

# **Development of a Regional Greenhouse Gas Inventory and Forecast Including Direct and Consumption-Based/Energy-Cycle Emissions**

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## **ABSTRACT**

This paper provides a summary of the greenhouse gas (GHG) inventory and forecast developed for the North Jersey Transportation Planning Authority (NJTPA) region. To best meet the needs of municipal, county, and regional GHG mitigation planners, inventory data was prepared to clearly inform planners of the relative merits of mitigation actions taken to reduce GHG emissions both directly and indirectly. Direct GHG reductions result from reducing emissions at the source. Indirect GHG reductions result from reducing consumption of GHG-emitting products or processes. Emissions relevant to indirect reductions are captured in the form of consumption-based GHG accounting. Another important GHG accounting issue concerns energy-cycle emissions, which cover emissions that result from upstream activities (e.g., material extraction, processing, and transport) associated with the consumption of fuel. While consumption-based accounting including energy-cycle emissions enables the comparison of the full costs and benefits of proposed actions, most inventories developed at the state, national, and local level are developed primarily on a direct emission basis. Also, some mitigation benefits goals may be better measured on a direct basis. To inform regional stakeholders of the full merits of all GHG mitigation options, as well as, maintain consistency with other efforts, the NJTPA inventory and forecast was developed based on two accounting methods, whenever possible: Direct Emissions, and Consumption-Based/Energy-cycle Emissions. The inventory covers all sources and sinks of GHG, provides emission estimates for all six Kyoto Protocol gases at the county and municipal levels, and covers a 2006 base year and forecast years of 2020, 2035 and 2050.

## **INTRODUCTION**

Pending Federal legislation, including the American Clean Energy and Security Act and pending authorization of the Federal Transportation Bill, may require municipal planning organizations (MPOs) such as North Jersey Transportation Planning Authority (NJTPA) to develop and implement greenhouse gas (GHG) emissions reduction plans and integrate such plans into the Regional Transportation Plan and Transportation Improvement Program. A region-wide GHG inventory is a necessary first step in the fulfillment of these anticipated mandates.

The purpose of this project was to develop a region-wide GHG inventory and forecast (I&F), which will be part of a larger multi-year climate change initiative at NJTPA. The inventory was developed at the MPO, county, and municipal-level, to allow local counties and municipalities to begin the process of GHG mitigation planning. The I&F and supporting subregional climate change mitigation and adaptation efforts will serve as the basis for formulating and evaluating GHG reduction policies and action plans at the regional, subregional, and municipal levels. The effort will also include support for analysis of mitigation and adaptation efforts in up to 13 counties and over 300 municipalities, and technical support and training for county and municipal officials conducting such analyses.

The technical approach developed for this inventory was designed to not only produce a quality I&F based on currently accepted practices, but to also set the foundation and begin to define the approach for those future mitigation and adaptation efforts by addressing consumption-based emissions

and full energy-cycle emissions along with direct emissions generally found in emission inventories. Consumption-based and energy-cycle analysis are important components of mitigation analysis, enabling the comparison of the full emissions benefits associated with potential mitigation programs (particularly in the electricity, transportation, and waste management sectors).

The I&F presents GHG emissions from direct fuel consumption and electricity use in the residential, commercial, industrial (RCI) sectors, including production in the power sector; on-road, non-road, aviation, marine, and rail transportation sectors including freight; industrial processes; agricultural sources, including soils, manure and livestock; waste management; and land use, land use change, and forestry. Emissions were analyzed for a 2006 baseline year, allocated to the NJTPA subregions and municipalities to the extent practicable, and forecast for the years 2020, 2035, and 2050.

## **TECHNICAL APPROACH**

In developing this protocol to prepare a GHG I&F for the NJTPA region, the Project Team designed an approach to best meet the needs of municipal, county, and regional GHG mitigation planners. Inventory data was prepared to clearly inform planners of the relative merits of mitigation actions taken to reduce GHG emissions both directly and indirectly, through reductions in consumption of some GHG-emitting product or process.

Direct GHG emissions reductions are the result of reducing emissions at the source. For example, direct source reductions might include landfill methane (CH<sub>4</sub>) collection and combustion, power plant upgrades, retrofitting vehicles with low rolling resistance tires. Direct emissions occur at the source of emissions (e.g., exhaust stack, tailpipe).

Indirect GHG emissions reductions result from reducing consumption of some GHG-emitting product or process. For example, lowered consumption of electricity indirectly reduces power plant emissions by reducing electricity demand. Another important example comes from the waste management sector, where composting or reduction/re-use/recycling programs reduce the need to landfill waste that would produce CH<sub>4</sub> and reduces emissions from extraction and production of virgin materials. This protocol captures relevant emissions data in the form of consumption-based GHG accounting. Consumption-based emissions are thought of as occurring at the point of consumption. For example, electricity consumption-based emissions are associated with households instead of power plants, and vehicular emissions are associated with the trip origin and destination, rather than along the trip route.

In addition to direct versus consumption-based accounting methods, another important GHG accounting issue concerns energy-cycle emissions. These emissions cover those that result from upstream activities (e.g., material extraction, processing, and transport). Capturing energy-cycle GHG reductions is an important aspect of mitigation planning from sources such as low carbon fuels and solid waste management.

It is expected that when considering mitigation options, policy-makers will want to understand and possibly take credit for all GHG reductions resulting from actions undertaken within their jurisdiction, whether or not the GHG emissions occur within the jurisdiction's boundaries (and vice-versa – to