPA SIT method and the New Jersey GHG Inventory data to confirm assumption validity and the soundness of the approach.

To estimate the amount of fuel used by the commercial and industrial sectors, the NJDEP point source inventory on fuel throughputs by North American Industry Classification System (NAICS) code at the municipal level, would be used. The emissions included in the NJDEP point source inventory would cover the large commercial and industrial fuel users. Any remaining fuel consumption will be allocated using NJDEP county-level estimates of commercial and industrial fuel consumption. County-level data would also be allocated to each municipality based on methods in the draft regional guidance[20], while ensuring that the fuel use associated with point sources is not being double-counted. Employment data from the Bureau of Labor Statistics for the desired geographic area will be used to apportion statewide consumption of a particular fuel by the commercial or industrial sector, based the fraction of statewide employees in each geographic area. Once fuel consumption information for each sector and fuel type is available, The Climate Registry emission factors will be applied. To the extent practicable, and to the extent that information is available, peak summer season emissions will be reported, in addition to annual emissions.

ELECTRICITY CONSUMPTION INVENTORY

The major utility supplying electricity to the SJTPO region is Atlantic City Electric. 2010 electricity consumption data by municipality, by sector (residential, commercial, industrial), and by month will be requested. The same information regarding electricity use would also be requested from Vineland Municipal Electrical Utility (VMEU), which provides electric service to the residents of Vineland.

To develop emission rates for electricity delivered to the grid, we would use the EPA eGRID2012[21] database for the RFCE subregion. The total output emission rate would be used. This approach is consistent with the guidance and emission rates recommended by The Climate Registry. Transmission and distribution losses would be accounted for using eGRID2012. For the Eastern region, eGRID2012 provides a grid gross loss as 5.82%. Total emissions would be calculated by multiplying the electricity consumed, including transmission and distribution losses, by the average emission factor for electricity delivered to the grid. Peak summer season emissions will be reported, in addition to annual emissions. Energy-cycle emissions will also be reported. The emission factors used for the 2010 baseline year are presented in **Table 2**.

[20] U.S. Environmental Protection Agency, Draft Regional Greenhouse Gas Inventory Guidance, January 2009.

[21] USEPA, eGRID2012, http://epa.gov/cleanenergy/energy-resources/egrid/index.html

Table 2: 2010 Baseline Year Emission Factors

2010 Base Year Emission Factors	Consumption Emission Factors	Energy-Cycle Emission Factors
CO_2 (metric tons/MWh)	0.4544	0.0445
CH_4 (metric tons/GWh)	0.0123	0.8335
N_2O (metric tons/GWh)	0.0070	$2.643x10^{-5}$
CO_2e (metric tons/MWh)	0.4568	0.0621

FUEL USE AND ELECTRICITY CONSUMPTION INVENTORY ALLOCATION

The natural gas and electricity consumption would be available or developed by municipality and the associated emissions would be allocated accordingly. For other fuels, county-level estimates from NJDEP criteria pollutant inventory work would be apportioned by municipality, using methods suggested in the preceding section.

FUEL USE AND ELECTRICITY CONSUMPTION INVENTORY FORECASTING

SJTPO population growth projections will be used to develop GHG emission forecast for fuel and electricity use in the residential sector. Commercial and industrial sector GHG emissions forecast will be developed using SJTPO employment projections. The projected changes in fuel and electricity use will be compared to past changes in electricity and fuel use, to the extent that information is available to ensure that these metrics are reasonable metrics for the forecast. For example, while the increase in consumption of electricity may scale with the growth in the number of households in the municipalities that are not greatly affected by seasonal population, in municipalities that are summer tourist destinations, the increase in consumption of electricity is likely to be influenced by both changes in the number of households and changes in tourism. Both will be accounted for as needed and as indicated by comparison of past and current data.

Electricity emission factors will account for planned increases in renewable power production and efficiency improvements included in the State Energy Plan, and the Renewable Energy Portfolio Standard goal of 22.5% by 2021. This will be discussed with the stakeholders prior to preparing the forecast to ensure consistency with other inventories and to account for the latest goals and renewable electricity programs. The metrics applied to each of the subsectors (residential, commercial, and industrial) will also be used to project growth in emissions from non-road engines used in each of these subsectors. Changes in engine efficiency in nonroad engines would be accounted for within the EPA model (see Nonroad Inventory section, below.)

Transportation

The inventory will estimate GHG emissions from the following transportation sources:

1. On-road mobile sources—All passenger vehicles including transit buses and commercial vehicles (light, medium, and heavy-duty commercial trucks)
2. Aviation
3. Marine (both recreational and commercial use)
4. Rail (both passenger rail and freight rail)
5. Non-road vehicles

Although CO_2 is the primary GHG emitted from the transportation sector (approximately 95%), CH_4 and N_2O are emitted as well. All three pollutants will be addressed from direct and consumption based emissions as well as from upstream well-to-pump emissions to be included in the energy-cycle analysis. Fuels used in the sector include not only gasoline and diesel, but electricity, various biofuels and synthetic fuels, natural gas, and others. In addition to on-road fuels, the transportation sector includes non-road fuels used in locomotives and non-road engines (*e.g.*, construction equipment), jet fuels used for aviation, and electricity used in the Rail and Non-Road sub-sectors. GHGs associated with non-road fuels are the same as those for on-road fuels, and the electricity sector is described in detail in “Direct Fuel Use and Electricity Consumption” section above.

ON-ROAD VEHICLES INVENTORY

The on-road transportation sector includes motor vehicles that typically travel on public roads. These include passenger cars and trucks, motorcycles, commercial trucks, heavy-duty vehicles, and buses. These vehicles may be fueled by gasoline, diesel, or other alternative fuels, including electricity. Although CO_2 is the main GHG emitted from this sector, CH_4, and N_2O are emitted as well.

Direct Emissions

There are two primary inputs to the development of an on-road GHG emissions inventory: GHG emission rates (grams/mile) and vehicle activity (vehicle miles traveled, VMT). EPAs MOVES model is the preferred tool to generate emission rates and vehicle activity is generated by the South Jersey Travel Demand Model (SJTDM).

Consistent with SJTPO’s FY 2014 air quality conformity analysis, MOVES 2010b will be used to produce the on-road mobile source emission rates. MOVES 2010b is the most recent model available, and is recommended in EPA’s guidelines for conducting inventories of on-road GHG emissions.

MOVES activity and non-activity input data have already been developed for the current SJTPO FY 2014 conformity analysis or were developed for the New Jersey state implementation plan (SIP) emissions estimates. The primary MOVES inputs and sources used by SJTPO to support the FY 2014 conformity analysis are presented in **Table 3**. For the SJTPO inventory, the MOVES input files are identical to the files used in the 2010 base year FY 2014 conformity analysis.

PPSUITE is a pre/post-processing software that establishes the connection between SJTDM output and MOVES. The program pre-processes SJTDM data prior to running MOVES and post-processes outputs from MOVES into summary reports for use in conformity documentation.

The following PPSUITE inputs were created during the FY 2014 conformity analysis and were used in combination with SJTDM outputs to create the five input files at the bottom of **Table 3** provided for use in the GHG inventory:

- Vehicle Type Map File—included in SIP analysis.
- Speed/Capacity Table—included in SIP analysis.
- Hour Pattern File—included in SIP analysis. The pattern data is based on 2007-2011 traffic count data from NJDOT.
- Vehicle Mix Pattern File—included in SIP analysis. The pattern data is based on 2007-2011 traffic count data from NJDOT.

- Vehicle Type Factor File (VFC) File—created using the Highway Capacity Manual and was included in SIP analysis.

Table 3: MOVES2010b Input Files

Input	Source	Description
MOVES Inputs – regional specific data		
Age distribution	NJDEP, 2010 estimated based on 2008 data	Fraction of vehicle population age by source type for a 31-year period for the region
Fuel supply	NJDEP, 2010	Market share of different fuel formulations by county, year, and month
Fuel formulation	NJDEP	Physical characteristics of modeled fuels for the region
Fuel Type and Technology	MOVES defaults	Fraction of fuel type and engine technology (gasoline, diesel, CNG, electric) by source type and model year.
Meteorology	AECOM, FY14 conformity analysis	Average hourly temperature and relative humidity for all months by county
Source Type Population	PPSUITE based on 2011 motor vehicle registration from NJDEP	Vehicle population by 13 MOVES source types by county
HPMS Vehicle Type Year	AECOM, PPSUITE based on 2010 NJDOT HPMS data	2010 HPMS VMT by 6 HPMS vehicle types by county
Daily VMT fraction	AECOM, PPSUITE based on 2006 NJDOT statewide counts	Fraction of VMT by average weekday and average weekend day by road type by county
I/M Programs	AECOM, from 2011 I/M input from NJDEP	Inspection and maintenance requirements by source type, fuel type, and model year by county
PPSUITE post-processed files from SJTDM		
Average speed distribution	PPSUITE, from SJTDM 2010 networks	Distribution of speed across 16 classes by source type, road type, and hour of day, by county and month
Ramp fractions	PPSUITE, from SJTDM 2010 networks	VMT share on ramps
Road type distribution	PPSUITE, from SJTDM 2010 networks	VMT distribution by 13 MOVES source types and 5 road types, by county and month
Month VMT fraction	PPSUITE	VMT distribution by source type by month
Hourly VMT fraction	PPSUITE	VMT distribution by road type, source type, and hour of day

Vehicle activity outputs from SJTDM will be input into the PPSUITE post-processing software to obtain estimates of vehicle activity by county for each month of the year, hour of the day, 13 MOVES source types, and 5 road types. As part of the process of post-processing SJTDM vehicle miles traveled (VMT) data, PPSUITE applies highway performance monitoring system (HPMS) VMT adjustments consistent with requirements for transportation conformity. As the identical PPSUITE setups for conformity are used in this analysis, the same HMPS adjustments will be incorporated into the inventory. For on-road transit vehicles (including NJ Transit local and regional bus, local jitney services, and Atlantic City casino shuttles), the same process utilized for conformity analysis will be applied to estimate GHG emissions.

Emissions will be aggregated based on VMT and congested speed by time of day on highway links within each jurisdiction. This approach is consistent with how conformity analysis is conducted and how PPSuite post-processes data from the SJTDM. This approach reports the actual emissions from vehicles operating on roadways within each jurisdiction.

At the county level, emission outputs from MOVES can report any combination of total GHG emissions (CO_2, $CH_{4,}$ and N_2O) by MOVES source type (13 vehicle classes), road type (5 types), and month in inventory mode. The on-road inventory will report emissions at the annual scale, and also at the seasonal scale for the summer (3 month total). These emissions estimates, based directly on network VMT, represent the results for the direct approach. Note, emissions from VMT in Gloucester and Camden counties are not included, although portions of these counties are included in the SJTDM.

The nature of tourism in the SJTPO region means that travel activity fluctuates depending on the month of the year and day of the week. The SJTDM accounts for this starting in its trip generation model, where it splits non-recreational and recreational trips. These trip types are tracked throughout the SJTDM model stream and are combined in the network assignment model (to support ozone conformity analysis focusing on the summer season).

For direct based emissions, average annual weekday network based emissions are compared to an average summer weekday (June, July, August) at the region and county scale. These results will be based on the monthly emission inventory outputs from MOVES at the county scale.

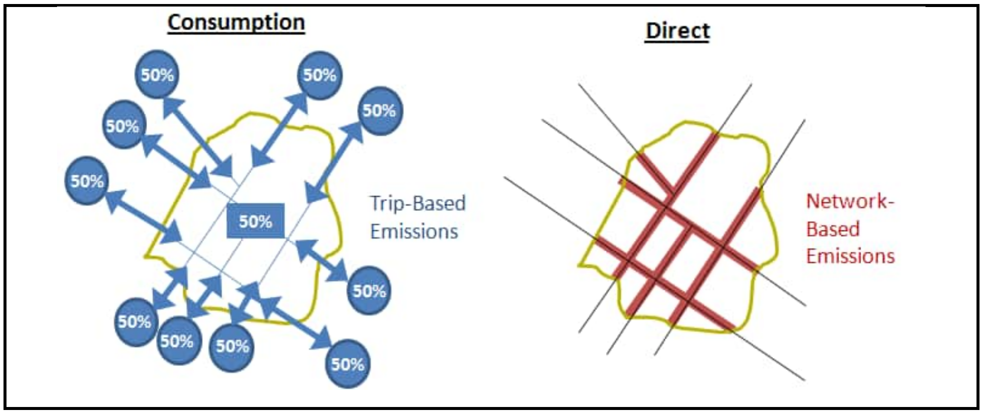
Consumption Emissions

With the exception of the allocation method, consumption based emissions will follow the same methods outlined above for direct emissions. Consumption based emissions will be aggregated based the location of any given trip's origin and destination. The consumption-based approach allocates 50% of emissions from each trip to the origin and 50% to the destination jurisdiction, as illustrated in **Figure 2**. This approach uses vehicle trip origins and destinations by time of day from the SJTDM and a congested travel time skim by time of day of the assigned SJTDM highway network. Note that since emissions will all be allocated to origin or destination locations in the region, through trips without an origin and destination in the SJTPO region are not included. The SJTPO consumption approach is overall consistent with the DVRPC and NJTPA approach except in the case of the separate summer season approach (see details below).

To complete the consumption based approach, the files required from the SJTDM include:

- Peak and off-peak vehicle trip tables;
- Peak and off-peak congested travel time and distance skims; and
- Equivalency file for traffic analysis zones (TAZs) to counties and municipalities.

Figure 2
Illustration of the Direct and Consumption-Based Approach



MOVES will be run in inventory mode, applying VMT data post-processed from SJTDM (via PPSUITE) and vehicle population data. The MOVES model directly calculates the emissions inventory, with one MOVES run conducted per county. Running MOVES separately for each county allows county specific inputs (particularly with regard to speed distribution, road type, and source type) to be used to improve the accuracy of the emission calculations. To ensure consistency with the outputs and file organization from PPSUITE, a separate MOVES run for each month for each county will be prepared (4 counties * 12 months = 48 model runs).

To assist in the developing of consumption-based emissions, composite emission rates by county, source type, and road type will also be estimated from MOVES. These emission rates will be applied to vehicle trips by time-of-day and by type (passenger, bus, commercial/truck) for each origin-destination pair by average origin-destination pair congested speed from the congested time-of-day network skims. The result of this combination of emission rates, vehicle trips, and average speeds will be total trip based emissions by TAZ, which can be aggregated to the region, county, and municipality scale. Note, emissions from trips internal and between Camden and Gloucester counties, which are included in the SJTPO model, but not the SJTPO region, are not included in this analysis.

The summer season analysis for consumption based emissions compares average annual weekday trip based emissions to an average summer weekday (June, July, August) at the region and county scale. This seasonal analysis will develop an average summer weekday vehicle trip table based on an approach that factors vehicle trip tables based on summer season VMT adjustment factors.

One complicating factor of the seasonal consumption-based approach is the accounting of internal-external trips. For SJTPO, this is particularly relevant in accounting for emissions from trips destined to shore points from the Northern New Jersey/New York metropolitan region, Camden region, the Philadelphia/Eastern Pennsylvania region, and Delaware/Eastern Maryland. However, emissions from the share of these trips that occur outside the SJTPO region are not included in the SJTDM. An approach to estimate these emissions relies on the distribution of trip origins for shore trips, and average trip distances. Per the New Jersey Beach Travel Survey (NJDOT & SJTPO, 1996), the following origin shares are observed:

- Philadelphia/DVPRC region (PA only)—36%
- Camden, Burlington, Gloucester Counties—17%
- SJTPO region—15%

- Remainder of New Jersey—8%
- Rest of Pennsylvania—8%
- Delaware/Maryland/Mid-Atlantic—6%
- New York City/New York—6%
- New England/Canada—3%

Average distances from each area to each SJTPO shore municipality will be estimated. For each municipality, an external-internal summer average trip length will be developed. The average summer weekday trip table will be multiplied by the average trip length for all external-internal trips (depending on the destination) to estimate total external-internal VMT. From this approach, an estimate of the total emissions contribution of external trips in the summer season will be developed.

As part of the consumption based inventory, a further investigation into truck emissions from trips outside the region with an origin or destination in the region is recommended in order to assist on a more comparable comparison particularly to freight rail. To accomplish this, estimates of consumption based emissions outside the region are generated by multiplying the total internal-external truck trips within each county by the average distance to/from the final destination/origin as documented in the Freight Analysis Framework (FAF). The "remainder of New Jersey" FAF region was used as a proxy for the SJTPO region in order to describe the patterns of origins and destinations for the region and develop an average length of haul for inbound and outbound cargo.[22] The results of this analysis indicate that the average inbound truck trip to the SJTPO region is 134 miles, and the average outbound truck trip from the SJTPO region is 117 miles. These average trip lengths are based on FAF data indicating that approximately 82% of truck tonnage entering the region have an origin in the remainder of New Jersey, the Philadelphia region, or New York City, and that approximately 87% of truck tonnage leaving the region has a destination in the remainder of New Jersey, the Philadelphia region, or New York City.

AVIATION INVENTORY

Direct Emissions

The proposed approach for aviation emission estimates will be to develop base and future year GHG emission estimates based on the estimated fuel used during the landing-takeoff (LTO) cycle (emissions occurring below 3,000 feet) using the Federal Aviation Administration's (FAA) Emissions and Dispersion Modeling System (EDMS). GHG emissions will be inventoried in accordance with Airport Cooperative Research Program (ACRP) *Guidebook on Preparing Airport Greenhouse Gas Emission Inventories* (*ACRP Report 11*).[23] Fuel usage per LTO cycle or touch and go (TGO, a practice maneuver which involves landing followed by immediate take off) will be calculated using fuel flow rates for each operating mode for each specific aircraft engine combined with the typical period of time the aircraft is within the operating mode. A LTO cycle consists of aircraft operating modes of approach, taxi in, engine startup, taxi out, takeoff, and climbout. A TGO is an aircraft operation where the pilot lands on a runway and taking off again without coming to a full stop.

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[22] The remainder of New Jersey FAF region only includes Cape May, Atlantic and Cumberland Counties in the SJTPO region (Salem is located in the Philadelphia Combined Statistical Area FAF region), and Warren County.

[23] Airport Cooperative Research Program, Report 11, Project 02-06, *Guidebook on Preparing Airport Greenhouse Gas Emissions Inventories*, http://onlinepubs.trb.org/onlinepubs/acrp/acrp_rpt_011.pdf.

Estimating the airport emissions by capturing the LTO activity up to 3,000 feet is preferable for assigning emissions to particular airports, and in keeping track of changes to operations at those airports that change with time. The baseline year (2010) annual operations by aircraft category (air carrier, air taxi, general aviation, and military)[24] for the nine airports within the SJTPO are presented in **Table 4**. For general aviation, both LTO and TGO will be included. Aircraft activity levels will be based on FAA's Terminal Area Forecasts (TAF), FAA's OPSNET, and Airport IQ5010™ Airport Master Records.

Table 4: Annual Airport Operations by Aircraft Category—Baseline Year

Airport	Air Carrier	Air Taxi	General Aviation (TGO)	General Aviation (LTO)	Military (TGO)	Military (LTO)
Atlantic City International Airport	12,630	5,607	9,944	23,010	33,294	22,765
Bucks Airport	0	0	1,150	50	0	0
Cape May County Airport	0	0	8,000	22,000	0	200
Hammonton Municipal Airport	0	0	8,400	7,500	0	0
Kroelinger Airport	0	0	150	20	0	0
Millville Municipal Airport	0	0	30,000	27,000	0	3,000
Ocean City Municipal Airport	0	0	8,060	12,098	0	0
Spitfire Aerodrome	0	0	12,720	4,243	0	0
Woodbine Municipal Airport	0	0	8,044	4,331	0	0

Source: Airport IQ5010™ Airport Master Records and Reports, http://www.gcr1.com/5010web/; FAA Terminal Area Forecast (TAF), http://aspm.faa.gov/main/taf.asp; and FAA Operations Network (OPSNET), https://aspm.faa.gov/opsnet/sys/Default.asp; accessed January 2014.

Application of this method requires that data on LTOs from each of the airports in the region by aircraft/engine type be determined. This critical detail about the aircraft focuses on whether each aircraft is turbine- or piston-driven, which allows the emissions estimation model to assign the fuel used, jet fuel, or aviation gas, respectively. The fraction of turbine- and piston-driven aircraft will either be assumed for air taxi and general aviation operation per EPA estimates. Specifically, EPA assumes that 72.5% of general aviation and 23.1% of all air taxi activity are powered by piston-powered aircraft, while the remainder powered by turbine aircraft.

Representative aircraft/engine combinations for each aircraft category will be developed based on EPA's 2011 National Emissions Inventory (NEI), Official Airline Guide (OAG) Aviation Database, the JP Airline-Fleets International Database (JP Fleets), or other appropriate sources. A detailed air carrier aircraft fleet mix for Atlantic City International Airport will also be developed. For air taxi, general aviation, and military operations, a representative aircraft will be assigned (*e.g.*, Cessna 172 with O-360-B engine will be assigned as a representative piston-driven general aviation aircraft).

International Civil Aviation Organization (ICAO) operating times will be used to estimate fuel usage within each aircraft operating mode: approach, taxi in, engine startup, taxi out, takeoff, and climbout. The fuel usage from each aircraft category will be added and converted to GHG

[24] Commercial aircraft include those used for transporting passengers, freight, or both. Commercial aircraft tend to be larger aircraft powered with jet engines. Air Taxis carry passengers, freight, or both, but usually are smaller aircraft and operate on a more limited basis than the commercial aircraft. General Aviation includes most other aircraft used for recreational flying and personal transportation. Finally, military aircraft are associated with military purposes, and they sometimes have activity at non-military airports.

emissions based on appropriate emission factors for each GHG by fuel type—Jet A and aviation gas).

In addition to aircraft emissions, GHG emissions from auxiliary power units (APUs) and ground support equipment (GSE), such as aircraft refueling vehicles, baggage handling vehicles, and equipment, aircraft towing vehicles, and passenger buses, will be also included in the aviation sector. These emissions will be based on assigned aircraft and default operating conditions within the EDMS.

Consumption-Based Emissions

A consumption-based accounting of emissions from the aircraft sector will not be developed for this inventory due to available project resources and the limited need for such data in local-scale GHG mitigation planning for airports.

Energy-Cycle Emissions

The Argonne National Laboratory's GHG, Regulated Emissions and Energy use in Transport (GREET) model will be used to determine the energy-cycle emissions for aviation fuel consumption. Energy-cycle emissions factors from GREET will be compared with direct emissions factors from The Climate Registry. The GREET model does not have an energy-cycle emissions estimate specifically for aviation fuels, so diesel fuel will be used as a surrogate.

MARINE VESSELS INVENTORY

Marine transportation is a component of personal and freight mobility in the SJTPO region. The Marine sub-sector covers both commercial marine vessels (CMVs) and recreational marine vessels.

Commercial Marine Vessels

Commercial marine vessels (CMVs) include ocean going vessels (OGVs), harbor boats, towboats, dredging boats, commercial fishing boats, ferry boats (*e.g.*, the Delaware River Port Authority (DRPA) Cape May—Lewes Ferry and Three Forts Ferry), excursion vessels, and government boats. The region does not have substantial cargo traffic; however, barges are used throughout the region for construction related activities. Only emissions occurring within the three-mile demarcation line of the shore are recommended for inclusion in this analysis consistent with the NJTPA inventory and also consistent with the boundary used for the ozone nonattainment area in the State Implementation Plan (SIP) emission inventory. Emissions in the CMV sector come from fuel combusted in these vessels, both in the main engines for propulsion and in the secondary engines for electrical power and other onboard services. This fuel combustion results in emissions of CO_2, CH_4, and N_2O, primarily from the combustion of diesel fuel.

To the extent that data is available, the inventory will follow a bottom-up direct approach to estimate GHG emissions within the three-mile demarcation line

Cargo Vessels

The region's cargo traffic is concentrated at a small container terminal at the Port of Salem. For 2013, the terminal generated 12,217 TEUs combining both inbound and outbound moves[25]. This

[25] IMO: 9234434, GRT, 2937 t, Summer DWT: 3725 t

was generated by 51 vessel calls[26]. For the purposes of the inventory, activity is presumed to be the same in 2010 as it is in 2013.

The vessel serving the port has a capacity of between 350-500 TEU of cargo. Based on the profile of similar vessels, the ship is projected to consume 15 tons (4,656 gallons) of diesel fuel per day, or 194 gallons per hour, when operating at full cruising speed. As the ship operates within the Delaware River, the rate of speed is likely to be under the typical service speed of 14 knots, however for the sake of simplicity it is assumed that the vessel operates at cruising speed for 3.7 hours in each direction to move from the port to the border of the SJTPO region (within the 3 mile boundary), as the rate of fuel consumption is directly proportional to the service speed. This would result in fuel consumption of 1,436 gallons of diesel fuel for the cruising portion for each round trip (including the inbound and outbound move). Fuel consumption while at berth will be approximately 5% of this total, equivalent to 233 gallons per day. Thus, the estimated fuel consumption per vessel call attributed to the SJTPO region would be 1,658 gallons of diesel fuel.

Bulk activity is concentrated at the Salem Municipal Wharf which is owned by the South Jersey Port Corporation but leased to a private operator. Currently, there is very little commercial maritime activity at the municipal wharf. In 2013, there was one vessel call which carried pilings[27]. Also, the DRPA 3 Forts Ferry uses the wharf as a boarding and arriving point during operations in the summer months for passengers traveling to and from Fort Delaware State Park and on to Delaware City.

There is additional barge activity throughout the region for construction related activities that use the Port of Salem.

Ferry Operations

For the Cape May—Lewes ferry services, detailed operations data required to generate the emission inventory, including annual operating hours, engine power and load factors, and average time in cruise, maneuvering, and idle modes are available through the Delaware Department of Natural Resources and Environmental Control (DNREC) *2002 Base Year State Implementation Plan Emissions Inventory for VOC, NO_x and CO*, and the *Delaware River Main Channel Deepening Project General Conformity Analysis and Mitigation Report.*[28]

To estimate total greenhouse gas emissions, annual operating hours are multiplied by engine horsepower (converted to kilowatts), an average load factor (recommended at 85% per EPA guidance), and an emission factor in grams of CO_2 per kilowatt hour (recommend at 690 g/kwh per EPA guidance).[29] 50% of total emissions from the ferry services would be attributed to New Jersey, while the remainder would be attributed to Delaware.

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[26] The vessel that is currently being utilized for this service is the Bermuda Islander - A small container vessel that was constructed in 2001. Email exchange with Mid-Atlantic Shipping, 1/11/2014. More information available at http://www.bermudaislander.bm/index.html

[27] Phone call with South Jersey Port Administration, 1/14/2014

[28] U.S. Army Corps of Engineers – Philadelphia District. Delaware River Main Channel Deepening Project – General Conformity Analysis and Mitigation Report. November, 2009. http://www.nap.usace.army.mil/Portals/39/docs/Civil/Deepening/CleanAirAct/DRMCD%20General%20Conformity_November_2009_Revised.pdf

[29] U.S. Environmental Protection Agency. Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories – Final Report. Washington D.C., April 2009.

Other Commercial Marine Vessels

For other CMVs (excluding the cargo vessels and the DRPA ferries), GHG emission estimates will be based on EPA emission rates documented within the State Greenhouse Gas Inventory Tool (SGIT) and total fuel consumption or fuel sales by type within the SJTPO region (marine gasoline, marine diesel, marine residual) available from NJDEP or estimated based on a proportional analysis of marine activity in the SJTPO region compared to all of New Jersey. Information regarding the share of total CMV fuel consumption that occurs within the 3-mile demarcation line will also be researched, and assumptions developed to support an inventory only including emissions from that activity.

Recreational Marine Vessels

Recreational boating is a key component of the lifestyle of the SJTPO region yet it is also a carbon intensive activity. While recent EPA regulations have specified reductions in criteria pollutants for personal watercraft and Outboard Marine Engines they have not significantly impacted carbon emissions. Carbon inventories of recreational boating have traditionally used the EPA's NONROAD model. NONROAD2008 was updated to include changes from the Small Spark Ignition (SI) and SI Recreational Marine final rule and Diesel (CI) recreational marine standards in the Locomotive/Marine final rule. These changes impact criteria pollutants and do not impact CO_2. The NONROAD model tracks CO_2 emissions at the county level and can be used to estimate emissions from recreational and commercial marine vessels. In addition, recreational vessels over ten feet in length are required to be registered. Registration data can be used to track the population of recreational boats within the counties over time and can thus be used to project population for future years.

RAIL INVENTORY

The rail transportation sector covers emissions associated with the operation of both passenger rail and freight rail locomotives. The GHGs involved are CO_2, CH_4, and N_2O, primarily from the combustion of diesel fuel and the consumption of electricity.

For rail transportation, direct emissions include only diesel emissions. Consumption-based emissions include both diesel and electric, and would be based on the origin and destination of freight and passenger trips. In the SJTPO region, this sector includes the following components:

- Passenger Rail—NJ Transit Atlantic City line
- Freight Rail—Heavy freight rail locomotives

For passenger rail operations, a consumption-based approach that takes into account emissions from the full length of each passenger trip within and outside the region will be conducted for the inventory.

Freight rail operations within the SJTPO region are a lower carbon alternative to trucking. For reasons of supporting future comparative analysis between rail and truck efficiency and data availability, the methodology used to inventory freight rail emissions in the region will include a direct inventory approach.

Given the geographic orientation of the region, there is little to no freight rail traffic that would be classified as through traffic. To conduct a true consumption based inventory that includes emissions from freight activity within and outside the region, information on trip origins and destinations, and average trip length is required. As part of the inventory, an estimate of consumption based freight rail emissions will be provided only at the county level. Allocating freight rail emissions lower than the county level is not recommended. This is due to data availability limitations, the very high effort involved in producing such detailed estimated, and the limited utility of providing municipal level results (decisions regarding freight rail are not generally made at the this level).

Passenger Rail

The only passenger rail line in the SJTPO region is the NJ Transit Atlantic City line. Within the region, this includes all NJ Transit diesel locomotives operating between Hammonton and Atlantic City.

For the passenger rail inventory, the consumption based approach is preferred. The advantages of the consumption-based approach for passenger rail include not assigning emissions to municipalities that the Atlantic City line passes through without a station, and the recognition of the emissions contributed by trips destined to Atlantic City from outside the region. This will allow for better analysis of potential transit and mode-shift measures in the future.

The consumption-based approach requires information on transit trip origins and destinations, the trip distance between the origins and destinations, and an estimate of average GHG emissions per passenger mile. For the Atlantic City line, total boarding's and alighting's data for each station pair by direction would be required, either from the SJTDM (which would identify transit trip origins and destinations by location) or directly from NJ Transit ridership data.

NJ Transit provided the following data to support development of a consumption-based inventory for the Atlantic City line:

- Atlantic City line FY 2010 passenger trips (see **Table 5**)
- Atlantic City Rail 2012 Survey raw passenger trip data (see **Table 6**)
- Atlantic City line annual fuel consumption – Information provided by NJ Transit indicated that in 2010, the Atlantic City Rail Line consumed 1,339,155 gallons of diesel fuel across revenue and non-revenue service.

Table 5: Atlantic City Line FY 2010 Passenger Trips by Origin-Destination Pair

	Atlantic City	Lindenwold	Philadelphia	***TOTAL***
Absecon	36,865	49,927	47,751	*134,543*
Egg Harbor	75,358	23,703	21,638	*120,699*
Hammonton	74,660	26,075	23,042	*123,777*
Atco	56,480	8,282	18,756	*83,518*
Lindenwold	203,915	---	26,920	*230,835*
Cherry Hill	102,898	7,957	56,845	*167,700*
Philadelphia	209,671	---	---	*209,671*
Subtotal	**759,847**	**115,944**	**194,952**	***1,070,743***
Local*				***56,882***
TOTAL				***1,127,625***

* Local represents trips made between Absecon, Egg Harbor, Hammonton, Atco, and Cherry Hill only

The combination of annual ridership data and station to station rail line link distance leads to a calculation of passenger miles. To estimate SJTPO only passenger miles, the data in **Table 5** is reorganized into three trip categories: intra-region, inter-region (50% of total trips allocated to SJTPO), and non-region trips (excluded from the inventory). The survey data (see **Table 7**) is used to estimate the origins and destinations of the trips characterized by NJ Transit as local trips (trips between Absecon, Egg Harbor, Hammonton, Atco, Cherry Hill as presented in **Table 6**), which are then organized into the same three trip categories. Each intra- and inter-regional trip is multiplied by station to station trip length in order to estimate passenger-miles for each origin and destination.

Table 6: Atlantic City Line 2012 Passenger Survey Eastbound Trips by Origin-Destination Pair

	Cherry Hill	Linden-wold	Atco	Hammo-nton	Egg Harbor	Absecon	Atlantic City	***TOTAL***
Friday								
Philadelphia	24	11	9	20	21	41	163	***292***
Cherry Hill		3	1	2	8	8	63	***86***
Lindenwold			1	13	15	26	127	***183***
Atco				1	3	3	34	***44***
Hammonton					1	4	38	***44***
Egg Harbor							18	***19***
Absecon							12	***14***
TOTAL	**24**	**14**	**11**	**36**	**48**	**82**	**455**	***682***
Saturday								
Philadelphia	9	-	2	9	5	33	133	***191***
Cherry Hill		-	1	-	-	10	86	***98***
Lindenwold			2	1	2	6	99	***110***
Atco				-	-	1	26	***27***
Hammonton					1	1	20	***22***
Egg Harbor						1	22	***25***
Absecon							8	***9***
TOTAL	**9**	**-**	**5**	**10**	**8**	**52**	**394**	***482***

The resulting 2010 annual passenger trips and passenger mile estimates are:

- Intra-region = 196,058 passenger trips, 3,653,956 passenger miles
- Inter-region (50% of total trips) = 398,147 passenger trips, 18,937,000 passenger miles
- SJTPO region total = 594,204 passenger trips, 22,590,956 passenger miles

Passenger miles are allocated to jurisdiction based on the origin station and destination station data from NJ Transit. The resulting 2010 passenger mile estimates by municipality, accounting for 50% of each trip to each origin and destination are:

- Atlantic City = 16,440,235 annual passenger miles
- Absecon = 2,885,239 annual passenger miles

- Egg Harbor = 1,495,880 annual passenger miles
- Hammonton = 1,769,602 annual passenger miles

To estimate a fuel consumption rate per passenger mile, total passenger miles for all trips on the Atlantic City Rail line (inside and outside the SJTPO region = 43,141,964 passenger trips) is divided by total gallons consumed as provided by NJ Transit. The resulting diesel consumption rate is 0.03 gallons diesel fuel/passenger mile.

The diesel consumption rate is multiplied by passenger miles by municipality to estimate total fuel consumption. Total fuel consumption is multiplied by the appropriate emission factor and GWP in order to estimate CO_2 equivalent emissions.

Freight Rail

Freight is transported in New Jersey by 14 short line railroads, two regional railroads and three national railroads. In the SJTPO region, the primary lines are Conrail (CSAO), Southern RR of New Jersey (SRNJ), Cape May Seashore Lines (CMSL), and Winchester and Western (WW).

The tonnage of freight within the region is available from NJDOT sources, from NJDEP through data developed for the State GHG Inventory, or from national sources such as the Surface Transportation Board waybill database. The most recent and authoritative source of freight rail tonnage at the county level is the New Jersey State Rail Plan. The plan uses TRANSEARCH data to model both inbound and outbound tonnage by county.

For the consumption based approach, total ton-miles attributable to rail activity is estimated by multiplying the county level totals by the average distance the cargo travels within and outside the region. For the direct based approach, total ton-miles attributable to rail activity only within the region is estimated by multiplying the county level total by the average distance the cargo travels within the county. Due to the alignment of rail corridors, in the direct approach cargo originating/terminating in Cape May County is modeled to transverse Atlantic County before exiting the region.

Given that there are no rail consolidation yards in the region, cargo is expected to travel directly into and out of the region. In addition, the inventory accounts for empty return trains within the region. As these trains are not carrying cargo, the metric of ton-miles per gallon is substituted by hourly locomotive fuel consumption.

Interviews with regional railroads revealed that most locomotives are too old to have a Tier rating. For example, the Winchester and Western uses original GP9 and SP9 locomotives that were constructed in the 1950's. This information was used to calculate the average estimated ton miles per gallon (452 ton miles per gallon). This figure is somewhat lower than the equivalent estimate for Class I rail operations (approximately 484 ton miles per gallon)[30].

The New Jersey State Rail Plan[31] presents destination of inbound rail flows and origination of outbound rail flows by weight and type by county. The base year weight data is 2007, which is assumed for purposes of the inventory to approximately equal 2010 weight data. A factoring process based on county population and proportion of inbound rail flows by county is used to

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[30] Association of American Railroads, Railroad Facts 2012 (Washington, D.C,, 2010) http://www.bts,gov/publciations/national_transportation_statistics/html/Table_04_25.html

[31] NJ Transit & NJ Department of Transportation. *New Jersey State Rail Plan - Final Draft*. Table 2-5 and Table 2-6. December, 2012.

subdivide the remaining category into estimates for Atlantic and Cape May Counties. **Table 7** presents the resulting tonnage data by county.

Table 7: SJTPO Region Carload, 2007 (tons)

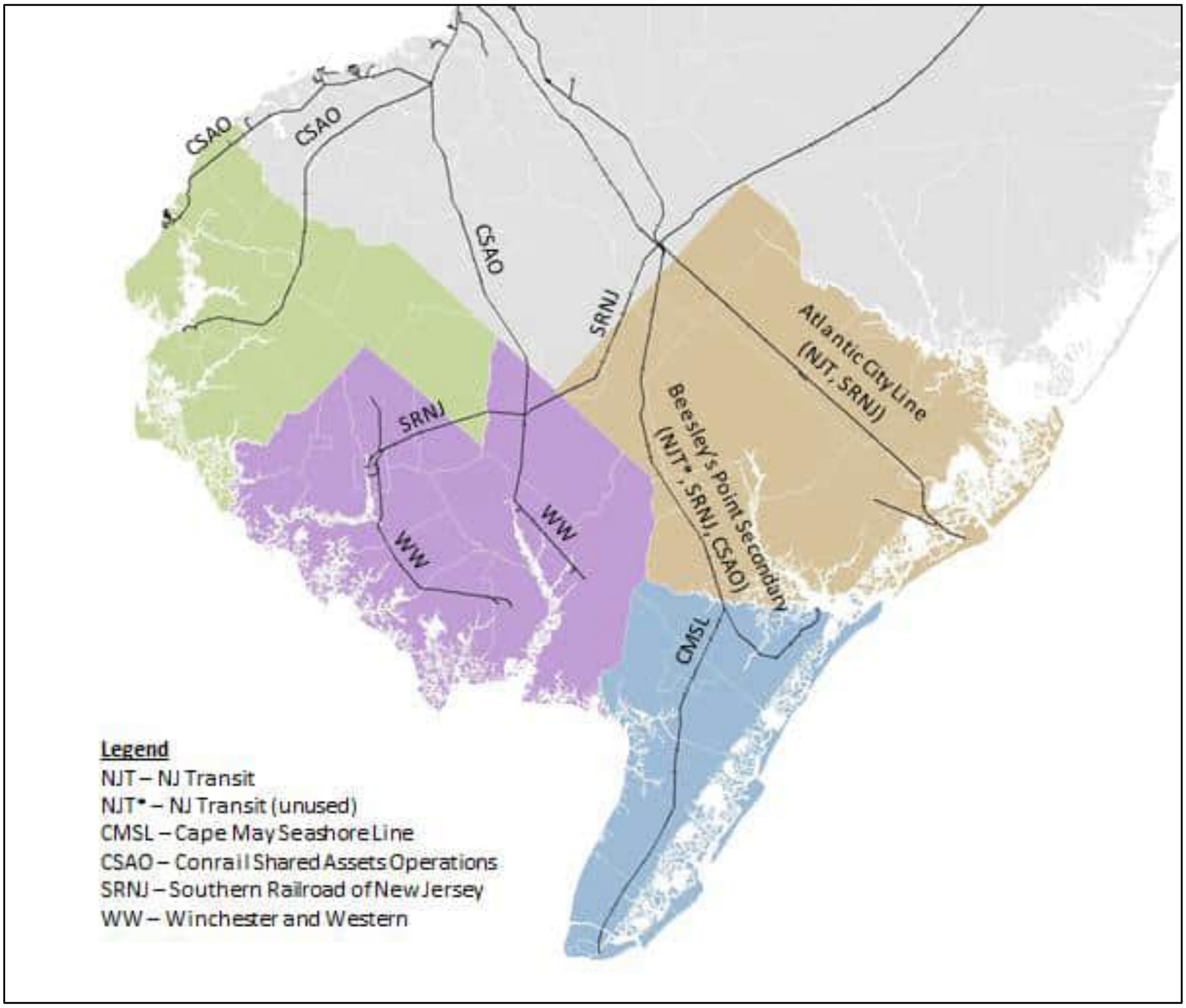
County	Inbound Carload by Destination	Outbound Carload by Origin
Atlantic	150,480	19,510
Cape May	541,899	70,257
Cumberland	261,838	162,100
Salem	1,322,081	286,662
TOTAL	**2,276,298**	**538,529**

Source: New Jersey State Rail Plan, Table 2-5 and 2-6

The regional rail network is presented in **Figure 3**. The rail network was measured to estimate the average rail distance from a typical county origin/destination to the edge of the county (for direct) and edge of the region (for consumption). The approach to estimate average distances is described below:

- *Cape May County*: The majority of rail traffic is destined for the Beesley's Point Generating Station in Upper Township. Some traffic also has an origin or destination at the Waste Management facility in Woodbine Borough. South of Woodbine, the CMSL line is abandoned. The total rail distance from the Camden County line to the Beesley Pont site is estimated at 34.5 miles, and the total distance to Woodbine is 28.5 miles. A weighted distance of 32 miles is assumed.
- *Atlantic County*: Freight trains operated by SRNJ share track with the NJ Transit Atlantic City Line, serving businesses in Pleasantville City, Galloway Township, Egg Harbor Township, Egg Harbor City, Mullica Township, and Hammonton Town. Based on a review of aerial photography, it appears most of the trains access lumber and building supply yards in Egg Harbor Township and Pleasantville City. An average distance of 30 miles is assumed for Atlantic County (most operations on the Beesley Point Secondary and Southern SRNJ Branch are through trips to Salem and Cape May Counties).
- *Cumberland County*: Most trains are destined to Millville, Vineland, or Bridgeton. The weighted distance for these three locations (assuming an even distribution of traffic among the three jurisdictions) is 9 miles.
- *Salem County*: The majority of freight rail activity in 2010 is destined to the Dupont Chambers Works site in Pennsville Township, approximately a 9 mile trip. The Salem Shortline (operated by SRNJ in Salem County) is currently in the process of being rehabilitated and upgraded (however as of 2010 was restricted to maximum speeds of 5 mph) to improve future access to the Port of Salem.

Figure 3: SJTPO Region Rail Lines



Direct

For the direct based approach, the primary difference is within Atlantic and Cape May Counties (**Table 8**). Freight rail ton miles in Atlantic County includes all activity on the SRNJ Atlantic City line as well as the SRNJ/CSAO Beesley's Point Secondary line which provides access to Cape May County.

Ton miles are multiplied by the average fuel consumption rate (452 ton miles per gallon) to estimate diesel consumption. Total fuel consumption is multiplied by emission factors and global warming potentials in order to estimate CO_2 equivalent emissions.

Table 8: SJTPO Direct Based – Freight Rail Movement (ton miles)

County	Total Carload Tons	Miles Within County	Total Ton Miles (millions)
Atlantic (SRNJ AC line)	169,990	30	5.10
Atlantic (SRNJ/CSAO Beesley's Point line)	612,156	24	14.69
Cape May	612,156	8	4.90
Cumberland	423,938	9	3.82
Salem	1,608,743	9	14.48
TOTAL	**2,814,827**		**42.98**

Consumption

For the consumption based approach, these average mileage estimates for travel within the region by county are multiplied by tons to estimate total ton miles (**Table 9**). The estimates for the consumption-based approach utilizing this data only represent total ton-miles within the region, and do not identify through traffic and specific routes. (As mentioned above, there is little to no traffic that would be classified as through traffic.)

Table 9: SJTPO Consumption Based—Freight Rail Movement (in region only)

County	Total Carload (tons)	Distance to Region Boundary (miles)	Freight Movement (million ton-miles)
Atlantic	169,990	30	5.10
Cape May	612,156	32	19.59
Cumberland	423,938	9	3.82
Salem	1,608,743	9	14.48
TOTAL	**2,814,827**	**—**	**42.98**

In order to complete the approach for consumption based emissions, an accounting of emissions associated with the entire trip length (similar to the approach for passenger rail) is required. To accomplish this, estimates of consumption based emissions are generated by multiplying the tonnage originating/terminating within each county by the average distance to the final destination as documented in the Freight Analysis Framework (FAF). The "remainder of New Jersey" FAF region was used as a proxy for the SJTPO region in order to describe the patterns of origins and destinations for the region and develop an average length of haul for inbound and outbound cargo.[32] **Table 10** presents total rail ton miles with an origin and destination in the "remainder of New Jersey" FAF region as documented in 2011.

[32] The remainder of New Jersey FAF region only includes Cape May, Atlantic and Cumberland Counties in the SJTPO region (Salem is located in the Philadelphia Combined Statistical Area FAF region), and Warren County.

Table 10: Remainder of New Jersey FAF Region—Freight Rail Movement

FAF Region	Total Weight (tons)	Freight Movement (ton-miles)	Average Distance (miles)
Origin	282,712	114,337,200	404
Destination	401,653	325,996,800	812
Total	**684,366**	**440,334,000**	**643**

The average rail trip distance of 643 miles is applied to the carload tons by county presented in Table a in order to estimate total ton miles by county (Note: For Salem and Cumberland Counties, 643 miles is used. Rail trips to Cape May and Atlantic County are assumed to be approximately 10 miles longer on average, so 653 miles is used). The total is multiplied by 50% consistent with the consumption accounting approach. The resulting totals are presented in **Table 11**.

Table 11: SJTPO Consumption Based—Total Freight Rail Movement (ton-miles)

County	Total Carload (tons)	Average Trip Length (miles)	Freight Movement (million ton-miles)
Atlantic	169,990	653	55.50
Cape May	612,156	653	199.87
Cumberland	423,938	643	136.30
Salem	1,608,743	643	517.21
TOTAL	**2,814,827**		**908.88**

NON-ROAD INVENTORY

The latest version of EPA's NONROAD model (NONROAD2008a) will be used to calculate CO_2 emissions and fuel consumption for the Non-Road subsector and non-road engines in other sectors. NONROAD provides the best estimate available for emissions down to the county level. N_2O and CH_4 emissions will be calculated based on fuel consumption for each fuel type (*i.e.*, diesel, gasoline, compressed natural gas, and propane), as described for highway fuels. Upstream emissions will be calculated as well for the energy-cycle analysis, based on fuel consumption, as described for highway vehicles.

In the transportation sector, non-road sources include railway maintenance, recreational marine, recreational vehicles (land based), and airport ground support. The NONROAD model will also be used to calculate emissions that will be attributed to other sectors as appropriate, including industrial, lawn and garden, commercial, agriculture, logging (forestry), and construction and mining engines. The emissions from non-road engines associated with those subsectors will be attributed to those subsectors. Other sectors such as construction and non-categorized non-road engines will be included as the Non-Road subsector in Transportation, including recreational vehicles, construction, industrial, lawn and garden, commercial, mining, and oil field engines. Final methodologies as defined in the protocol development (Task 1) will be examined to ensure that double counting does not occur. For example, if natural gas use for non-road vehicles is included in the natural gas supply to the industrial or commercial sectors, this fuel will be excluded from the non-road emissions.

The model will be run according to the latest procedures and assumptions used by NJDEP in SIP preparation, in consultation with NJDEP. These parameters are summarized in **Table 12**. The model estimates emissions for all equipment types by power rating (horsepower), engine load, fuel type, and hours of operation.

Table 12: NONROAD Emission Model Input Parameters

Parameter	Baseline	Future
Reid Vapor Pressure	9.84	
Fuel Oxygen Weight Fraction	3.45%	
Gasoline Sulfur Fraction	0.0387%	
Diesel Sulfur Fraction	0.0165%	0.0011%
Marine Diesel Sulfur Fraction	0.0319%	0.0055%
LPG/CNG Sulfur Fraction	0.0030%	
Minimum Temperature	48.4	
Maximum Temperature	68.1	
Average Temperature	58.3	
Stage II Control Fractions:		
EtOH Blend	100.00%	
EtOH Volume	9.87%	

Sources: NJDEP, direct correspondence, November 25, 2013.

TRANSPORTATION INVENTORY ALLOCATION

On-Road

The method for allocating emissions from the region to counties and municipalities will vary by inventory approach.

For the direct allocation approach, emissions are modeled using SJTDM and MOVES initially at the county scale. Emissions will be allocated to the municipality based on the share of VMT weighted by speed and by vehicle type within each municipality.

For the consumption allocation approach, total annual emissions (based on an average weekday) are generated from SJTDM time-of-day vehicle trip tables, time-of-day congested skims, and average emission rates by speed bin and vehicle type at the TAZ scale. Emissions are then aggregated up to the region, county, and municipality scale based on assigning 50% of emissions from each TAZ to the origin jurisdiction and 50% to the destination jurisdiction.

The full detail of the allocation approach for both direct and consumption inventories for the on-road mobile source transportation sector are presented in **Table 13**.

A regional travel demand model can be too coarse a tool to assess on-road GHG emissions at a municipal scale. In small municipalities, the differences between direct and consumption-based emissions can be very significant. The emission estimates can also be incomplete due to shortcomings in network or TAZ geography. Presenting both direct and consumption-based emissions allow these locations to best understand the role of on-road GHG emissions in their jurisdiction, as well as possible strategies to mitigate GHG emissions.

Aviation

Aviation GHG emissions in South Jersey are expected to be dominated by Atlantic City International Airport. The aviation GHG will be allocated by airport, as a function of available data. These will be allocated directly to the airport location.

Table 13: On-Road Mobile Source Sector Inventory Allocation Approaches

Method:	Direct	Consumption
Description:	Total on-road emissions from VMT derived from SJTDM highway networks at the region, county, and municipal scales.	Total trip-based emissions for all trips with an origin or destination in the SJTPO region at the region, county, and municipal scales. (While this approach excludes the length of the trips occurring outside the SJTPO region boundary, for some trips, long distance trucking and summer seasonal visitor trips will be included in an effort to provide most of the consumption trip emissions and to provide comparable emissions for rail and truck freight.)
Region:	Add emission inventory for the four counties.	Add the emission inventory for the four counties.
County (4):	Run MOVES for each county, incorporating county specific data including VMT and speed distribution.	1. For each trip end (origin or destination), total emissions are estimated based on total time-of-day vehicle trips by type (passenger, bus, commercial/ truck), time-of-day average speed, and emission rates by vehicle type and speed bin output from MOVES.. 2. Emissions are aggregated to each county from the TAZ scale based on 50% assigned to the trip origin county and 50% assigned to the trip destination county.
Municipality (68):	Allocate total county emissions to each municipality based on the share of county VMT by vehicle type within each municipality, while accounting for vehicle speeds.	1. For each trip end (origin or destination), total emissions are estimated based on total time-of-day vehicle trips by type (passenger, bus, commercial/ truck), time-of-day average speed, and emission rates by vehicle type and speed bin output from MOVES. 2. Emissions are aggregated to each municipality from the TAZ scale based on 50% assigned to the trip origin municipality and 50% assigned to the trip destination municipality.

Marine

Emissions from OGVs using the Delaware River Shipping Channel to access the Port of Philadelphia, Port of Wilmington, Port of Camden will not be included in the inventory. All other commercial vessel emissions will be allocated to the county within which the main harbor is located. Most of the harbors in the SJTPO region only accommodate small recreational vessels, and minor fleets of commercial fishing vessels and excursion vessels. The exceptions are:

- In Cape May County, Cape May Terminal (which serves the Cape May – Lewes Ferry operated by the Delaware River and Bay Authority (DRBA)), and Cape May Harbor (which accommodates fishing vessels, excursion vessels, recreational boats, and government boats from the Coast Guard Training Facility);
- In Cumberland County, Port Norris Harbor (large fleet of fishing vessels); and
- In Salem County, the Port of Salem Terminal, which is a 22-acre complex that includes both South Jersey Port Corporation and private terminal related operations. The Port of

> Salem currently handles aggregate (*e.g.*, sand), clothing apparel, fishing apparel, motor vehicles, food products, and consumer goods as part of regular scheduled container service to and from Bermuda. Barbers Basin (privately owned marina within the Port of Salem) serves the Delaware City to Salem (Three Forts) ferry operated by DRBA.

In the case of recreational boats, use of the NONROAD model will support the allocation to counties. Where data is available for commercial vessels, emissions will be allocated to the appropriate county. Marine emissions will not be allocated lower than the county level due to data availability limitations.

Rail

The description of the allocation approach for passenger rail and freight rail is described in detail within the methodology section for each sector. For passenger rail, passenger miles are allocated by municipality based on station boarding and alighting information provided by NJ Transit. For freight rail, ton miles are calculated for each county based on total inbound and outbound tonnage by county as estimated in the New Jersey State Rail Plan.

Non-Road

Non-Road sector emissions are calculated by county according to the method presented above. Due to the significant effort involved in estimating further detailed allocation to the municipality level, the uncertainty involved in such allocation, and the relatively small part of the inventory these sources represent, further allocation is not proposed here. Non-road emissions associated with other subsectors (rail, recreational marine, agriculture, forestry, marine, and aviation) would be allocated using the same metrics and methods applied to each sector.

TRANSPORTATION INVENTORY FORECAST

On-Road Vehicles Forecast

The approach presented in the inventory protocol, above, relies on a combination of VMT and speed data from the SJTDM and the use of MOVES, along with associated MOVES input files supporting SJTPOs FY 2014 air quality conformity analysis. To conduct a 2040 forecast for the on-road sector, the same information is required—SJTDM 2040 model files (consistent with the horizon year of the current regional transportation plan) and MOVES input files for 2040. Interim SJTDM model years can be used to support 2020 and 2030 analysis as required.

To extrapolate to 2050, a constant annual rate of VMT growth obtained from multiple SJTDM model years would be applied to composite emission factors derived for 2050. For VMT growth, the presumption is that forecasted growth in truck VMT within SJTDM accounts for potential mode shifts to the freight and commercial marine sector. If mode share for alternative freight modes is anticipated to increase more significantly as a result of investment or policy strategies, options should be considered as part of a scenario testing approach, not within development of a future emissions baseline. The development of 2050 composite emissions factors will be based off the results for 2040, accounting only for vehicle turnover occurring during the decade, without any application of new vehicle or fuel standards. The expectation is that 2050 regional total GHG emissions will increase compared to 2040 as a results of VMT growth paired with minimal change in overall fleet efficiency.

The critical difference between conducting a GHG inventory using MOVES (specifically MOVES 2010b) and a GHG forecast using MOVES is the extent to which recently approved federal fuel economy/GHG emission standards are accounted for. The difference in emissions through 2040 when accounting for the impact of these standards is significant. For example, the Final 2017-2025 Light-Duty Vehicle Standard, as posted in the Federal register by EPA and NHTSA on

October 15th, 2012, establishes the MY 2025 car and light-duty truck standard at 54.5 mpg, compared to 35.5 mpg for MY 2016.

MOVES 2010b does not include the following GHG standards. Post MOVES adjustments will be made to reflect these, based on an approach consistent with assumptions that Cambridge Systematics developed when developing the NJTPA GHG inventory and forecast.

- *Final rule for MY 2014-2018 medium/heavy duty trucks*: Post MOVES adjustments are made for inclusion in the forecast. The adjustments are based on fractional changes in fuel consumption and greenhouse gas emissions for model year 2018 and later vehicles found in the EPA/NHTSA factsheet[33]. These fraction changes vary by vehicle type as shown in **Table 14**. Linear interpolation between zero and the 2018 values are used get values for model years 2014-2017. The rule is assumed to impact all model years 2014 and beyond. Based on vehicle age distribution by MOVES source type (vehicle 31 type), the share of vehicles conforming to the standards for future can be estimated. The emission rate adjustment factors are summarized in **Table 15**.

Table 14: Adjustments for HD MY 2014-2018 Final Rule

Model Year	GHG Rate % Improvement		
	Combination Truck	HD Pickups & Vans	Vocational
2014	4.00%	3.00%	2.00%
2015	8.00%	6.00%	4.00%
2016	12.00%	9.00%	6.00%
2017	16.00%	12.00%	8.00%
2018 & Later	20.00%	15.00%	10.00%

Table 15: Emission Rate Adjustment Factor for the 2014-2018 M/HDV Standard

Vehicle Type	2020	2035	2040	2050
Light Truck	0.9951	0.9892	0.9891	0.9890
Buses	0.9624	0.9038	0.9010	0.9000
Single Unit Truck	0.9706	0.9116	0.9046	0.9000
Combination Truck	0.9381	0.8192	0.8076	0.8000

- *Proposed rule for MY 2017-2025 light duty vehicles (Alternative Baseline)*: Post MOVES adjustments will be applied to the forecast. The adjustments for the proposed light duty vehicle rule are based on new fuel economy estimates for each model year from 2017-2025,

[33] U.S. Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA). "FACTSHEET: Paving the Way Toward Cleaner, More Efficient Trucks." Available:

http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/Factsheet.08092011.pdf which is included in the summary notes on the final rule as published in October 2012.[34] These fuel economy estimates and the corresponding fraction of improvement in GHG rates are shown in **Table 16**. The rule is assumed to impact all model years 2017 and beyond. Based on vehicle age distribution by MOVES source type (vehicle type), the share of vehicles conforming to the standards for future years can be estimated. The vehicle age distribution by source type is based on SJTPO MOVES input data. The emission rate adjustment factors are summarized in **Table 17**.

Table 16: Adjustments for LD MY 2017-2025 Final Rule

Model Year	Fuel Economy (mpg)		GHG Rate % Improvement	
	Passenger Cars	Light Trucks	Passenger Cars	Light Trucks
2016 Base	37.8	28.8	—	—
2017	40.0	29.4	5.82%	2.08%
2018	41.4	30	9.52%	4.17%
2019	43.0	30.6	13.76%	6.25%
2020	44.7	31.2	18.25%	8.33%
2021	46.6	33.3	23.28%	15.63%
2022	48.8	34.9	29.10%	21.18%
2023	51.0	36.6	34.92%	27.08%
2024	53.5	38.5	41.53%	33.68%
2025 & Later	56.0	40.3	48.15%	39.93%

Table 17: Emission Rate Adjustment Factor for the 2017-2025 LDV Standard

Vehicle Type	2020	2035	2040	2050
Passenger Car	0.966	0.585	0.537	0.520
Light Truck	0.978	0.658	0.631	0.620

If MOVES2014 is available for use when SJTPO conducts the GHG emissions forecast, the post-processing steps detailed above will not be required.[35] However, since MOVES2014 will be considered a new model for SIP and conformity purposes with a new conformity grace period, it is anticipated SJTPO may not be using the updated version of MOVES as part of conformity of GHG emissions analysis until late 2014 or more likely 2015. The most recent information on the release of MOVES2014 is that EPA is waiting for finalization of the Proposed Tier 3 Vehicle Emission and Fuel Standards program submitted by EPA for public comment in March 2013.[36] The intent is for MOVES2014 to also incorporate the impact of these the Tier 3 standards into the next model release.

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[34] http://www.epa.gov/otaq/climate/regs-light-duty.htm#new1

[35] The updated MOVES model was originally called MOVES2013. The new name “MOVES2014” reflects the anticipated release date later this year following finalization of the Tier 3 standards.

[36] Additional information available here: http://www.epa.gov/otaq/tier3.htm

Aviation Forecast

Future-year aviation emissions will be projected using general aviation and commercial aircraft operation projections data from the FAA's TAF.[37] Forecast year estimates will be adjusted to reflect the projected increase in national aircraft fuel efficiency (indicated by increased number of seat miles per gallon) as reported in the Annual Energy Outlook (AEO).[38]

Table 18 presents the forecast years (2015, 2020, 2025, 2030, 2035, 2040, 2045, 2050) annual operations by aircraft category (air carrier, air taxi, general aviation, and military)[39] for Atlantic City International Airport. The forecast year's annual operations for the eight general aviation airports within the SJTPO will be assumed to remain the same as the baseline year. Growth in ground support equipment emissions, analyzed using the NONROAD model, will be based on the growth in aircraft operations.

Table 18: Annual Airport Operations by Aircraft Category—Forecast Years
Atlantic City International Airport

Year	Air Carrier	Air Taxi	General Aviation (TGO)	General Aviation (LTO)	Military (TGO)	Military (LTO)
2015	9,369	6,187	4,852	20,999	17,501	18,445
2020	9,669	6,502	5,139	21,493	17,501	18,445
2025	10,143	6,832	5,444	21,999	17,501	18,445
2030	10,815	7,179	5,767	22,518	17,501	18,445
2035	11,721	7,542	6,108	23,049	17,501	18,445
2040	12,906	7,929	6,470	23,593	17,501	18,445
2045	14,091	8,316	6,832	24,137	17,501	18,445
2050	15,276	8,703	7,194	24,681	17,501	18,445

Source: Federal Aviation Administration Terminal Area Forecast (TAF), http://aspm.faa.gov/main/taf.asp

Marine Forecast

Commercial Marine

Future assumptions of marine activity should take into account the future capacity of the Salem terminal. With only one weekly vessel call, container operations at the Salem container terminal have the potential for significant growth if poor highway access and virtually unusable rail access is upgraded. There are a number of plans that document the potential for growth at the Port of Salem:

[37] Federal Aviation Administration, Terminal Area Forecast, http://aspm.faa.gov/main/taf.asp, accessed January 2014.

[38] US DOE, Annual Energy Outlook, Transportation Supplement, http://www.eia.doe.gov/oiaf/aeo/supplement/index.html, accessed January 2014.

[39] Commercial aircraft include those used for transporting passengers, freight, or both. Commercial aircraft tend to be larger aircraft powered with jet engines. Air Taxis carry passengers, freight, or both, but usually are smaller aircraft and operate on a more limited basis than the commercial aircraft. General Aviation includes most other aircraft used for recreational flying and personal transportation. Finally, military aircraft are associated with military purposes, and they sometimes have activity at non-military airports.

- *Southern New Jersey Freight Transportation and Economic Development Assessment***:** The investment blueprint included in this plan notes improvements to the Salem Secondary and Salem Shortline railroads, added capacity at the Port of Salem, and improvements to Route 49 from I-295 to Salem. In total these projects are estimated to cost a total of $63.6 million to implement.[40]

- *Application for the Designation of the New Jersey Marine Highway Platform*: The application notes that the southern portion of New Jersey has unique industries and strength—this area is one of the largest US producers and exporters of agricultural products, including grain, soybeans, fruits, vegetables and seafood. The area also includes significant deposits of sand and silica that is valuable for glass and solar panel production, as well as construction projects. However, the area has significant transportation barriers to the effective movement of these commodities to key markets. Currently, no direct rail service exists between the northern and southern portions of the State, meaning that heavy bulk products, such as aggregates from southern New Jersey, cannot be readily or cost effectively utilized for construction projects in the New York City area. The application also notes that marine highway service from Salem to Northern New Jersey/New York would be a more cost effective option than improving rail infrastructure. The application forecasts the potential of up to 750,000 annual tons of cargo shipped from Salem to locations such as New York, Baltimore, and Norfolk.

As part of a TIGER III grant award for $18.5 million, improvements are underway on the Salem Shortline, including $3.5 million to replace the Oldmans Trestle Bridge and $800,000 for Salem track rehabilitation and replacement. These projects are expected to be completed in early 2015, resulting in improvement in train speeds to 10 to 25 mph (up from 5 mph currently).[41]

For the Cape May–Lewes Ferry, the preferred forecast approach is to model a rate of growth in total service consistent with population growth in Cape May County, Atlantic County, and Sussex County, Delaware. Through 2040, it is anticipated that the five vessels making up the fleet (all built in the 1970s and 1980s) would have either been retrofitted with engines meeting the most recent off-road heavy duty diesel engine standards, or replaced with newer, more fuel efficient vessels.

For all other commercial marine vessel activity, growth is likely to occur consistent with population and employment change in the region.

Recreational Marine

Forecast recreational Marine emissions, analyzed using the NONROAD model, will be based on the growth assumptions built in to the EPA NONROAD model.

Rail

Passenger Rail Forecasting Approach

Growth rates for passenger activity on the Atlantic City rail line can be obtained from NJ Transit or drawn from outputs of the SJTDM for model year 2010 compared to 2040.

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[40] New Jersey Department of Transportation. Southern New Jersey Freight Transportation and Economic Development Assessment. December, 2010. http://www.state.nj.us/transportation/freight/plan/ pdf/sjfeda_final.pdf

[41] South Jersey Port Corporation. *PortoCall*. Spring 2013. http://www.southjerseyport.com/upload/news/135_DocFile_POCMAG2013-web.pdf

Freight Rail Forecasting Approach

The New Jersey State Rail plan provides estimates of originating and terminating rail cargo tonnage for the SJTPO counties through the year 2035. These estimates are based on assumptions in the growth in key commodities and changes in population. In most cases, these demand rates of growth are modest and should not be significantly impacted by capacity constraints or changes in capacity. For this reason, the forecast estimates can be accepted as plausible future totals for rail tonnage activity by county for the SJTPO region. As the horizon year of this study is 2050, the trends should be extended in a linear fashion to this year based on the rate of change from 2007 to 2035.

Average freight rail trip distances for the consumption based approach can be developed from the Freight Analysis Framework for 2040 following the same approach conducted for 2010. It is assumed that freight rail trip distances projected for 2040 are representative of future conditions in 2050 as well.

Non-Road Forecast

Future-year (2015, 2020, 2025, 2030, 2035, 2040, 2045, 2050) non-road equipment and vehicles emissions will be estimated using the NONROAD model based on forecasted activity levels. Growth assumptions will be based on the EPA model data (the NONROAD model uses economic input/output data adjusted for each county) other than for specific sectors where growth projections specific to the sector will be developed and applied also to the non-road engines (*e.g.*, growth in emissions from agricultural engines will be tied to growth in crop output)—see the description for each sector in each sector's Forecasting section,

Industrial Processes

Industrial Process emissions include CO_2, CH_4, sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and N_2O released as by-products from industrial activities, excluding combustion of fuels and electricity use (which would be included in Direct Fuel Use and Electricity Consumption emissions from the RCI sector), and from the use of refrigerants and SF_6. Also included in this sector are CH_4 emissions released from the distribution of natural gas (although not technically a 'process' emission, this is included here since the fossil fuel industry is not called out as a separate sector).

The Industrial Process sector in the EPA National Inventory, prepared based on IPCC guidance, includes iron and steel production, cement production, lime production, ammonia production and urea consumption, limestone and dolomite use (*e.g.*, flux stone, flue gas desulfurization, and glass manufacturing), soda ash production and use, aluminum production, titanium dioxide production, CO_2 consumption, ferroalloy production, phosphoric acid production, zinc production, lead production, petrochemical production, silicon carbide production and consumption, nitric acid production, and adipic acid production. Also included are the use and release of fluorinated compounds from the use of ozone depleting substance (ODS) substitutes for cooling and refrigeration equipment and from industries such as aluminum production, HCFC-22 production, semiconductor manufacture, electric power transmission and distribution, and magnesium metal production and processing.

This sector comprised approximately 2% of the New Jersey State GHG emissions in 2000, and about 5.0% of New Jersey's gross GHG emissions projected for 2020. Many of the above mentioned sources, including some larger ones such as cement, iron, and steel production (which were explicitly identified in the request for this proposal), are not found in New Jersey. The sources identified in the New Jersey I&F are consumption of limestone and soda ash, nitric acid production, the use of ODS substitutes, semiconductor manufacturing, and electric power transmission and distribution.

There are no major refineries in the SJTPO region.

Natural gas distribution emissions are a portion of the upstream emissions for fuel consumption, included in the energy-cycle emissions, which will be presented for fuel consumption from the RCI sector. Regarding ODS, SF_6, and other compounds which are ultimately to be included in the protocol, a literature review will be undertaken to identify any available factors for upstream emissions, and upstream emissions can be included, under the optional effort, where applicable. Given the high GWP for these substances, we expect that upstream emissions will be small compared with the direct emissions.

INDUSTRIAL PROCESSES INVENTORY

Direct Emissions

Detailed data regarding the manufacturing output and usage of all of the substances included in this sector within the SJTPO region are not available, and the level of effort required to produce such data would be well beyond the scope of this proposal. Furthermore, this sector is expected to have a small footprint overall, and it is unlikely that actions to mitigate these emissions can be taken at the local level. Therefore, the approach for the Industrial Process sector will be to allocate the emissions of this sector from the New Jersey I&F and/or the National Inventory, based on the methodology provided by the *Draft Regional Inventory Guidance* (EPA 2009). In cases where the New Jersey I&F is used, and where the New Jersey I&F was based on the National Inventory, the data will be updated as necessary based on the latest National Inventory.

Consumption-Based Emissions

In addition to direct Industrial Process sector emission, we will calculate emissions associated with the consumption of cement and steel (*e.g.*, for construction). This will include the upstream emissions associated with extraction, production, and transport of these materials and would be very useful when assessing measures such as recycling construction materials, enhanced use of cement replacements, or extending the lifetime of existing structures. While this does not include all consumption of products associated with industrial process emissions, it does provide useful data for these specific common products which can be part of mitigation efforts.

INDUSTRIAL PROCESS INVENTORY ALLOCATION

For ODS substitutes, the emissions are associated with the use of refrigerants, and therefore their geographic distribution can be estimated to be correlated with population. This method would be used to allocate the state-wide emissions down to the region, counties, and municipality levels.

The release of SF_6 from electric power transmission and distribution can be estimated for the SJTPO region and further allocated down to the county level based on the proportion of the electric power consumption in each area relative to the State of New Jersey. Similarly for natural gas distribution losses, allocation will be based on the allocation of natural gas consumption emissions (from the RCI sector). Although this method could be used to further allocate emissions down to the municipality level, since the actual release is associated with specific transmission facilities, this would not likely produce an accurate allocation at that level. Furthermore, the utility of that information at the municipality level would be limited since the expected emissions would be a very small component of the inventory, and actions to reduce these emissions are not likely to be taken at the municipal level.

As for the rest of the compounds, since emissions are generally associated with the process rather than the distribution or consumption, allocation would be based on the number of facilities for each industry. While developing the protocol, the available statistics regarding the existence of such facilities in the region will be estimated using the U.S. Census Bureau's *County Business Patterns* database and other data sources, which may be found during the protocol development, and where relevant, will be included. These emissions will not be further allocated down to the county or municipality level due to the limited information regarding facility distribution and the output of facilities in each area. In the future, local action regarding specific facilities should be considered based on detailed local information, whereas region-wide actions can address the larger sources without specific allocation data.

INDUSTRIAL PROCESS INVENTORY FORECAST

The forecast of emissions in the direct industrial process sector will be based on metrics appropriate to the consumption or production of each source type, as outlined in **Table 19**. Emissions associated with transmission and distribution of natural gas and electricity will be assumed to grow in direct correlation to the growth in the amount of natural gas and electricity consumed (*i.e.*, based on the forecast for those components of the inventory.)

Table 19: Growth Metrics for Industrial Process and Natural Gas Transmission

Subsector	Growth Metric
Limestone Use	Employment
Soda Ash Production and Use	Employment
Nitric Acid Production	Employment
Semiconductor Manufacture	Employment
Fluorinated Compounds (ODS substitutes) for Cooling and Refrigeration Equipment	Population
Fluorinated Compounds (ODS substitutes) for Aerosols, Foams, Solvent, Fire Protection	Population
Electric Power Transmission and Distribution (SF6)	Electricity Consumption
Natural Gas Transmission and Distribution Loss	Natural Gas Consumption

In the consumption analysis, emissions will be provided only for consumption of concrete and steel. Forecast of these emissions will be based on the best available consumption forecasts for these products in existing at the time the forecast is undertaken. The NJTPA analysis used forecasts available from industry studies—*Long-Term Cement Consumption Outlook*[42] and *Freight Analysis Framework*[43]—which can be used here unless newer estimates are available.

Waste Management Sector

The waste management sector includes two primary subsectors: solid waste management and wastewater treatment. Each of these is discussed separately below.

SOLID WASTE INVENTORY AND ALLOCATION

Baseline for the municipal solid waste (MSW) sector will be developed using state-of-science methods for analyzing solid waste management that address all of the GHG emissions

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[42] Portland Cement Association. *Long-Term Cement Consumption Outlook*. May 30, 2006.

[43] FHWA. *Freight Analysis Framework (FAF*^{3}*)*. http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/.

associated with the management of waste generated within each of the region's municipalities. This represents a consumption-based approach for emissions accounting. In contrast, a direct accounting approach would only capture GHG emissions from waste management activities within the region's boundaries (*e.g.*, landfills, composting sites, combustion facilities).

Due to the amount of waste exporting that occurs within New Jersey, a direct accounting approach provides a poor accounting of emissions attributable to the management of waste generated by SJTPO residents and businesses. This is clearly shown in the NJTPA results shown in **Figure 4** and **Figure 5** below.[44] Direct emissions are shown to be relatively low overall and declining over time since most waste is exported and NJTPA landfill CH_4 emissions are declining over time. On the other hand, a consumption-based approach indicates an upward trajectory in emissions. This is due to increased waste generation within the NJTPA region and the use of an approach that captures emissions regardless of where they occur (*e.g.*, a landfill in Pennsylvania).

Figure 6 below provides an illustration of how important it is to take a full energy-cycle view of GHG emissions, especially in the waste sector. Ocean County, New Jersey has a single closed landfill with emissions that are diminishing over time (with no further action by the County, as shown in the green wedge). However, the purple wedge shows that when all waste management is addressed (including exported waste), then the emissions are remaining fairly static during the forecast (even with higher levels of recycling, increasing generation rates keep emissions from going down). Finally, the blue-green wedge shows that when the energy-cycle emissions are addressed, the emissions are actually still increasing fairly dramatically due to higher future waste generation. Standard direct (downstream) approaches to assessing the waste sector fail to identify these important issues and subsequent opportunities to achieve GHG reductions and broader sustainability metrics (*e.g.*, through reduced waste generation).

The EPA draft Regional Guidance does not recognize the importance of the issues presented above and somewhat myopically addresses only solid waste management from a landfilling perspective. DVRPC and NJTPA have addressed solid waste management emissions using a consumption-based approach which captures waste management emissions occurring both within and outside of each jurisdiction as a result of managing all waste generated within each jurisdiction. Based on the above, a set of both direct and consumption-based estimates will be developed. Much of the direct emissions estimates have to be developed in order to develop the consumption-based estimates. Energy-cycle estimates addressing upstream emissions for all waste generated in the region will not be included in the inventory (note that fuel consumption in this sector and its associated energy-cycle emissions are included under RCI).

Both the solid waste and wastewater treatment sectors can be further broken down into municipal and industrial components. We don't anticipate much industrial activity within the SJTPO; however, we intend to contact NJDEP for any available data on industries that may operate within the region that have their own solid waste management processes (and wouldn't be captured within the Industrial Processes sector) or wastewater treatment processes. If these sources are identified, emissions data will be obtained directly from NJDEP or via the EPA GHG Reporting Program data. If emissions data are not directly available, emission estimates will be developed based on reported industrial activity (*e.g.*, production) and standard EPA or IPCC methods. The rest of the discussion on the waste sector is devoted to municipal waste management.

[44] North Jersey Transportation Planning Authority, Final GHG I&F Report: http://www.njtpa.org/plan/Element/Climate/documents/NJTPAGHGInventoryFINALReport_pdf.pdf

Figure 4
NJTPA Region Direct Emissions from MSW Management

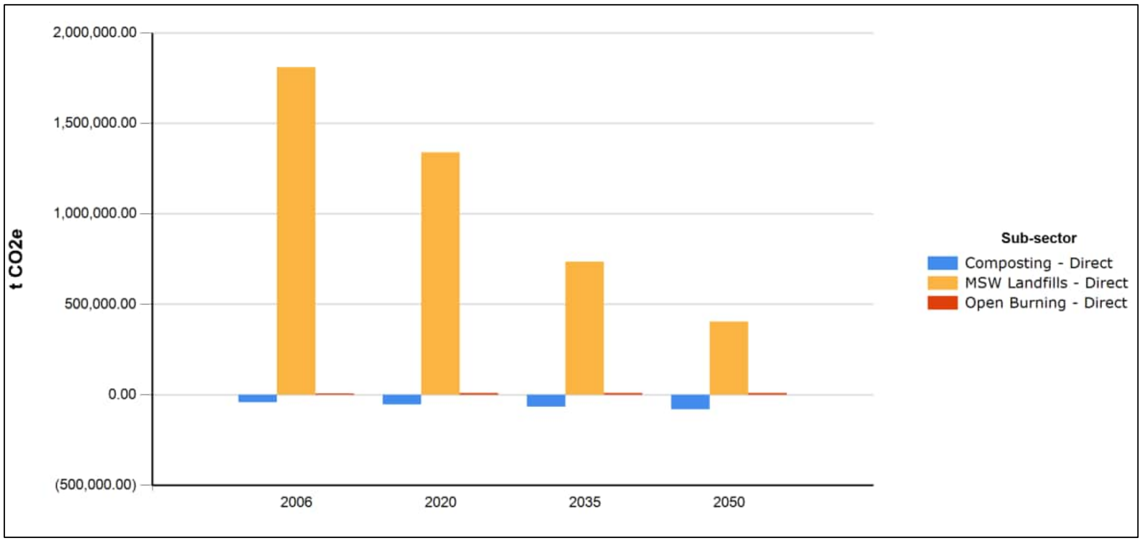


Figure 5
NJTPA Region Consumption-Based Emissions from MSW Management

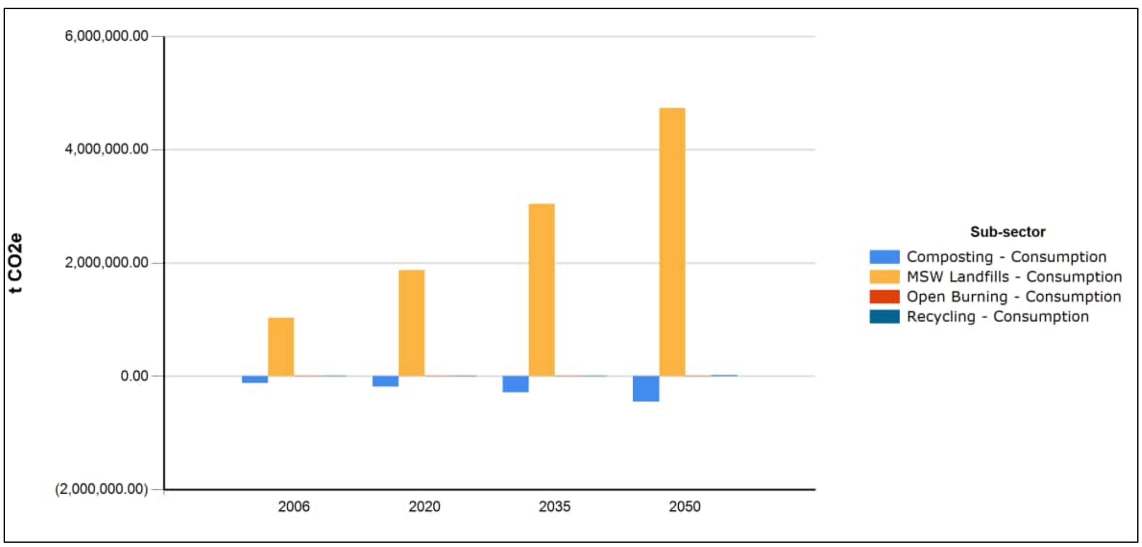
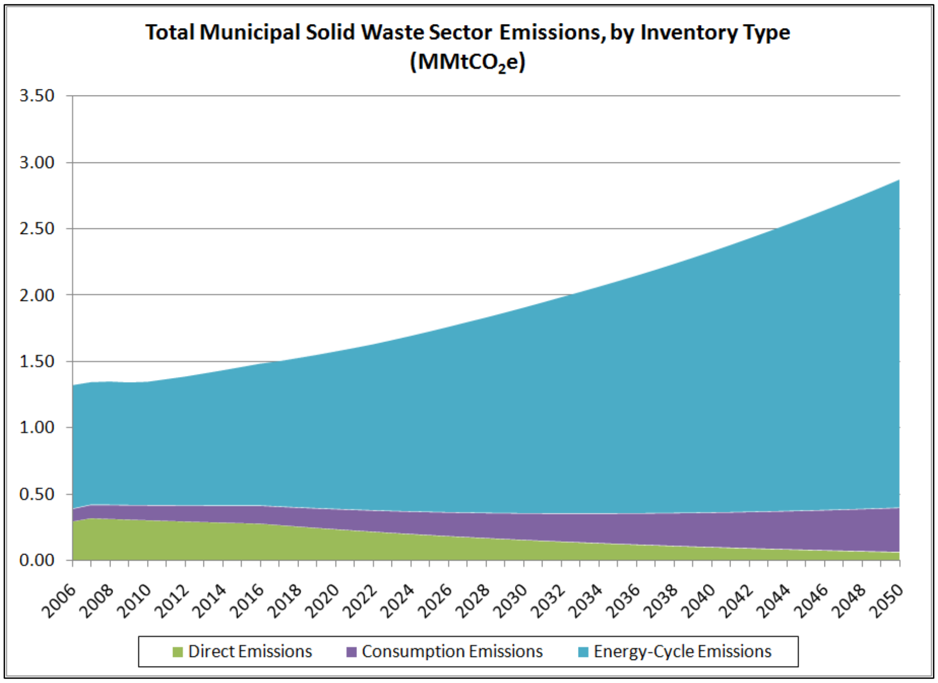


Figure 6
Ocean County, NJ, 2008 Emissions Comparison



North Jersey Transportation Planning Authority, Final GHG I&F Report:
http://www.njtpa.org/plan/Element/Climate/documents/NJTPAGHGInventoryFINALReport_pdf.pdf

Solid Waste Direct Emissions

These will include emissions from landfills (both open and closed) within the region), composting operations, and waste combustion (for non-energy purposes). For these analyses, we employ tools such as the EPA Landfill Gas Emissions Model (LandGEM[45]), standard EPA or IPCC emission factors for composting and waste combustion, and activity data from each SJTPO waste management department and NJDEP[46]. NJDEP can provide information on the municipal location of both landfills and composting operations. NJDEP data on the amounts and types of feedstocks composted will be used along with the standard emission factors mentioned above to estimate CH_4 and N_2O emissions.

For open landfills, we intend to use CH_4 generation data supplied by NJDEP (as was done for our NJTPA work) and for sites that employ CH_4 controls, we will apply standard assumptions for collection efficiency (75%) and CH_4 oxidation in surface soils (10%). In a situation where NJDEP has not already modeled landfill CH_4 generation, we will use the EPA LandGEM model to develop those estimates. In such cases, NJDEP data on landfills will be supplemented with locally-available data from each waste management department (*e.g.*, landfill CH_4 controls, site operating history).

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[45] http://www.epa.gov/nrmrl/appcd/combustion/cec_models_dbases.html.

[46] Locations for landfills are available at NJDEP's searchable database: http://www.nj.gov/dep/dshw/lrm/landfill.htm. There are currently 135 landfills in the region.

There are a large number of small closed landfills within the state (>300), including many in the SJTPO region. NJDEP's previous analysis of the potential CH_4 contributions from these sites indicated a low level of potential contribution due to their size and age (<5% of landfill CH_4 totals at the state level). As a result, they were excluded from the NJTPA inventory; we recommend that SJTPO adopt a similar approach.

For solid waste combustion (for non-energy purposes), we will survey both NJDEP and local agencies to determine whether any of this activity occurs in the region. For our work in NJTPA, NJDEP acknowledged that some amount of residential open burning may occur in the state, particularly in rural areas. Therefore, we intend to use a similar approach to developing emission estimates for SJTPO. This uses results from a study conducted by the Mid-Atlantic/Northeast Visibility Union[47] for county-level activity data on open burning and emission factors from EPA and IPCC.

Local agencies will be surveyed for historical data on waste combusted and composted at the county-level in addition to the selected base year. These additional data are needed to support the consumption-based estimates described below. In summary, direct solid waste management sector GHG emissions will include CO_2, CH_4, and N_2O from landfilling, waste combustion (for non-energy purposes), and composting for all operations located within the SJTPO region.

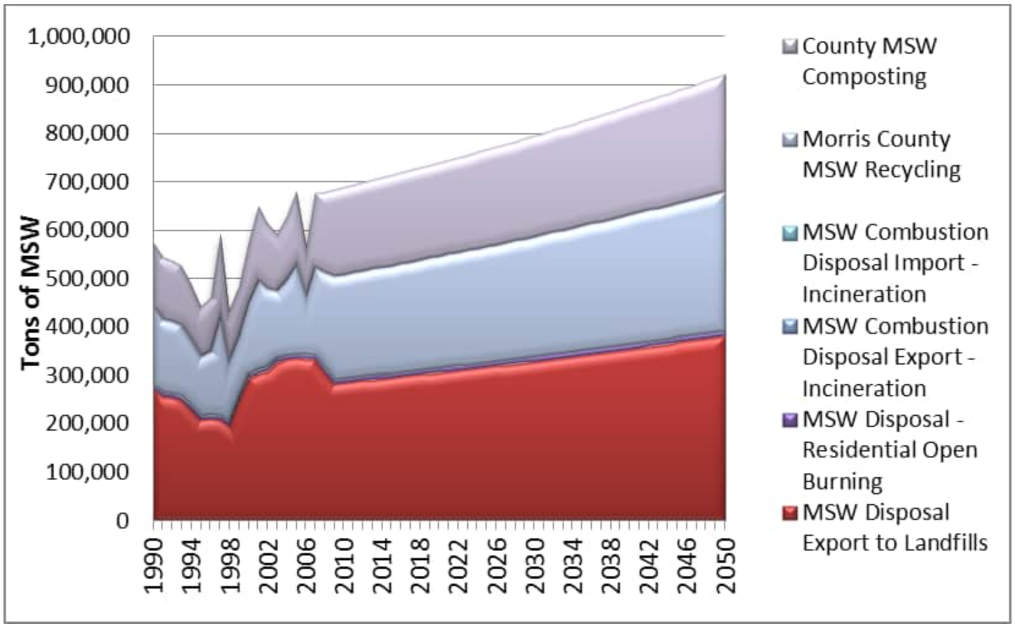
Direct emissions (landfill methane) do not vary seasonally, so the summer season estimates will be derived as one-fourth of the annual total.

Solid Waste Consumption-Based Estimates

In order to prepare the base-year inventory and develop information to support the forecast protocol for a consumption-based emissions inventory, it will be necessary to complete a historical and projected MSW management profile. Survey methods developed and successfully applied for the NJTPA project will be used to conduct these surveys of local waste management agencies. At a minimum, each of the four SJTPO counties will be surveyed and a profile generated. In addition, through discussions with SJTPO and the Technical Advisory Committee for this project, we will determine if there are any large municipalities that employ waste management practices that are significantly different than the county in which they are located (*e.g.*, due to much different waste generation rates, recycling rates, composting rates). The waste management profile uses existing data as a basis to identify the amount of waste generated, landfilled, combusted, recycled, and composted in each year from at least the base year if not earlier through a selected forecast year (*e.g.*, 2035 or 2050). The forecast portion of the waste management profile is based on the average annual growth in per-capita waste generation through the most recent year of data available, the most recent rates of landfill disposal, combustion, recycling, and composting. **Figure 7** below provides an example for Morris County from the NJTPA project. Most waste in that county is managed via a combination of recycling, composting, or exported for landfill disposal (only small amounts of open burning occur and no incineration is practiced).

[47] E.H. Pechan and Associates. 2004. "Open Burning in Residential Areas, Emission Inventory Development Report." Available at: http://www.marama.org/visibility/OpenBurn/OB_FnlReport_Jan31_04.pdf.

Figure 7
Morris County, NJ MSW Management Profile



A profile will be developed for each SJTPO county from data available from NJDEP. This should cover historic landfill disposal, combustion, recycling, and composting. When these initial profiles are complete, a copy will be sent to each county waste management director in order to review and improve these data. Follow-up will be done individually with each survey contact via email and phone conversations to assure that data requirements needed to support the solid waste profiles are understood. The counties will be asked to review/supply the amount of waste generated that was disposed of in-county/municipality and exported outside the county to landfills and/or waste combustion units, the amount of waste collected that was eventually recycled and composted, and the composition of waste generated, disposed, or diverted within the county. The counties/municipalities will be asked to supply data for each year available, but will be informed that the selected base year will be the most vital year for this project. The counties will also be asked whether there are any large municipalities within their jurisdiction that have significantly different waste management systems than the rest of the county (*e.g.*, much different recycling rates, different fractions of waste managed locally versus exported out of the municipality, etc.).

Based on the waste management profiles for each county/municipality, downstream GHG emission estimates will be developed for each of the waste management methods (combustion, landfilling, composting). Methods to develop emission estimates (models, emission factors) will mirror those described above for the direct emission estimates.

For the consumption-based estimates, a set of emissions will also be calculated for waste transport. Transport distances will be established for each county/municipality through the local survey work. Emissions per ton-mile transported will be based on defaults from EPA's Waste Reduction Model (WARM).[48] The transport estimates will overlap those in the on-road transport

[48] http://epa.gov/epawaste/conserve/tools/warm/index.html.

sector and will be designated as such, so that the user is aware of possible double-counting issues in any summation of emissions across sectors.

In summary, consumption-based MSW management sector GHG emissions will include CO_2, CH_4, and N_2O from landfilling, waste combustion (for non-energy purposes), waste transport, and composting for all waste generated within the SJTPO region, regardless of where it is managed.

The development of summer seasonal emission estimates will be different for direct versus consumption-based accounting methods. Consumption-based emissions are driven by population and the waste generation rates of each population. Information from the county surveys on monthly solid waste generation will be used along with the incremental summer season population in order to estimate separate waste generation rates for year round residents versus summer season residents/visitors. These separate incremental estimates of waste generation will be used to estimate incremental GHG emissions for each waste management method. The summer season estimates will then be a sum of waste generated by year round residents + summer residents + visitors.

The seasonal discussion for the wastewater treatment sector below provides an example of how the seasonal population data would be used to derive separate summer resident and visitor populations on an annual basis.

WASTEWATER TREATMENT INVENTORY AND ALLOCATION

Direct emissions from the wastewater treatment (WWT) sector include CH_4 and N_2O emissions from municipal wastewater treatment facilities. These are process emissions only. Any fuel combustion-related emissions in the WWT sector are included within the industrial/commercial/institutional fuel combustion sector totals. A bigger issue with WWT is the use of electricity, which is captured within the industrial/commercial/institutional electricity consumption sectors. Since utilities are not likely to provide facility-specific electricity consumption data, it often isn't possible to assign electricity consumption-based emissions to specific facilities or even the WWT subsector.

For the purposes of this project, we assume that the direct N_2O emissions include both those that occur on-site as well as indirect N_2O emissions that occur downstream in the receiving waters of the plant. For simplicity, as well as accurate source attribution, all emissions are assigned to the actual WWT plant.

For municipal WWT, the the population-based methods from the New Jersey state I&F and recommended by EPA will be used in the draft Regional Guidance to estimate emissions. County-level emissions will be developed by applying CH_4 and N_2O emission factors to the population for each county. The county emissions will then be allocated to each municipality with one or more WWT plants based on the average daily volume treated provided by NJDEP (this is the same approach as applied for the NJTPA project). The N_2O emissions from biosolids management will also be estimated using the methods outlined in the EPA draft Regional Guidance. This will require that information be gathered on how biosolids are managed within the region; in particular, the fraction of biosolids used as fertilizer. We will survey both county wastewater treatment agency staff and NJDEP as needed to gather this information.

For summer seasonal emissions, summer seasonal population data will be used to construct a set of separate incremental GHG emissions estimates associated with seasonal residents and visitors. We will first use "Total Population" to estimate emissions for year round residents. Separate summer season estimates will be calculated for: "summer weekday household", "summer weekend household", "summer weekday visitors", and "summer weekend visitors" (we understand the weekend populations to be the incremental values of weekend and weekday values). As an example for 2020 for the SJTPO region, for use in GHG emissions calculations, an annual equivalent population for summer weekend households would be calculated by first subtracting summer weekday households (965,201) from summer weekend household (1,011,674) to yield 46,473. The annual equivalent is determined by multiplying this value by 24/365, which yields 3,056 (24 is the number of weekend days during the summer season). The supporting data in the sector spreadsheet will contain these estimates which should be useful in subsequent mitigation planning.

WASTE MANAGEMENT INVENTORY FORECAST

For solid waste management, direct emissions from landfills, the modeling of methane emissions from these sites that is conducted for the inventory estimates will also produce modeled emissions for the forecast period. We will need to gather information from county contacts about whether there will be any changes in landfill gas management during the forecast period and will factor those changes in during forecast development (e.g. installing gas collection and flaring systems, suspension of gas collection/flaring).

For the consumption-based solid waste emissions forecast, future waste generation will be modeled by extrapolating county-level generation rates and multiplying this value in each year by the population forecast. Using monthly county-level generation data, separate growth rates will be developed for waste generation for the year round residents versus summer seasonal residents. Then, information on future solid waste management gathered during the county surveys will be used to forecast the fractions of waste managed by each method (*e.g.*, locally landfilled, exported for landfilling, exported for waste combustion, recycled, composted). Finally, the emissions associated with each management method will be estimated in a manner that is consistent with the inventory estimates (with the exception of known changes to future waste management practices, such as future collection of landfill gas at local landfills).

For wastewater, since the emissions estimation method is tied to population, we will forecast GHG emissions for this subsector using growth rates derived from the population forecasts of RTP 2040. We will discuss with both NJDEP and county contacts whether there is any information that would support additional revisions to estimation methods other than the change in activity indicated by population growth rates. These would include possible changes to the fraction of the population served by centralized treatment in the future and changes to biosolids application. If such changes to future management are identified, we will integrate these changes into the future calculation of GHG emissions.

Land Use, Land Use Change, and Forestry

FORESTED LAND USE INVENTORY AND ALLOCATION

For this sector, only direct emissions/sink estimates will be developed. Conceptually, a consumption-based set of estimates for forestry would also capture the emissions associated with the consumption of forest products by each community's population (*e.g.*, wood products, fiber products). Some of these emissions are captured within the consumption-based estimates for the solid waste management sector (*e.g.*, those forest products that find their way into the solid waste stream); however, a complete consumption-based accounting for the forestry sector is well beyond the scope of the project outlined by SJTPO.

Consistent with the methods suggested in the EPA draft Regional Guidance and that were used for the NJTPA I&f, estimates of net CO_2 sequestration/emissions will be developed using two primary sources of input data:

1. Estimates of carbon stocks for SJTPO region forests at the county-level: these will be derived from the US Forest Service (USFS) and National Council for Air and Stream Improvement (NCASI) Carbon On-Line Estimator (COLE).[49] We will contact the New Jersey Forest Service to discuss whether the county-level data currently available within COLE are precise enough for use in estimating carbon stocks. Previous efforts (most recently DVRPCs inventory updates) have found problems using the COLE data due to insufficient coverage of the underlying USFS Forest Inventory Analysis (FIA) survey data. These surveys are done on a rotating basis (5 or 10-year cycles); so depending on where the surveys are for southern NJ, the use of state-level carbon density estimates instead may be necessary.

2. Municipal-level estimates of forest acreage and their historical trends: for this input, we will develop GIS data on forested acreage using land use/land cover (LULC) data available from DEP for each municipality or at the Watershed Management Area (WMA) level as a starting point. Data for 1995, 2002, and 2007 will be used.[50] **Figure 7** below shows an example of the 2007 LULC data for the Cape May WMA. We will work with DEP and the TAC to ensure a correct categorization of the two LULC categories of interest: urban areas (for use under the urban forestry subsector below); and forests (in some areas, wetlands should be included within the definition of forested land, which is an important consideration in the areas like the Cape May WMA). Efforts will also be made to gather information from studies conducted on wetlands regarding methane emissions in order to determine if these can (and should) be captured within the inventory.

Carbon density estimates (*e.g.*, metric tons of carbon per hectare) and forested area estimates for the years 1995, 2002, and 2007 will be available from the above two data sources,. For each municipality, forest carbon stocks will be estimated for each year by multiplying the carbon density by the forested area. Net CO_2 sequestration/emission for each municipality is then determined by the net accumulation of carbon (sequestration) or loss of carbon (emission).[51] This net loss or gain is then multiplied by 44/12 to convert carbon to CO_2. New Jersey Forest Service staff will be contacted to determine whether any harvests of forest biomass occur in the SJTPO region for durable wood products manufacturing. If so, estimates of carbon sequestration in these long-lived products will be included in the inventory.

Seasonal emissions will not be calculated separately for this sector since it is not dependent on or directly correlated with seasonal tourist population.

For fuel consumption related emissions (*e.g.*, non-road logging equipment), we will apply the same approach used for NJTPA. This involves the use of the county-level estimates from the EPA NONROAD model and allocating them to the municipal-level using the fraction of forest land cover.

Summer seasonal emissions will be reported as one-fourth of the annual estimates. While it could be easily argued that forests sequester carbon at much higher rates during the spring and summer (and lose carbon during fall and winter), we believe that an effort to develop and report

[49] COLE homepage: http://www.nrs.fs.fed.us/carbon/tools/#cole.

[50] NJDEP data at the WMA level are available from their GIS webpage: http://www.nj.gov/dep/gis/download.htm.

[51] Based on discussions with USFS researchers and work with USFS Forest Inventory and Analysis data in over 25 states, the Team plans to exclude the soil organic carbon pool from these calculations of net carbon gain/loss due to the large degree of uncertainty in these data.

these emissions would add little to the body of knowledge needed for GHG mitigation (and could very easily confuse the reader).

URBAN FORESTS INVENTORY AND ALLOCATION

We will develop the urban forest sequestration estimates from the bottom-up using the urban area for each municipality developed above from the NJDEP LULC data (see **Figure 8**), USFS carbon canopy data,[52] and a state-specific urban forest carbon accumulation rate.[53] Annual sequestration rates are determined by multiplying the municipality's urban area by the fraction of canopy cover and then by the carbon sequestration rate.

Also, within the urban land use sector, we will add emissions of N_2O from "settlement soils", which captures emissions associated with nitrogen inputs (commercial fertilizers) to urban soils. We will use state-level output from the EPA's State Inventory Tool (SIT) as the starting point and allocate emissions to each municipality based on their share of the total state urban area.

As with the forested land use subsector, we will report the seasonal emissions as one-fourth of the annual total.

LAND USE, LAND USE CHANGE, AND FORESTRY INVENTORY FORECAST

Forested Land Use

For the forested land use subsector, forest carbon sequestration rates through the near-term (2020) will be forecasted based on the expected change in forest and wetland land use area inferred by the trends from 1995-2007 (NJDEP land use data). Unfortunately, data for 2012 won't be available until later in the year. Hence, the growth in emissions/sinks will be driven solely by the expected change in land use. In reality, growth will also be a function of changes in carbon accumulation rates in the future. These changes could come as a result of changes in climate, forest health, harvest practices, and forest age. However, modeling these potential changes would require detailed information at the municipal scale on forest type, age, harvesting, etc. Construction of a dataset of this type is well beyond the scope of this project.

For forecasting over the long term (post-2020), the project team is unaware of any land use forecasts for the region that would help us construct a net sequestration forecast. However, an alternative method is provided here for consideration. The method would rely on Sewer Service Area (SSA) Maps provided by the counties that show existing and planned areas for expansion.[54] Areas where sewer service is planned for expansion will be assumed to be converted from the existing land use (ag/forestry/wetlands/other) to urbanized use (residential). The steps that we would use are as follows:

- The SSA maps showing area expansion would be laid over the NJ DEP land use maps to derive the total change in land use from agriculture/forestry/wetlands/other to urbanized area.
- The key unknown from the previous step is the rate at which this change would occur. To estimate that, the Team would use municipal population forecasts and historical rates of urbanization (hectares/yr) to assess land requirements for the future

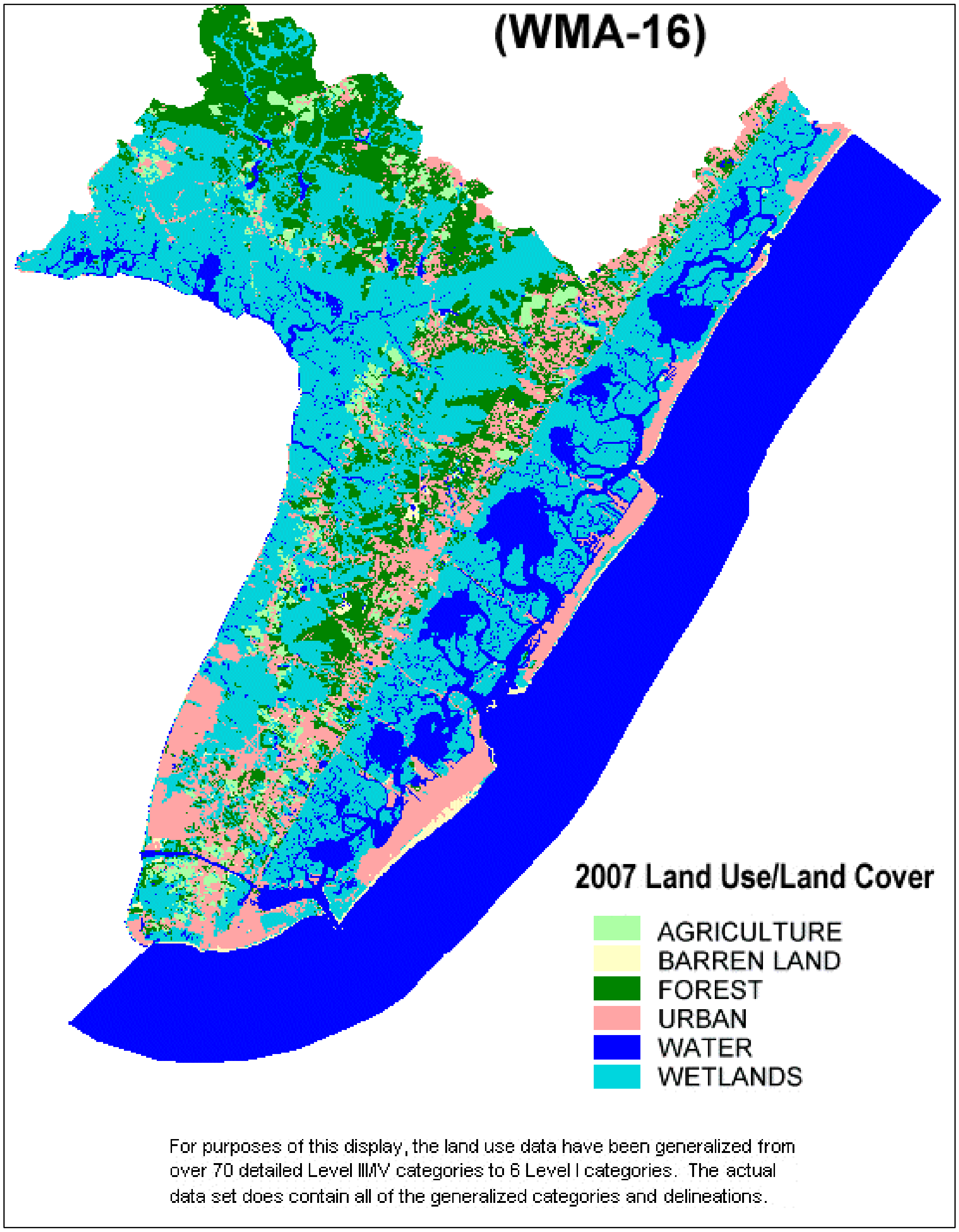
[52] New Jersey urban forestry data can be found here: http://www.nrs.fs.fed.us/data/urban/state/?state=NJ.

[53] Also, from the same site above; the estimate is for the year 2000; the Team will adjust this value for specific SJTPO municipalities/counties, if those estimates are available from stakeholders.

[54] The Team has obtained and reviewed SSA GIS data for Cumberland County to test the viability of this method.

population. A trend of urbanized density (population/Ha) would be developed for each municipality through 2035.

Figure 8
Cape May Watershed Management Area 2007 Land Use/Land Cover



• The population forecast would then drive the rate at which the total new urbanized area is used up (new area as inferred from the SSA maps). For municipalities where the new urbanized area is projected to be used up before 2035, the rate of land use change (urbanization) will be held at 0 from that year onwards.

- For annual forested area change to urbanized use, a one-time loss of carbon to the atmosphere will be calculated for all above-ground biomass; annual sequestration rates for forested use will also be reduced from that year on as a result of forest area loss (while urban forest sequestration rates will increase). The procedures for calculating net carbon sequestration will be the same as those previously described in the Protocol for inventory development.

For fuel use in the forestry sector, we will use the same growth rates calculated to quantify land use change and carbon sequestration (i.e. trend analysis up to 2020; following forecasted land use change after 2020).

Urban Forests

For the urban forests subsector, similar to the forested land use subsector, we will forecast net emissions based on near term land use trends and long term expectations in the rate of urbanization. Ideally, we would also factor in the expected growth in urban forest cover during the forecast period. While we plan to confirm this with the New Jersey Forest Service, we don't expect to find multiple estimates for historic years that could support an assessment of near term trends in urban forest cover (generally one state-level estimate is available). Hence, growth will be a function of the increase in urban area only. For municipalities that can provide information on the expected change in urban forest sequestration rates or canopy cover, the Team can factor those into the forecast approach.

Agriculture

AGRICULTURE INVENTORY AND ALLOCATION

In many GHG inventories, the agriculture sector covers only non-fuel combustion emissions associated with production of crops and livestock management (the emissions are treated this way in the EPA draft Regional Guidance as well). Emissions from fuel combustion within the agriculture sector are often included within the industrial fuel combustion emissions. Similar to the way the approach this issue for the Forestry & Land Use Sector, we plan to include fuel combustion emissions associated with the use of agricultural equipment within the Agriculture sector (as was done for the NJTPA inventory). These emissions will be estimated using the EPA NONROAD Model as described above.

The non-fuel combustion GHGs involved are primarily N_2O and CH_4. N_2O emissions result from the application of synthetic and organic nitrogen additions to soils and during manure management. CH_4 emissions are produced during manure management and from enteric fermentation within ruminant animals (primarily cattle). Some CO_2 emissions also occur as a result of soil carbon losses during cultivation and application of limestone/dolomite and urea. Overall, the agricultural sector contributes very little to the state-wide total GHG emissions (0.5 $MMtCO_2e$ in 2005, which is less than 0.5% of the New Jersey total).[55] Of this amount, about 80% is contributed by crop soils. SJTPO counties produce fair amounts of certain commodities for the State (cattle, corn, soybeans, vegetables, wheat).

Although the contributions of GHGs from the agricultural sector at the state-level are small, the fraction of these contributions within the SJTPO region could be more significant. Therefore, we intends to survey the county agricultural extension offices to determine whether bottom-up (*e.g.*, municipal-level or county-level) livestock populations and crop cultivation data are available.

[55] New Jersey GHG I&F, http://www.nj.gov/globalwarming/home/documents/pdf/20081031inventory-report.pdf. Note that these estimates do not include CO_2 emissions from the application of limestone/dolomite and urea.

Using these activity data, we will develop emission estimates for livestock using standard EPA emission factors (correcting for the use of anaerobic digesters, if present). For crop cultivation, we will build the bottom-up estimates using the cultivated area of each primary crop, reported/recommended applications of nitrogen and limestone/dolomite, and any specific information on fertilizer types available from the agricultural extension offices. From the DEP LU/LC data at the municipal level (described under the Forestry sector above), we will evaluate whether there has been any significant change in agricultural land area that could indicate significant changes in terrestrial carbon pools that should also be addressed (*e.g.*, conversion of forest to agriculture or vice versa).

Seasonal emissions in this subsector are not tied to seasonal population changes, and will be estimated simply as one-fourth of the annual estimated emissions.

AGRICULTURE INVENTORY FORECAST

The forecast approach for the agriculture sector will be similar to that employed for the forestry sector. Near term forecasts (through 2020) will be developed based on trends of the underlying activity data (historic USDA National Agricultural Statistics Service county livestock populations and crop production data). We don't believe that extrapolation of these trends is useful for periods of more than about 10 years, so for the long term (>2020), we intend to base these on the expected land use change forecast as described above for Forest Land Use.

Since, the assessment of land use change could also indicate losses of agricultural land; this means that some adjustments could be needed to account for reduced emissions associated with agricultural production. The first assumption will be that these losses only impact crop production, not livestock operations (as most livestock emissions occur at confined operations which should be impacted less than crop production). For crop production, it isn't possible to know whether these losses in available land will occur in areas where crops are actively cultivated versus pasture or other uncultivated areas (much more detailed ag land use data would be required for that). Therefore, the team will make adjustments to the forecasted emissions for crop soils based simply on the fraction of agricultural land lost during each future year (this assumes equal losses of crop and pasture lands).

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ATTACHMENT A: 2014 CLIMATE REGISTRY DEFAULT EMISSION FACTORS

Table 12.1 U.S. Default Factors for Calculating CO_2 Emissions from Fossil Fuel and Biomass Combustion

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Coal and Coke	**MMBtu / short ton**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / short ton**
Anthracite	25.09	28.24	1	103.54	2597.82
Bituminous	24.93	25.47	1	93.40	2328.46
Subbituminous	17.25	26.46	1	97.02	1673.60
Lignite	14.21	26.28	1	96.36	1369.28
Coke	24.80	27.83	1	102.04	2530.59
Mixed Electric Utility/Electric Power	19.73	25.74	1	94.38	1862.12
Unspecified Residential/Com*	21.18	25.71	1	94.27	1996.54
Mixed Commercial Sector	21.39	25.98	1	95.26	2037.61
Mixed Industrial Coking	26.28	25.54	1	93.65	2461.12
Mixed Industrial Sector	22.35	25.61	1	93.91	2098.89
Natural Gas	**Btu / scf**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / scf**
US Weighted Average	1028	14.46	1	53.02	0.05
Greater than 1,000 Btu*	>1000	14.47	1	53.06	Varies
975 to 1,000 Btu*	975 – 1,000	14.73	1	54.01	Varies
1,000 to 1,025 Btu*	1,000 – 1,025	14.43	1	52.91	Varies
1,025 to 1,035 Btu*	1025 – 1035	14.45	1	52.98	Varies
1,025 to 1,050 Btu*	1,025 – 1,050	14.47	1	53.06	Varies
1,050 to 1,075 Btu*	1,050 – 1,075	14.58	1	53.46	Varies
1,075 to 1,100 Btu*	1,075 – 1,100	14.65	1	53.72	Varies
Greater than 1,100 Btu*	>1,100	14.92	1	54.71	Varies
(EPA 2010) Full Sample*		14.48	1	53.09	n/a
(EPA 2010) <1.0% CO_2*		14.43	1	52.91	n/a
(EPA 2010) <1.5% CO_2*		14.47	1	53.06	n/a
(EPA 2010) <1.0% CO_2 and <1,050 Btu/scf*	<1,050	14.42	1	52.87	n/a
(EPA 2010) <1.5% CO_2 and <1,050 Btu/scf*	<1,050	14.47	1	53.06	n/a
(EPA 2010) Flare Gas*	>1,100	15.31	1	56.14	n/a

Table 12.1 U.S. Default Factors for Calculating CO_2 Emissions from Fossil Fuel and Biomass Combustion

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Petroleum Products	**MMBtu / gallon**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Distillate Fuel Oil No. 1	0.139	19.98	1	73.25	10.18
Distillate Fuel Oil No. 2	0.138	20.17	1	73.96	10.21
Distillate Fuel Oil No. 4	0.146	20.47	1	75.04	10.96
Residual Fuel Oil No. 5	0.140	19.89	1	72.93	10.21
Residual Fuel Oil No. 6	0.150	20.48	1	75.10	11.27
Still Gas*	0.143	18.20	1	66.73	9.53
Used Oil	0.135	20.18	1	74.00	9.99
Kerosene	0.135	20.51	1	75.20	10.15
LPG	0.092	17.18	1	62.98	5.79
Propane (Liquid)	0.091	16.76	1	61.46	5.59
Propylene	0.091	17.99	1	65.95	6.00
Ethane	0.069	17.08	1	62.64	4.32
Ethylene	0.100	18.39	1	67.43	6.74
Isobutane	0.097	17.70	1	64.91	6.30
Isobutylene	0.103	18.47	1	67.74	6.98
Butane	0.101	17.77	1	65.15	6.58
Butylene	0.103	18.47	1	67.73	6.98
Naptha (<401 deg F)	0.125	18.55	1	68.02	8.50
Natural Gasoline	0.110	18.23	1	66.83	7.35
Other Oil (>401 deg F)	0.139	20.79	1	76.22	10.59
Pentanes Plus	0.110	19.10	1	70.02	7.70
Petrochemical Feedstocks	0.129	19.36	1	70.97	9.16
Petroleum Coke (Liquid)	0.143	27.93	1	102.41	14.64
Special Naptha	0.125	19.73	1	72.34	9.04
Unfinished Oils	0.139	20.32	1	74.49	10.35
Heavy Gas Oils	0.148	20.43	1	74.92	11.09
Lubricants	0.144	20.26	1	74.27	10.69
Motor Gasoline	0.125	19.15	1	70.22	8.78
Aviation Gasoline	0.120	18.89	1	69.25	8.31
Kerosene Type Jet Fuel	0.135	19.70	1	72.22	9.75
Asphalt and Road Oil	0.158	20.55	1	75.36	11.91
Crude Oil	0.138	20.32	1	74.49	10.28
Waxes*	0.132	19.80	1	72.60	9.57
Fossil Fuel-derived Fuels (gaseous)	**MMBtu / scf**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / scf**
Acetylene**	0.00147	19.53	1	71.61	0.1053

Table 12.1 U.S. Default Factors for Calculating CO_2 Emissions from Fossil Fuel and Biomass Combustion

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)
Fossil Fuel-derived Fuels (solid)	**MMBtu / short ton**	**kg C / MMBtu**		**kg CO_2 / mmBtu**	**kg CO_2 / short ton**
Municipal Solid Waste	9.95	24.74	1	90.7	902.47
Tires	26.87	23.45	1	85.97	2310.01
Plastics	38	20.45	1	75	2850.00
Petroleum Coke (Solid)	30	27.93	1	102.41	3072.30
Fossil Fuel-derived Fuels (gaseous)	**MMBtu / scf**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / scf**
Blast Furnace Gas	0.000092	74.81	1	274.32	0.0252
Coke Oven Gas	0.000599	12.78	1	46.85	0.0281
Propane (Gas)	0.002516	16.76	1	61.46	0.1546
Fuel Gas	0.001388	16.09	1	59.00	0.0819
Biomass Fuels-Solid	**MMBtu / short ton**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / short ton**
Wood and Wood Residuals (12% moisture content)	15.38	25.58	1	93.80	1442.64
Agricultural Byproducts	8.25	32.23	1	118.17	974.90
Peat	8.00	30.50	1	111.84	894.72
Solid Byproducts	25.83	28.78	1	105.51	2725.32
Kraft Black Liquor (NA hardwood)		25.55	1	93.70	n/a
Kraft Black Liquor (NA softwood)		25.75	1	94.40	n/a
Kraft Black Liquor (Bagasse)		26.05	1	95.50	n/a
Kraft Black Liquor (Bamboo)		25.55	1	93.70	n/a
Kraft Black Liquor (Straw)		25.94	1	95.10	n/a
Municipal Solid Waste (Biomass)	9.95	24.74	1	90.7	902.47
Biomass Fuels-Gaseous	**MMBtu / scf**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / scf**
Biogas (Captured Methane)	0.000841	14.20	1	52.07	0.0438
Landfill Gas (50% CH_4/50%CO_2)***	0.0005025	14.20	1	52.07	0.0262
Wastewater Treatment Biogas***	Varies	14.20	1	52.07	Varies
Biomass Fuels - Liquid	**MMBtu / gallon**	**kg C / MMBtu**		**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Ethanol (100%)	0.084	18.67	1	68.44	5.75
Biodiesel (100%)	0.128	20.14	1	73.84	9.45
Rendered Animal Fat	0.125	19.38	1	71.06	8.88
Vegetable Oil	0.120	22.24	1	81.55	9.79

Table 12.1 U.S. Default Factors for Calculating CO_2 Emissions from Fossil Fuel and Biomass Combustion

Fuel Type	Heat Content	Carbon Content (Per Unit Energy)	Fraction Oxidized	CO_2 Emission Factor (Per Unit Energy)	CO_2 Emission Factor (Per Unit Mass or Volume)

Source: Heat Content and CO_2 Emission factors per unit energy are from EPA Final Mandatory Reporting of Greenhouse Gases Rule Tables C-1 and AA-1. Carbon Content derived using the heat content and/or default emission factor. Except those marked with * are from US Inventory of Greenhouse Gas Emissions and Sinks 1990-2011 (April 2013) Annex 2.2, Tables A-38, A-42 and A-44, ans A-55 (heat content factor for Unspecified Residential/Com. from U.S. Energy Information Administration, Monthly Energy Review (September 2013), Table A-5) and ** derived from the API Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry (August 2009), Section 3.6.3, Table 3-8. A fraction oxidized value of 1.00 is from the Intergovernmental Panel on Climate Change (IPCC), Guidelines for National Greenhouse Gas Inventories (2006) and *** EPA Climate Leaders Technical Guidance (2008) Table B-2.

NOTE: Where not provided from the EPA Final Mandatory Reporting of Greenhouse Gases Rule, default CO_2 emission factors (per unit energy) are calculated as: Carbon Content × Fraction Oxidized × 44/12. Default CO_2 emission factors (per unit mass or volume) are calculated using the equation: Heat Content × Carbon Content × Fraction Oxidized × 44/12 × Conversion Factor (if applicable).

Table 12.2 Canadian Default Factors for Calculating CO_2 Emissions from Combustion of Natural Gas, Petroleum Products, and Biomass

Fuel Type	Carbon Content (Per Unit Energy)	Heat Content	Fraction Oxidized	CO_2 Emission Factor (Per Unit Mass or Volume)
Natural Gas	**kg C / GJ**	**GJ / megalitre**		**g CO_2 / m^3**
Electric Utilities, Industry, Commercial, Pipelines, Agriculture, Residential*	n/a	38.56	1	1900.46
Producer Consumption*	n/a	38.56	1	2400.95
Newfoundland and Labrador				
Marketable	n/a	38.56	1	1900.46
NonMarketable	n/a	38.56	1	2494.41
Nova Scotia				
Marketable	n/a	38.56	1	1900.46
NonMarketable	n/a	38.56	1	2494.41
New Brunswick				
Marketable	n/a	38.56	1	1900.46
NonMarketable	n/a	38.56	1	NO
Quebec				
Marketable	n/a	38.56	1	1887.39
NonMarketable	n/a	38.56	1	NO
Ontario				
Marketable	n/a	38.56	1	1888.40
NonMarketable	n/a	38.56	1	NO
Manitoba				
Marketable	n/a	38.56	1	1886.39
NonMarketable	n/a	38.56	1	NO
Saskatchewan				
Marketable	n/a	38.56	1	1829.10
NonMarketable	n/a	38.56	1	2441.15
Alberta				
Marketable	n/a	38.56	1	1927.59
NonMarketable	n/a	38.56	1	2391.90
British Columbia				
Marketable	n/a	38.56	1	1925.58
NonMarketable	n/a	38.56	1	2161.76
Yukon				
Marketable	n/a	38.56	1	1900.46
NonMarketable	n/a	38.56	1	2400.95
Northwest Territories				
Marketable	n/a	38.56	1	2466.27
NonMarketable	n/a	38.56	1	2466.27

Table 12.2 Canadian Default Factors for Calculating CO_2 Emissions from Combustion of Natural Gas, Petroleum Products, and Biomass

Fuel Type	Carbon Content (Per Unit Energy)	Heat Content	Fraction Oxidized	CO_2 Emission Factor (Per Unit Mass or Volume)
Natural Gas Liquids	**kg C / GJ**	**GJ / kilolitre**		**g CO_2 / L**
Propane				
Residential Propane	n/a	25.31	1	1514.54
Other Uses Propane	n/a	25.31	1	1514.54
Ethane	n/a	17.22	1	980.88
Butane	n/a	28.44	1	1738.65
Refinery LPGs (All Stationary)	n/a	n/a	1	1616.00
Petroleum Products	**kg C / GJ**	**GJ / kilolitre**		**g CO_2 / L**
Light Fuel Oil Electric Utilities	n/a	38.80	1	2752.25
Light Fuel Oil Industrial	n/a	38.80	1	2752.25
Light Fuel Oil Producer Consumption	n/a	38.80	1	2669.43
Light Fuel Oil Residential	n/a	38.80	1	2752.25
Light Fuel Oil Forestry, Construction, Public Administration, Commercial/Institutional	n/a	38.80	1	2752.25
Heavy Fuel Oil (Electric Utility, Industrial, Forestry, Construction, Public Administration, Commercial/Institutional)	n/a	42.50	1	3155.24
Heavy Fuel Oil (Residential)	n/a	42.50	1	3155.24
Heavy Fuel Oil (Producer Consumption)	n/a	42.50	1	3189.58
Kerosene (Electric Utility, Industrial, Producer Consumption, Residential, Forestry, Construction, Public Administration, Commercial/Institutional)	n/a	37.68	1	2559.34
Diesel	n/a	38.30	1	2689.63
Petroleum Coke from Upgrading Facilities	n/a	40.57	1	3528.94
Petroleum Coke from Refineries & Others	n/a	46.35	1	3852.14
Still Gas	**kg C / TJ**	**TJ / GL**		**g / m^3**
Upgrading Facilities	n/a	43.24	1	2161.4
Refineries & Others	n/a	36.08	1	1616

Table 12.2 Canadian Default Factors for Calculating CO_2 Emissions from Combustion of Natural Gas, Petroleum Products, and Biomass

Fuel Type	Carbon Content (Per Unit Energy)	Heat Content	Fraction Oxidized	CO_2 Emission Factor (Per Unit Mass or Volume)
Biomass	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Wood Fuel/Wood Waste	n/a	18.00	1	848.4
Spent Pulping Liquor	n/a	14.00	1	935.55
Biomass				**kg CO_2 / t**
Landfill Gas	n/a	n/a	1	2752

NO=Not Occurring, n/a=not available. Source: Default CO_2 emission factors: Environment Canada, *National Inventory Report, 1990-2011: Greenhouse Gas Sources and Sinks in Canada* (2013), Annex 8: Emission Factors, Tables A8-1, A8-3, A8-4, A8-5, A8-26 and A8-27. Except those marked with * are from Environment Canada, National Inventory Report, 1990-2006: Greenhouse Gas Sources and Sinks in Canada (2008), Annex 12: Emission Factors, Table A12-1; Default Heat Content: Statistics Canada, *Report on Energy Supply and Demand in Canada, 2011-Preliminary* (2013), Energy conversion factors, p. 121; Default Carbon Content: Canada-specific carbon content coefficients are not available. If you cannot obtain measured carbon content values specific to your fuels, you should use the default emission factor; Default Fraction Oxidized: Intergovernmental Panel on Climate Change (IPCC), *Guidelines for National Greenhouse Gas Inventories* (2006). Note: CO_2 emission factors from Environment Canada originally included fraction oxidized factors of less than 100%. Values were converted to include a 100% oxidation rate using 99.5% for natural gas and NGLs; 99% for petroleum products and wood fuel/wood waste; and 95% for spent pulping liquor based on the rates used to calculate the original factors.

Table 12.3 Canadian Default Factors for Calculating CO_2 Emissions from Combustion of Coal

Province and Coal Type	Carbon Content	Heat Content	Fraction Oxidized	CO_2 Emission Factor
Newfoundland and Labrador	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	28.96	1	2212
Foreign Bituminous	n/a	29.82	1.000	2570
Prince Edward Island	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	28.96	1	2212
Foreign Bituminous	n/a	29.82	1.000	2570
Nova Scotia	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	28.96	1	2212
Foreign Bituminous	n/a	29.82	1	2570
New Brunswick	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	26.80	1	2333
Foreign Bituminous	n/a	29.82	1	2570
Quebec	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	28.96	1	2212
Foreign Bituminous	n/a	29.82	1	2626
Ontario	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	25.43	1	2212
Foreign Bituminous	n/a	29.82	1	2626
Foreign Sub-Bituminous	n/a	19.15	1	1743
Manitoba	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Foreign Sub-Bituminous	n/a	19.15	1	1743
Saskatchewan	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	25.43	1	2212
Canadian Sub-Bituminous	n/a	19.15	1	1762
Lignite	n/a	15.00	1	1465
Alberta	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	25.43	1	2212
Canadian Sub-Bituminous	n/a	19.15	1	1762
British Columbia	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Canadian Bituminous	n/a	26.02	1	2212
Canadian Sub-Bituminous	n/a	19.15	1	1762
All Provinces and Territories	**kg C / GJ**	**GJ / t**		**g CO_2 / kg**
Coke	n/a	28.83	1	2504
Anthracite	n/a	27.70	1	2411
All Provinces and Territories	**kg C / GJ**	**GJ / megalitre**		**g / m^3**
Coke Oven Gas	n/a	19.14	1	694

Table 12.3 Canadian Default Factors for Calculating CO_2 Emissions from Combustion of Coal

Province and Coal Type	Carbon Content	Heat Content	Fraction Oxidized	CO_2 Emission Factor
Source: Default CO_2 Emission Factors: Environment Canada, National Inventory Report, 1990-2011: Greenhouse Gas Sources and Sinks in Canada (2013), Annex 8: Emission Factors, Tables A8-7 and A8-8; Default Heat Content: Statistics Canada, *Report on Energy Supply and Demand in Canada, 2011-Preliminary* (2013), Energy conversion factors, p. 121 (value for Foreign Bituminous uses heat content of "Imported bituminous" value for Foreign Sub-Bituminous uses heat content of "Sub-bituminous"); Default Carbon Content: Canada-specific carbon content coefficients are not available. If you cannot obtain measured carbon content values specific to your fuels, you should use the default emission factor; Default Fraction Oxidized: Intergovernmental Panel on Climate Change (IPCC), *Guidelines for National Greenhouse Gas Inventories* (2006). Note: CO_2 emission factors from Environment Canada originally included a fraction oxidized factor of 99%. Values were converted to instead include a 100% oxidation rate.				

Table 12.4 Canadian Default Factors for Calculating CH_4 and N_2O Emissions from Combustion of Natural Gas, Petroleum Products, Coal, and Biomass

Fuel Type	CH_4 Emission Factor (Per Unit Mass or Volume)	N_2O Emission Factor (Per Unit Mass or Volume)
Natural Gas	**g CH_4 / m^3**	**g N_2O / m^3**
Electric Utilities	0.49	0.049
Industrial	0.037	0.033
Producer Consumption (NonMarketable)	6.4	0.06
Pipelines	1.9	0.05
Cement	0.037	0.034
Manufacturing Industries	0.037	0.033
Residential, Construction, Commercial/Institutional, Agriculture	0.037	0.035
Natural Gas Liquids	**g CH_4 / L**	**g N_2O / L**
Propane (Residential)	0.027	0.108
Propane (All Other Uses)	0.024	0.108
Ethane	0.024	0.108
Butane	0.024	0.108
Refined Petroleum Products	**g CH_4 / L**	**g N_2O / L**
Light Fuel Oil (Electric Utilities)	0.18	0.031
Light Fuel Oil (Industrial and Producer Consumption)	0.006	0.031
Light Fuel Oil (Residential)	0.026	0.006
Light Fuel Oil (Forestry, Construction, Public Administration, and Commercial/Institutional)	0.026	0.031
Heavy Fuel Oil (Electric Utilities)	0.034	0.064
Heavy Fuel Oil (Industrial and Producer Consumption)	0.12	0.064
Heavy Fuel Oil (Residential, Forestry, Construction, Public Administration, and Commercial/Institutional)	0.057	0.064
Kerosene (Electric Utilities, Industrial, and Producer Consumption)	0.006	0.031
Kerosene (Residential)	0.026	0.006
Kerosene (Forestry, Construction, Public Administration, and Commercial/Institutional)	0.026	0.031
Diesel (Refineries and Others)	0.133	0.4
Diesel (Upgraders)	0.15	1.1
Still Gas	n/a	0.00002
Refinery LPGs	0.024	0.108
Petroleum Coke	**g CH_4 / L**	**g N_2O / L**
Upgrading Facilities	0.12	0.024
Refineries & Others	0.12	0.0275
Coal	**g CH_4 / kg**	**g N_2O / kg**
Coal (Electric Utilities)	0.022	0.032
Coal (Industry and Heat & Steam Plants)	0.03	0.02
Coal (Residential, Public Administration)	4	0.02
Coke	0.03	0.02

Table 12.4 Canadian Default Factors for Calculating CH_4 and N_2O Emissions from Combustion of Natural Gas, Petroleum Products, Coal, and Biomass

Fuel Type	CH_4 Emission Factor (Per Unit Mass or Volume)	N_2O Emission Factor (Per Unit Mass or Volume)
Coal (gas)	**g CH_4 / m^3**	**g N_2O / m^3**
Coke Oven Gas	0.037	0.035
Biomass	**g CH_4 / kg**	**g N_2O / kg**
Wood Fuel/Wood Waste (Industrial Combustion)	0.09	0.06
Spent Pulping Liquor (Industrial Combustion)	0.02	0.02
Stoves and Fireplaces (Advance Technology or Catalytic Control)	6.9	0.16
Stoves and Fireplaces (Conventional, Inserts, and Other Wood-Burning Equipment)	15	0.16
Landfill Gas	**kg CH_4 / t**	**kg N_2O / t**
Landfill Gas (Industrial Combustion)	0.05	0.005

Source: Environment Canada, National Inventory Report, 1990-2011: Greenhouse Gas Sources and Sinks in Canada (2013), Annex 8: Emission Factors, Tables A8-2, A8-3, A8-4, A8-6, A8-9, A8-26, and A-27.

Table 12.5 Default CH_4 and N_2O Emission Factors by Technology Type for the Electricity Generation Sector

Fuel Type and Basic Technology	Configuration	CH_4 (g / MMBtu)	N_2O (g / MMBtu)
Liquid Fuels			
Residual Fuel Oil/Shale Oil Boilers	Normal Firing	0.8	0.3
	Tangential Firing	0.8	0.3
Gas/Diesel Oil Boilers	Normal Firing	0.9	0.4
	Tangential Firing	0.9	0.4
Large Diesel Oil Engines >600hp (447kW)		4	NA
Solid Fuels			
Pulverized Bituminous Combustion Boilers	Dry Bottom, wall fired	0.7	0.5
	Dry Bottom, tangentially fired	0.7	1.4
	Wet Bottom	0.9	1.4
Bituminous Spreader Stoker Boilers	With and without re-injection	1	0.7
Bituminous Fluidized Bed Combustor	Circulating Bed	1	61.1
	Bubbling Bed	1	61.1
Bituminous Cyclone Furnace		0.2	1.6
Lignite Atmospheric Fluidized Bed		NA	71.2
Natural Gas			
Boilers		0.9	0.9
Gas-Fired Gas Turbines >3MW		3.8	0.9
Large Dual-Fuel Engines		245	NA
Combined Cycle		0.9	2.8
Peat			
Peat Fluidized Bed Combustor	Circulating Bed	3	7
	Bubbling Bed	3	3
Biomass			
Wood/Wood Waste Boilers		9.3	5.9
Wood Recovery Boilers		0.8	0.8

Source: IPCC, Guidelines for National Greenhouse Gas Inventories (2006), Chapter 2: Stationary Combustion, Table 2.6. Values were converted back from LHV to HHV using IPCC's assumption that LHV are five percent lower than HHV for coal and oil, 10 percent lower for natural gas, and 20 percent lower for dry wood. (The IPCC converted the original factors from units of HHV to LHV, so the same conversion rates used by the IPCC were used here to obtain the original values in units of HHV.) Values were converted from kg/TJ to g/MMBtu using 1 kg = 1000 g and 1 MMBtu = 0.001055 TJ. NA = data not available.

Table 12.6 Default CH_4 and N_2O Emission Factors for Kilns, Ovens, and Dryers

Industry	Source	CH_4 (g / MMBtu)	N_2O (g / MMBtu)
Cement, Lime	Kilns - Natural Gas	1.04	NA
Cement, Lime	Kilns – Oil	1	NA
Cement, Lime	Kilns – Coal	1	NA
Coking, Steel	Coke Oven	1	NA
Chemical Processes, Wood, Asphalt, Copper, Phosphate	Dryer - Natural Gas	1.04	NA
Chemical Processes, Wood, Asphalt, Copper, Phosphate	Dryer – Oil	1	NA
Chemical Processes, Wood, Asphalt, Copper, Phosphate	Dryer – Coal	1	NA

Source: IPCC, Guidelines for National Greenhouse Gas Inventories (2006), Chapter 2: Stationary Combustion, Table 2.8. Values were converted back from LHV to HHV using IPCC's assumption that LHV are five percent lower than HHV for coal and oil and 10 percent lower for natural gas. Values were converted from kg/TJ to g/MMBtu using 1 kg = 1000 g and 1 MMBtu = 0.001055 TJ. NA = data not available.

Table 12.7 Default CH_4 and N_2O Emission Factors by Technology Type for the Industrial Sector

Fuel Type and Basic Technology	Configuration	CH_4 (g / MMBtu)	N_2O (g / MMBtu)
Liquid Fuels			
Residual Fuel Oil Boilers		3	0.3
Gas/Diesel Oil Boilers		0.2	0.4
Large Stationary Diesel Oil Engines >600hp (447 kW)		4	NA
Liquefied Petroleum Gases Boilers		0.9	4
Solid Fuels			
Other Bituminous/Sub-bit. Overfeed Stoker Boilers		1	0.7
Other Bituminous/Sub-bit. Underfeed Stoker Boilers		14	0.7
Other Bituminous/Sub-bituminous Pulverized	Dry Bottom, wall fired	0.7	0.5
	Dry Bottom, tangentially fired	0.7	1.4
	Wet Bottom	0.9	1.4
Other Bituminous Spreader Stokers		1	0.7
Other Bituminous/Sub-bit. Fluidized Bed Combustor	Circulating Bed	1	61.1
	Bubbling Bed	1	61.1
Natural Gas			
Boilers		0.9	0.9
Gas-Fired Gas Turbines >3MW		3.8	0.9
Natural Gas-fired Reciprocating Engines	2-Stroke Lean Burn	658	NA
	4-Stroke Lean Burn	566.9	NA
	4-Stroke Rich Burn	104.4	NA
Biomass			
Wood/Wood Waste Boilers		9.3	5.9

Source: IPCC, Guidelines for National Greenhouse Gas Inventories (2006), Chapter 2: Stationary Combustion, Table 2.7. Values were converted from LHV to HHV assuming that LHV are five percent lower than HHV for coal and oil, 10 percent lower for natural gas, and 20 percent lower for dry wood. (The IPCC converted the original factors from units of HHV to LHV, so the same conversion rates used by the IPCC were used here to obtain the original values in units of HHV.) Values were converted from kg/TJ to g/MMBtu using 1 kg = 1000 g and 1 MMBtu = 0.001055 TJ. NA = data not available.

Table 12.8 Default CH_4 and N_2O Emission Factors by Technology Type for the Commercial Sector

Fuel Type and Basic Technology	Configuration	CH_4 (g / MMBtu)	N_2O (g / MMBtu)
Liquid Fuels			
Residual Fuel Oil Boilers		1.4	0.3
Gas/Diesel Oil Boilers		0.7	0.4
Liquefied Petroleum Gases Boilers		0.9	4
Solid Fuels			
Other Bituminous/Sub-bit. Overfeed Stoker Boilers		1	0.7
Other Bituminous/Sub-bit. Underfeed Stoker Boilers		14	0.7
Other Bituminous/Sub-bit. Hand-fed Units		87.2	0.7
Other Bituminous/Sub-bituminous Pulverized Boilers	Dry Bottom, wall fired	0.7	0.5
	Dry Bottom, tangentially fired	0.7	1.4
	Wet Bottom	0.9	1.4
Other Bituminous Spreader Stokers		1	0.7
Other Bituminous/Sub-bit. Fluidized Bed Combustor	Circulating Bed	1	61.1
	Bubbling Bed	1	61.1
Natural Gas			
Boilers		0.9	0.9
Gas-Fired Gas Turbines >3MWa		3.8	1.3
Biomass			
Wood/Wood Waste Boilers		9.3	5.9

Source: IPCC, Guidelines for National Greenhouse Gas Inventories (2006), Chapter 2: Stationary Combustion, Table 2.10. Values were converted from LHV to HHV assuming that LHV are five percent lower than HHV for coal and oil, 10 percent lower for natural gas, and 20 percent lower for dry wood. (The IPCC converted the original factors from units of HHV to LHV, so the same conversion rates used by the IPCC were used here to obtain the original values in units of HHV.) Values were converted from kg/TJ to g/MMBtu using 1 kg = 1000 g and 1 MMBtu = 0.001055 TJ.

Table 12.9 Default CH_4 and N_2O Emission Factors By Fuel Type Industrial and Energy Sectors

Fuel Type / End-Use Sector	CH_4 (kg / MMBtu)	N_2O (kg / MMBtu)
Coal		
Industrial	0.011	0.0016
Energy Industry	0.011	0.0016
Coke		
Industrial	0.011	0.0016
Energy Industry	0.011	0.0016
Petroleum Products		
Industrial	0.003	0.0006
Energy Industry	0.003	0.0006
Natural Gas		
Industrial	0.001	0.0001
Energy Industry	0.001	0.0001
Municipal Solid Waste		
Industrial	0.032	0.0042
Energy Industry	0.032	0.0042
Tires		
Industrial	0.032	0.0042
Energy Industry	0.032	0.0042
Blast Furnace Gas		
Industrial	0.000022	0.0001
Energy Industry	0.000022	0.0001
Coke Oven Gas		
Industrial	0.00048	0.0001
Energy Industry	0.00048	0.0001
Biomass Fuels Solid		
Industrial	0.032	0.0042
Energy Industry	0.032	0.0042
Biogas		
Industrial	0.0032	0.00063
Energy Industry	0.0032	0.00063
Biomass Fuels Liquid		
Industrial	0.0011	0.00011
Energy Industry	0.0011	0.00011
Pulping Liquors		
Industrial*	0.030	0.005

Source: EPA Final Mandatory Reporting of Greenhouse Gases Rule Table C-2. Except those marked with * are from Table AA-1.

Table 12.9 Default CH_4 and N_2O Emission Factors By Fuel Type Residential and Commercial Sectors

Fuel Type / End-Use Sector	CH_4 (g / MMBtu)	N_2O (g / MMBtu)
Coal		
Residential	301	1.5
Commercial	10	1.5
Petroleum Products		
Residential	10	0.6
Commercial	10	0.6
Natural Gas		
Residential	5	0.1
Commercial	5	0.1
Wood		
Residential	253	3.4
Commercial	253	3.4

Source: IPCC, Guidelines for National Greenhouse Gas Inventories (2006), Chapter 2: Stationary Combustion, Tables 2.4 and 2.5. Values were converted from LHV to HHV assuming that LHV are five percent lower than HHV for coal and oil, 10 percent lower for natural gas, and 20 percent lower for dry wood. (The IPCC converted the original factors from units of HHV to LHV, so the same conversion rates used by the IPCC were used here to obtain the original values in units of HHV.) Values were converted from kg/TJ to g/MMBtu using 1 kg = 1000 g and 1 MMBtu = 0.001055 TJ.

Table 13.1 US Default CO_2 Emission Factors for Transport Fuels

Fuel Type	Carbon Content (Per Unit Energy)	Heat Content	Fraction Oxidized	CO_2 Emission Factor (Per Unit Volume)
Fuels Measured in Gallons	**kg C / MMBtu**	**MMBtu / barrel**		**kg CO_2 / gallon**
Gasoline	19.15	5.25	1	8.78
Diesel Fuel	20.17	5.80	1	10.21
Aviation Gasoline	18.89	5.04	1	8.31
Jet Fuel (Jet A or A-1)	19.70	5.67	1	9.75
Kerosene	20.51	5.67	1	10.15
Residual Fuel Oil No. 5	19.89	5.88	1	10.21
Residual Fuel Oil No. 6	20.48	6.30	1	11.27
Crude Oil	20.32	5.80	1	10.28
Biodiesel (B100)	20.14	5.38	1	9.45
Ethanol (E100)	18.67	3.53	1	5.75
Methanol	NA	NA	1	4.10
Liquefied Natural Gas (LNG)*	NA	NA	1	4.46
Liquefied Petroleum Gas (LPG)	17.18	3.86	1	5.79
Propane (Liquid)	16.76	3.82	1	5.59
Ethane	17.08	2.90	1	4.32
Isobutane	17.70	4.07	1	6.30
Butane	17.77	4.24	1	6.58
Fuels Measured in Standard Cubic Feet	**kg C / MMBtu**	**Btu / Standard cubic foot**		**kg CO_2 / Standard cubic foot**
Compressed Natural Gas (CNG)*	14.47	1,027	1	0.054
Propane (Gas)	16.76	2,516	1	0.1546

Source: Heat content and default emission factors are from EPA Final Mandatory Reporting of Greenhouse Gases Rule Table C-1. Carbon content derived using the heat content and default emission factor. Except those marked * are from EPA Climate Leaders, Mobile Combustion Guidance, Tables B-4, B-5, (2008). A fraction oxidized value of 1.00 is from the IPCC, *Guidelines for National Greenhouse Gas Inventories* (2006). Methanol emission factor is calculated from the properties of the pure compounds.
Note: Carbon contents are calculated using the following equation: (Emission Factor / (44/12)) / Heat Content × Conversion Factor. Heat content factors are based on higher heating values (HHV). NA = data not available.

Table 13.2 Canadian Default CO_2 Emission Factors for Transport Fuels

Fuel Type	Carbon Content (kg C / GJ)	Heat Content	Fraction Oxidized	CO_2 Emission Factors
		GJ / kiloliter		g CO_2 / L
Motor Gasoline	n/a	35.00	1	2311.89
Diesel	n/a	38.30	1	2689.63
Light Fuel Oil	n/a	38.80	1	2752.25
Heavy Fuel Oil	n/a	42.50	1	3155.24
Aviation Gasoline	n/a	33.52	1	2365.42
Aviation Turbo Fuel	n/a	37.40	1	2559.34
Propane	n/a	25.31	1	1532.65
Ethanol	n/a	n/a	1	1568.70
Biodiesel	n/a	n/a	1	2571.45
		GJ / megaliter		g CO_2 / L
Natural Gas	n/a	38.56	1	1.92

Source: Default CO_2 Emission Factors: Environment Canada, National Inventory Report, 1990-2011: Greenhouse Gas Sources and Sinks in Canada (2013) Annex 8: Emission Factors, Table A8-11; Default Heat Content: Statistics Canada, Report on Energy Supply and Demand in Canada, 2011-Preliminary (2013), Energy conversion factors, p. 121; Default Carbon Content: Not available for Canada, If you cannot obtain measured carbon content values specific to your fuels, you should use the default emission factor. Default Fraction Oxidized: A value of 1.00 is used following the Intergovernmental Panel on Climate Change (IPCC), *Guidelines for National Greenhouse Gas Inventories* (2006).
Note: CO_2 emission factors from Environment Canada originally included fraction oxidized factors of less than 100%. Values were converted to 100% oxidation rate using 99% for all fuels except natural gas and propane, where a value of 99.5% was used, and Ethanol and Biodiesel, where a value of 95% was used, based on the rates used to calculate the original factors.

Table 13.3 Canadian Default Factors for Calculating CH_4 and N_2O Emissions from Mobile Combustion

Vehicle Type	CH_4 Emission Factor (g CH_4 / L)	N_2O Emission Factor (g N_2O / L)
Light-Duty Gasoline Vehicles (LDGVs)		
Tier 2	0.14	0.022
Tier 1	0.23	0.47
Tier 0	0.32	0.66
Oxidation Catalyst	0.52	0.2
Non-Catalytic Controlled	0.46	0.028
Light-Duty Gasoline Trucks (LDGTs)		
Tier 2	0.14	0.022
Tier 1	0.24	0.58
Tier 0	0.21	0.66
Oxidation Catalyst	0.43	0.2
Non-Catalytic Controlled	0.56	0.028
Heavy-Duty Gasoline Vehicles (HDGVs)		
Three-Way Catalyst	0.068	0.2
Non-Catalytic Controlled	0.29	0.047
Uncontrolled	0.49	0.084
Gasoline Motorcycles		
Non-Catalytic Controlled	0.77	0.041
Uncontrolled	2.3	0.048
Light-Duty Diesel Vehicles (LDDVs)		
Advance Control*	0.051	0.22
Moderate Control	0.068	0.21
Uncontrolled	0.1	0.16
Light-Duty Diesel Trucks (LDDTs)		
Advance Control*	0.068	0.22
Moderate Control	0.068	0.21
Uncontrolled	0.085	0.16
Heavy-Duty Diesel Vehicles (HDDVs)		
Advance Control	0.11	0.151
Moderate Control	0.14	0.082
Uncontrolled	0.15	0.075
Gas Fueled Vehicles		
Natural Gas Vehicles	9×10^{-3}	6×10^{-5}
Propane Vehicles	0.64	0.028
Off-Road Vehicles		
Off-Road Gasoline	2.7	0.05
Off-Road Diesel	0.15	1.1
Railways		
Diesel Train	0.15	1.1

Table 13.3 Canadian Default Factors for Calculating CH_4 and N_2O Emissions from Mobile Combustion

Vehicle Type	CH_4 Emission Factor (g CH_4 / L)	N_2O Emission Factor (g N_2O / L)
Marine		
Gasoline Boats	1.3	0.066
Diesel Ships	0.15	1.1
Light Fuel Oil Ships	0.26	0.073
Heavy Fuel Oil Ships	0.28	0.079
Aviation		
Aviation Gasoline	2.2	0.23
Aviation Turbo Fuel	0.038	0.071
Renewable Fuels		
Biodiesel	**	**
Ethanol	***	***

Source: Environment Canada, National Inventory Report, 1990-2011: Greenhouse Gas Sources and Sinks in Canada (2013) Annex 8: Emission Factors, Table A8-11.
* Advanced control diesel emission factors shall be used for Tier 2 diesel vehicles.
** Diesel CH_4 and N_2O emission factors (by mode and technology) shall be used to calculate biodiesel emissions
*** Gasoline CH_4 and N_2O emission factors (by mode and technology) shall be used to calculate ethanol emissions.

Table 13.4 Default CH_4 and N_2O Emission Factors for Highway Vehicles by Technology Type

Vehicle Type/Control Technology	CH_4 (g / mi)	N_2O (g / mi)
Gasoline Passenger Cars		
EPA Tier 2	0.0173	0.0036
Low Emission Vehicles	0.0105	0.015
EPA Tier 1	0.0271	0.0429
EPA Tier 0	0.0704	0.0647
Oxidation Catalyst	0.1355	0.0504
Non-Catalyst Control	0.1696	0.0197
Uncontrolled	0.178	0.0197
Gasoline Light Trucks (Vans, Pickup Trucks, SUVs)		
EPA Tier 2	0.0163	0.0066
Low Emission Vehicles	0.0148	0.0157
EPA Tier 1	0.0452	0.0871
EPA Tier 0	0.0776	0.1056
Oxidation Catalyst	0.1516	0.0639
Non-Catalyst Control	0.1908	0.0218
Uncontrolled	0.2024	0.022
Gasoline Medium and Heavy-Duty Vehicles Trucks and Busses		
EPA Tier 2	0.0333	0.0134
Low Emission Vehicles	0.0303	0.032
EPA Tier 1	0.0655	0.175
EPA Tier 0	0.263	0.2135
Oxidation Catalyst	0.2356	0.1317
Non-Catalyst Control	0.4181	0.0473
Uncontrolled	0.4604	0.0497
Diesel Passenger Cars		
Advanced	0.0005	0.001
Moderate	0.0005	0.001
Uncontrolled	0.0006	0.0012
Diesel Light Trucks		
Advanced	0.001	0.0015
Moderate	0.0009	0.0014
Uncontrolled	0.0011	0.0017
Diesel Medium and Heavy-Duty Vehicles (Trucks and Busses)		
Aftertreatment	0.0051	0.0048
Advanced	0.0051	0.0048
Moderate	0.0051	0.0048
Uncontrolled	0.0051	0.0048

Table 13.4 Default CH_4 and N_2O Emission Factors for Highway Vehicles by Technology Type

Vehicle Type/Control Technology	CH_4 (g / mi)	N_2O (g / mi)
Motorcycles		
Non-Catalyst Control	0.0672	0.0069
Uncontrolled	0.0899	0.0087
Source: US Inventory of Greenhouse Gas Emissions and Sinks 1990-2011 (April 2013) Annex 3, Table A-104.		

Table 13.5 CH_4 and N_2O Emission Factors for Highway Vehicles by Model Year

Vehicle Type and Year	CH_4 (g / mi)	N_2O (g / mi)
Gasoline Passenger Cars		
Model Years 1984-1993	0.0704	0.0647
Model Year 1994	0.0531	0.0560
Model Year 1995	0.0358	0.0473
Model Year 1996	0.0272	0.0426
Model Year 1997	0.0268	0.0422
Model Year 1998	0.0249	0.0393
Model Year 1999	0.0216	0.0337
Model Year 2000	0.0178	0.0273
Model Year 2001	0.0110	0.0158
Model Year 2002	0.0107	0.0153
Model Year 2003	0.0114	0.0135
Model Year 2004	0.0145	0.0083
Model Year 2005	0.0147	0.0079
Model Year 2006	0.0161	0.0057
Model Year 2007	0.0170	0.0041
Model Year 2008	0.0172	0.0038
Model Year 2009	0.0173	0.0036
Model Year 2010	0.0173	0.0036
Model Year 2011	0.0173	0.0036
Gasoline Light Trucks (Vans, Pickup Trucks, SUVs)		
Model Years 1987-1993	0.0813	0.1035
Model Year 1994	0.0646	0.0982
Model Year 1995	0.0517	0.0908
Model Year 1996	0.0452	0.0871
Model Year 1997	0.0452	0.0871
Model Year 1998	0.0391	0.0728
Model Year 1999	0.0321	0.0564
Model Year 2000	0.0346	0.0621
Model Year 2001	0.0151	0.0164
Model Year 2002	0.0178	0.0228
Model Year 2003	0.0155	0.0114
Model Year 2004	0.0152	0.0132
Model Year 2005	0.0157	0.0101
Model Year 2006	0.0159	0.0089
Model Year 2007	0.0161	0.0079
Model Year 2008	0.0163	0.0066
Model Year 2009	0.0163	0.0066
Model Year 2010	0.0163	0.0066
Model Year 2011	0.0163	0.0066

Table 13.5 CH_4 and N_2O Emission Factors for Highway Vehicles by Model Year

Vehicle Type and Year	CH_4 (g / mi)	N_2O (g / mi)
Gasoline Medium and Heavy-Duty Trucks and Busses		
Model Years 1985-1986	0.4090	0.0515
Model Year 1987	0.3675	0.0849
Model Years 1988-1989	0.3492	0.0933
Model Years 1990-1995	0.3246	0.1142
Model Year 1996	0.1278	0.1680
Model Year 1997	0.0924	0.1726
Model Year 1998	0.0641	0.1693
Model Year 1999	0.0578	0.1435
Model Year 2000	0.0493	0.1092
Model Year 2001	0.0528	0.1235
Model Year 2002	0.0526	0.1307
Model Year 2003	0.0533	0.1240
Model Year 2004	0.0341	0.0285
Model Year 2005	0.0326	0.0177
Model Year 2006	0.0327	0.0171
Model Year 2007	0.0330	0.0153
Model Year 2008	0.0333	0.0134
Model Year 2009	0.0333	0.0134
Model Year 2010	0.0333	0.0134
Model Year 2011	0.0333	0.0134
Diesel Passenger Cars		
Model Years 1960-1982	0.0006	0.0012
Model Years 1983-2011	0.0005	0.0010
Diesel Light Duty Trucks		
Model Years 1960-1982	0.0010	0.0017
Model Years 1983-1995	0.0009	0.0014
Model Years 1996-2011	0.0010	0.0015
Diesel Medium and Heavy-Duty Trucks and Busses		
All Model Years 1960-2011	0.0051	0.0048
Source: US Inventory of Greenhouse Gas Emissions and Sinks 1990-2011 (April 2013) Annex 3, Tables A-100 - A-104.		

Table 13.6 US Default CH_4 and N_2O Emission Factors for Alternative Fuel Vehicles

Vehicle Type	CH_4 (g / mi)	N_2O (g / mi)
Light Duty Vehicles		
Methanol	0.018	0.067
CNG	0.737	0.050
LPG	0.037	0.067
Ethanol	0.055	0.067
Biodiesel (BD20)	0.0005	0.001
Medium and Heavy Duty Vehicles		
Methanol	0.066	0.175
CNG	1.966	0.175
LNG	1.966	0.175
LPG	0.066	0.175
Ethanol	0.197	0.175
Biodiesel (BD20)	0.005	0.005
Buses		
Methanol	0.066	0.175
CNG	1.966	0.175
Ethanol	0.197	0.175
Biodiesel (BD20)	0.005	0.005

Source: US Inventory of Greenhouse Gas Emissions and Sinks 1990-2011 (April 2013) Annex 3, Table A-105.

Table 13.7 US Default CH_4 and N_2O Emission Factors for Non-Highway Vehicles

Vehicle Type / Fuel Type	CH_4 (g / gallon)	N_2O (g / gallon)
Ships and Boats		
Residual Fuel Oil	0.11	0.60
Diesel Fuel	0.74	0.45
Gasoline	0.06	0.22
Locomotives		
Diesel Fuel	0.80	0.26
Agricultural Equipment		
Gasoline	1.26	0.22
Diesel Fuel	1.44	0.26
Construction/Mining Equipment		
Gasoline	0.50	0.22
Diesel Fuel	0.58	0.26
Other Non-Highway		
Snowmobiles (Gasoline)	0.50	0.22
Other Recreational (Gasoline)	0.50	0.22
Other Small Utility (Gasoline)	0.50	0.22
Other Large Utility (Gasoline)	0.50	0.22
Other Large Utility (Diesel)	0.58	0.26
Aircraft		
Jet Fuel	0.00	0.31
Aviation Gasoline	7.05	0.11
Source: US Inventory of Greenhouse Gas Emissions and Sinks 1990-2011 (April 2013) Annex 3, Table A-106. Original factors converted to g/gallon fuel using fuel density defaults from U.S. EPA Climate Leaders, Mobile Combustion Guidance (2008) Table A-6.		

Table 13.8 LTO Emission Factors for Typical Aircraft

Aircraft	CO_2 (kg/LTO)	CH_4 (kg/LTO)	N_2O (kg/LTO)
A300	5450	0.12	0.2
A310	4760	0.63	0.2
A319	2310	0.06	0.1
A320	2440	0.06	0.1
A321	3020	0.14	0.1
A330-200/300	7050	0.13	0.2
A340-200	5890	0.42	0.2
A340-300	6380	0.39	0.2
A340-500/600	10660	0.01	0.3
707	5890	9.75	0.2
717	2140	0.01	0.1
727-100	3970	0.69	0.1
727-200	4610	0.81	0.1
737-100/200	2740	0.45	0.1
737-300/400/500	2480	0.08	0.1
737-600	2280	0.1	0.1
737-700	2460	0.09	0.1
737-800/900	2780	0.07	0.1
747-100	10140	4.84	0.3
747-200	11370	1.82	0.4
747-300	11080	0.27	0.4
747-400	10240	0.22	0.3
757-200	4320	0.02	0.1
757-300	4630	0.01	0.1
767-200	4620	0.33	0.1
767-300	5610	0.12	0.2
767-400	5520	0.1	0.2
777-200/300	8100	0.07	0.3
DC-10	7290	0.24	0.2
DC-8-50/60/70	5360	0.15	0.2
DC-9	2650	0.46	0.1
L-1011	7300	7.4	0.2
MD-11	7290	0.24	0.2
MD-80	3180	0.19	0.1
MD-90	2760	0.01	0.1
TU-134	2930	1.8	0.1
TU-154-M	5960	1.32	0.2
TU-154-B	7030	11.9	0.2
RJ-RJ85	1910	0.13	0.1
BAE 146	1800	0.14	0.1
CRJ-100ER	1060	0.06	0.03

Table 13.8 LTO Emission Factors for Typical Aircraft

Aircraft	CO_2 (kg/LTO)	CH_4 (kg/LTO)	N_2O (kg/LTO)
ERJ-145	990	0.06	0.03
Fokker 100/70/28	2390	0.14	0.1
BAC111	2520	0.15	0.1
Dornier 328 Jet	870	0.06	0.03
Gulfstream IV	2160	0.14	0.1
Gulfstream V	1890	0.03	0.1
Yak-42M	2880	0.25	0.1
Cessna 525/560	1070	0.33	0.03
Beech King Air	230	0.06	0.01
DHC8-100	640	0	0.02
ATR72-500	620	0.03	0.02

Source: IPCC, Guidelines for National Greenhouse Gas Inventories (2006), Volume 2: Energy, Chapter 3: Mobile Combustion, Table 2.7.

Table 13.9 SEMS CH_4 and N_2O Emission Factors for Gasoline and Diesel Vehicles

GHG	MT GHG per MT of CO_2
CH_4	4.93E-05
N_2O	4.07E-05

Source: Derived from EPA Inventory of U.S. GHG Emissions and Sinks 1990-2011, Table 2-15. Only includes data for passenger cars and light-duty trucks.

Table 14.1 US Emission Factors by eGRID Subregion

eGRID 2012 Subregion	eGRID 2012 Subregion Name	2009 Emission Rates		
		(lbs CO_2 / MWh)	(lbs CH_4 / GWh)	(lbs N_2O / GWh)
AKGD	ASCC Alaska Grid	1,280.86	27.74	7.69
AKMS	ASCC Miscellaneous	521.26	21.78	4.28
AZNM	WECC Southwest	1,191.35	19.13	15.58
CAMX	WECC California	658.68	28.94	6.17
ERCT	ERCOT All	1,181.73	16.70	13.10
FRCC	FRCC All	1,176.61	39.24	13.53
HIMS	HICC Miscellaneous	1,351.66	72.40	13.80
HIOA	HICC Oahu	1,593.35	101.74	21.98
MROE	MRO East	1,591.65	23.98	27.04
MROW	MRO West	1,628.60	28.80	27.79
NEWE	NPCC New England	728.41	75.68	13.86
NWPP	WECC Northwest	819.21	15.29	12.50
NYCW	NPCC NYC/Westchester	610.67	23.75	2.81
NYLI	NPCC Long Island	1,347.99	96.86	12.37
NYUP	NPCC Upstate NY	497.92	15.94	6.77
RFCE	RFC East	947.42	26.84	14.96
RFCM	RFC Michigan	1,659.46	31.41	27.89
RFCW	RFC West	1,520.59	18.12	25.13
RMPA	WECC Rockies	1,824.51	22.25	27.19
SPNO	SPP North	1,815.76	21.01	28.89
SPSO	SPP South	1,599.02	23.25	21.79
SRMV	SERC Mississippi Valley	1,002.41	19.45	10.65
SRMW	SERC Midwest	1,749.75	19.57	28.98
SRSO	SERC South	1,325.68	22.27	20.78
SRTV	SERC Tennessee Valley	1,357.71	17.28	22.09
SRVC	SERC Virginia/Carolina	1,035.87	21.51	17.45
US Territories (not an eGRID Region)*	n/a	1,891.57	75.91	17.13

Source: U.S. EPA eGRID2012 Version 1.0 (2009 data: eGRID subregion annual CO_2 total output emission rate). Except * from Department of Energy Guidance on Voluntary Reporting of Greenhouse Gases, Form EIA-1605 (2007), Appendix F, Electricity Emission Factors, Table F-1. Factors do not include emissions from transmission and distribution losses.

Table 14.2 Canadian Emission Factors for Grid Electricity by Province

Province	2010 Emission Rates		
	g CO_2 / kWh	g CH_4 / kWh	g N_2O / kWh
Alberta	856	0.03	0.02
British Columbia	23.1	0.006	0.0007
Manitoba	2.54	0.0001	0.0001
New Brunswick	499	0.031	0.01
Newfoundland and Labrador	17.7	0.0002	0.0005
Northwest Territories & Nunavut	364	0.024	0.05
Nova Scotia	756	0.036	0.01
Ontario	132	0.01	0.003
Prince Edward Island	3.39	0	0
Quebec	2.48	0.0004	0.0001
Saskatchewan	794	0.04	0.02
Yukon	44	0.002	0.01

Source: Greenhouse Gas Division, Environment Canada, National Inventory Report, 1990-2011: Greenhouse Gas Sources and Sinks in Canada (2013) Annex 13: Emission Factors, Table A13-2 - A13-13.

Table 14.3 Mexican Emission Factors for Grid Electricity

Year	Emission Rates (kg CO_2-e/MWh)
2000	604.1
2001	625.0
2002	600.0
2003	571.2
2004	549.6
2005	550.1

Source: Asociación de Técnicos y Profesionistas en Aplicación Energética (ATPAE), 2003, Metodologías para calcular el Coeficiente de Emisión Adecuado para Determinar las Reducciones de GEI Atribuibles a Proyectos de EE/ER – Justificación para la selección de la Metodología, versión final 4.1 (junio de 2003), proyecto auspiciado por la Agencia Internacional de Estados Unidos para el Desarrollo Internacional, México, D.F., México.

Note: Emission rates include emissions of CO_2, CH_4, and N_2O. Factors are a national average of all the power plants operating and delivering electricity to the National Electric System and do not include transmission and distribution losses. Factors for 2002 to 2005 were not calculated with actual data but instead estimated using the Electricity Outlooks published by Mexico's Ministry of Energy.

Table 14.4 Non-North American Emission Factors for Electricity Generation

Region / Country / Economy	2010 Emission Rates g CO_2 / kWh
Albania	2
Algeria	548
Angola	440
Argentina	367
Armenia	92
Australia	841
Austria	188
Azerbaijan	439
Bahrain	640
Bangladesh	593
Belarus	449
Belgium	220
Benin	720
Bolivia	423
Bosnia and Herzegovina	723
Botswana	2 517
Brazil	87
Brunei Darussalam	717
Bulgaria	535
Cambodia	804
Cameroon	207
Chile	410
Chinese Taipei	624
Colombia	176
Congo	142
Costa Rica	56
Côte d'Ivoire	445
Croatia	236
Cuba	1 012
Cyprus	697
Czech Republic	589
Dem. Rep. of Congo	3
Denmark	360
Dominican Republic	589
DPR of Korea	465
Ecuador	389
Egypt	450
El Salvador	223
Eritrea	646
Estonia	1 014
Ethiopia	7

Table 14.4 Non-North American Emission Factors for Electricity Generation

Region / Country / Economy	2010 Emission Rates g CO_2 / kWh
Finland	229
France	79
FYR of Macedonia	685
Gabon	383
Georgia	69
Germany	461
Ghana	259
Gibraltar	762
Greece	718
Guatemala	286
Haiti	538
Honduras	332
Hong Kong, China	723
Hungary	317
Iceland	0
India	912
Indonesia	709
Iraq	1 003
Ireland	458
Islamic Rep. of Iran	565
Israel	689
Italy	406
Jamaica	711
Japan	416
Jordan	566
Kazakhstan	403
Kenya	274
Korea	533
Kosovo	1 287
Kuwait	842
Kyrgyzstan	59
Latvia	120
Lebanon	709
Libya	885
Lithuania	337
Luxembourg	410
Malaysia	727
Malta	872
Mongolia	949
Montenegro	405
Morocco	718

Table 14.4 Non-North American Emission Factors for Electricity Generation

Region / Country / Economy	2010 Emission Rates g CO_2 / kWh
Mozambique	1
Myanmar	262
Namibia	197
Nepal	1
Netherlands	415
Netherlands Antilles	707
New Zealand	150
Nicaragua	460
Nigeria	405
Norway	17
Oman	794
Pakistan	425
Panama	298
Paraguay	-
People's Rep. of China	766
Peru	289
Philippines	481
Poland	781
Portugal	255
Qatar	494
Republic of Moldova	517
Romania	413
Russian Federation	384
Saudi Arabia	737
Senegal	637
Serbia	718
Singapore	499
Slovak Republic	197
Slovenia	325
South Africa	927
Spain	238
Sri Lanka	379
Sudan	344
Sweden	30
Switzerland	27
Syrian Arab Republic	594
Tajikistan	14
Thailand	513
Togo	195
Trinidad and Tobago	700
Tunisia	463

Table 14.4 Non-North American Emission Factors for Electricity Generation

Region / Country / Economy	2010 Emission Rates g CO_2 / kWh
Turkey	460
Turkmenistan	954
Ukraine	392
United Arab Emirates	598
United Kingdom	457
United Rep. of Tanzania	329
Uruguay	81
Uzbekistan	550
Venezuela	264
Vietnam	432
Yemen	655
Zambia	3
Zimbabwe	660
Source: CO_2 Emissions from Fuel Combustion Highlights (2012 Edition, revised March 2013)© OECD/IEA, 2012 CO_2 emissions per kWh from electricity generation.	

Table 14.5 Average Cost per Kilowatt Hour by US State

State	2012 Average Retail Price Residential (¢/kWh)	2012 Average Retail Price Commercial (¢/kWh)	2012 Average Retail Price Industrial (¢/kWh)
AK Total	17.88	14.93	16.82
AL Total	11.4	10.63	6.22
AR Total	9.3	7.71	5.76
AZ Total	11.29	9.53	6.53
CA Total	15.34	13.41	10.49
CO Total	11.46	9.39	6.95
CT Total	17.34	14.65	12.67
DC Total	12.28	12.02	5.46
DE Total	13.58	10.13	8.36
FL Total	11.42	9.66	8.04
GA Total	11.17	9.58	5.98
HI Total	37.34	34.88	30.82
IA Total	10.82	8.01	5.3
ID Total	8.67	6.86	5.48
IL Total	11.37	7.99	5.8
IN Total	10.53	9.14	6.34
KS Total	11.24	9.24	7.09
KY Total	9.43	8.73	5.35
LA Total	8.37	7.75	4.76
MA Total	14.91	13.84	12.57
MD Total	12.84	10.43	8.09
ME Total	14.66	11.53	7.98
MI Total	14.13	10.93	7.62
MN Total	11.35	8.84	6.54
MO Total	10.17	8.2	5.89
MS Total	10.26	9.33	6.24
MT Total	10.08	9.13	5.1
NC Total	10.91	8.66	6.42
ND Total	9.06	8.02	6.55
NE Total	10.04	8.38	7.01
NH Total	16.07	13.36	11.83
NJ Total	15.78	12.78	10.52
NM Total	11.37	9.32	5.83
NV Total	11.83	8.83	6.48
NY Total	17.62	15.06	6.7
OH Total	11.76	9.47	6.24
OK Total	9.51	7.32	5.09
OR Total	9.8	8.31	5.59
PA Total	12.75	9.44	7.23
RI Total	14.4	11.87	10.68

Table 14.5 Average Cost per Kilowatt Hour by US State

State	2012 Average Retail Price Residential (¢/kWh)	2012 Average Retail Price Commercial (¢/kWh)	2012 Average Retail Price Industrial (¢/kWh)
SC Total	11.77	9.63	6.02
SD Total	10.07	8.1	6.57
TN Total	10.1	10.31	7.08
TX Total	10.98	8.16	5.57
UT Total	9.93	8.06	5.62
VA Total	11.08	8.08	6.72
VT Total	17.01	14.32	9.98
WA Total	8.53	7.68	4.13
WI Total	13.19	10.51	7.34
WV Total	9.85	8.42	6.33
WY Total	9.85	8.24	6.03
Source: Energy Information Administration: Electric Power Annual, Table 2.10: Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, State 2012 and 2011. (December 2013)			

Table 14.6 Canadian Electricity Intensity

Principal Building Activity Annual Electricity Intensity	GJ/m^2
Commercial and institutional accommodation	0.53
Entertainment and recreation	0.93
Office	0.97
Food retails	1.86
Non food retails	0.52
Food service	1.34
Non food service	0.58
Shopping malls	0.72
Warehouse/wholesale	0.79
Administration	0.82
Education	0.4
Health care	0.93
Public assembly	0.55
Other	0.58

Source: Natural Resources Canada, Commercial and Institutional Building Energy Use Survey 2000 Table 11.1 *Total electricity consumption and electricity intensity by building characteristics, occupancy characteristics, energy efficiency features, heating energy sources and equipment, cooling energy sources and equipment, and water heating energy sources*

Table 14.7 US Electricity Intensity

Principal Building Activity Annual Electricity Intensity	Electricity Intensity (kWh/ft^2)
Education	11
Food Sales	49.4
Food Service	38.4
Health Care	22.9
Inpatient	27.5
Outpatient	16.1
Lodging	13.5
Retail (other than mall)	14.3
Office	17.3
Public Assembly	12.5
Public Order and Safety	15.3
Religious Worship	4.9
Service	11
Warehouse and Storage	7.6
Other	22.5
Vacant	2.4
Source: 2003 Commercial Buildings Energy Consumption Survey, Energy Information Administration (http://www.eia.doe.gov/emeu/cbecs/)	

Table 16.2 Default Emission Factors for Refrigeration/Air Conditioning Equipment

Type of Equipment	Capacity (kg)	Installation Emission Factor k (% of capacity)	Operating Emission Factor k (% of capacity/year)	Refrigerant Remaining at Disposal y (% of capacity)	Recovery Efficiency z (% of remaining)
Domestic Refrigeration	0.05 - 0.5	1%	0.50%	80%	70%
Stand-alone Commercial Applications	0.2 - 6	3%	15%	80%	70%
Medium & Large Commercial Refrigeration	50 - 2,000	3%	35%	100%	70%
Transport Refrigeration	8-Mar	1%	50%	50%	70%
Industrial Refrigeration including Food Processing and Cold Storage	10 -10,000	3%	25%	100%	90%
Chillers	10 - 2,000	1%	15%	100%	95%
Residential and Commercial A/C including Heat Pumps	0.5 - 100	1%	10%	80%	80%
Mobile Air Conditioning	0.5 – 1.5	0.50%	20%	50%	50%

Source: IPCC, *Guidelines for National Greenhouse Gas Inventories* (2006), Volume 3: Industrial Processes and Product Use, Table 7.9.
Note: Emission factors above are the most conservative of the range provided by the IPCC. The ranges in capacity are provided for reference. You should use the actual capacity of your equipment. If you do not know your actual capacity, you should use the high end of the range provided (e.g., use 2,000 kg for chillers).

U.S. Default Factors for Calculating CO_2 Emissions from Geothermal Energy Production

Fuel Type	Carbon Content (Per Unit Energy)	CO_2 Emission Factor (Per Unit Energy)
Geothermal	**kg C / MMBtu**	**kg CO_2 / MMBtu**
Geothermal	2.05	7.52
Source: US Inventory of Greenhouse Gas Emissions and Sinks 1990-2011 (April 2013) Annex 2.2, Table A-35		

Table B.1. Global Warming Potential Factors for Required Greenhouse Gases

Common Name	Formula	Chemical Name	SAR	TAR	AR4
Carbon dioxide	CO_2		1	1	1
Methane	CH_4		21	23	25
Nitrous oxide	N_2O		310	296	298
Nitrogen trifluoride	NF_3		NA	10,800	17,200
Sulfur hexafluoride	SF_6		23,900	22,200	22,800
Hydrofluorocarbons (HFCs)					
HFC-23 (R-23)	CHF_3	trifluoromethane	11,700	12,000	14,800
HFC-32 (R-32)	CH_2F_2	difluoromethane	650	550	675
HFC-41 (R-41)	CH_3F	fluoromethane	150	97	92
HFC-125 (R-125)	C_2HF_5	pentafluoroethane	2,800	3,400	3,500
HFC-134 (R-134)	$C_2H_2F_4$	1,1,2,2-tetrafluoroethane	1,000	1,100	1,100
HFC-134a (R-134a)	$C_2H_2F_4$	1,1,1,2-tetrafluoroethane	1,300	1,300	1,430
HFC-143 (R-143)	$C_2H_3F_3$	1,1,2-trifluoroethane	300	330	353
HFC-143a (R-143a)	$C_2H_3F_3$	1,1,1-trifluoroethane	3,800	4,300	4,470
HFC-152 (R-152)	$C_2H_4F_2$	1,2-difluoroethane	NA	43	53
HFC-152a (R-152a)	$C_2H_4F_2$	1,1-difluoroethane	140	120	124
HFC-161 (R-161)	C_2H_5F	fluoroethane	NA	12	12
HFC-227ea (R-227ea)	C_3HF_7	1,1,1,2,3,3,3- heptafluoropropane	2,900	3,500	3,220
HFC-236cb (R-236cb)	$C_3H_2F_6$	1,1,1,2,2,3-hexafluoropropane	NA	1,300	1,340
HFC-236ea (R-236ea)	$C_3H_2F_6$	1,1,1,2,3,3-hexafluoropropane	NA	1,200	1,370
HFC-236fa (R-236fa)	$C_3H_2F_6$	1,1,1,3,3,3-hexafluoropropane	6,300	9,400	9,810
HFC-245ca (R-245ca)	$C_3H_3F_5$	1,1,2,2,3-pentafluoropropane	560	640	693
HFC-254fa (R-245fa)	$C_3H_3F_5$	1,1,1,3,3-pentafluoropropane	NA	950	1,030
HFC-365mfc	$C_4H_5F_5$	1,1,1,3,3-pentafluorobutane	NA	890	794
HFC-43-10mee (R-4310)	$C_5H_2F_{10}$	1,1,1,2,3,4,4,5,5,5- decafluoropentane	1,300	1,500	1,640
Perfluorocarbons (PFCs)					
PFC-14 (Perfluoromethane)	CF_4	tetrafluoromethane	6,500	5,700	7,390
PFC-116 (Perfluoroethane)	C_2F_6	hexafluoroethane	9,200	11,900	12,200
PFC-218 (Perfluoropropane)	C_3F_8	octafluoropropane	7,000	8,600	8,830
PFC-318 (Perfluorocyclobutane)	$c\text{-}C_4F_8$	octafluorocyclobutane	8,700	10,000	10,300
PFC-3-1-10 (Perfluorobutane)	C_4F_{10}	decafluorobutane	7,000	8,600	8,860
PFC-4-1-12 (Perfluoropentane)	C_5F_{12}	dodecafluoropentane	NA	8,900	9,160
PFC-5-1-14 (Perfluorohexane)	C_6F_{14}	tetradecafluorohexane	7,400	9,000	9,300
PFC-9-1-18 (Perfluorodecalin)	$C_{10}F_{18}$		NA	NA	>7,500

Source: Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (SAR) published in 1995, Third Assessment Report (TAR), published in 2001, and Fourth Assessment Report (AR4) published in 2007. All defaults 100-year GWP values. For any defaults provided as a range, use exact value provided for the purpose of reporting to The Registry. NA = data not available.

NOTE: Complete reporters must include emissions of all Kyoto-defined GHGs (including all HFCs and PFCs) in inventory reports. If HFCs or PFCs are emitted that are not listed above, complete reporters must use industry best practice to calculate CO_2e from those gasses.

Table B.2. Global Warming Potentials of Refrigerant Blends

Refrigerant Blend	Gas	SAR	TAR	AR4
R-401A	HFC	18.2	15.6	16.12
R-401B	HFC	15	13	14
R-401C	HFC	21	18	18.6
R-402A	HFC	1,680	2,040	2,100
R-402B	HFC	1,064	1,292	1,330
R-403A	PFC	1,400	1,720	1,766
R-403B	PFC	2,730	3,354	3,444
R-404A	HFC	3,260	3,784	3,922
R-407A	HFC	1,770	1,990	2,107
R-407B	HFC	2,285	2,695	2,804
R-407C	HFC	1,526	1,653	1,774
R-407D	HFC	1,428	1,503	1,627
R-407E	HFC	1,363	1,428	1,552
R-407F	HFC	1,555	1,705	1,825
R-408A	HFC	1,944	2,216	2,301
R-410A	HFC	1,725	1,975	2,088
R-410B	HFC	1,833	2,118	2,229
R-411A	HFC	15	13	14
R-411B	HFC	4.2	3.6	3.72
R-412A	PFC	350	430	442
R-415A	HFC	25.2	21.6	22.32
R-415B	HFC	105	90	93
R-416A	HFC	767	767	843.7
R-417A	HFC	1,955	2,234	2,346
R-417B	HFC	2,450	2,924	3,027
R-417C	HFC	1,570	1,687	1,809
R-418A	HFC	3.5	3	3.1
R-419A	HFC	2,403	2,865	2,967
R-419B	HFC	1,982	2,273	2,384
R-420A	HFC	1,144	1,144	1,258
R-421A	HFC	2,170	2,518	2,631
R-421B	HFC	2,575	3,085	3,190
R-422A	HFC	2,532	3,043	3,143
R-422B	HFC	2,086	2,416	2,526
R-422C	HFC	2,491	2,983	3,085
R-422D	HFC	2,232	2,623	2,729
R-422E	HFC	2,135	2,483	2,592
R-423A	HFC	2,060	2,345	2,280
R-424A	HFC	2,025	2,328	2,440
R-425A	HFC	1,372	1,425	1,505
R-426A	HFC	1,352	1,382	1,508
R-427A	HFC	1,828	2,013	2,138

Table B.2. Global Warming Potentials of Refrigerant Blends

Refrigerant Blend	Gas	SAR	TAR	AR4
R-428A	HFC	2,930	3,495	3,607
R-429A	HFC	14	12	12
R-430A	HFC	106.4	91.2	94.24
R-431A	HFC	41	35	36
R-434A	HFC	2,662	3,131	3,245
R-435A	HFC	28	24	25
R-437A	HFC	1,567	1,684	1,805
R-438A	HFC	1,890	2,151	2,264
R-439A	HFC	1,641	1,873	1,983
R-440A	HFC	158	139	144
R-442A	HFC	1,609	1,793	1,888
R-444A	HFC	85	72	87
R-445A	HFC	117	117	128.7
R-500	HFC	37	31	32
R-503	HFC	4,692	4,812	5,935
R-504	HFC	313	265	325
R-507 or R-507A	HFC	3,300	3,850	3,985
R-509 or R-509A	PFC	3,920	4,816	4,945
R-512A	HFC	198	179	189.3
Source: ASHRAE Standard 34-2013				

Table B.3. Refrigerant Blends (Contain HFCs and PFCs)

Blend	Constituents	Composition (%)
R-405A	HCFC-22/HFC-152a/HCFC-142b/PFC-318	(45.0/7.0/5.5/42.5)
R-413A	PFC-218/HFC-134a/HC-600a	(9.0/88.0/3.0)
R-508A	HFC-23/PFC-116	(39.0/61.0)
R-508B	HFC-23/PFC-116	(46.0/54.0)
Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 3, Table 7.8, page 7.44.		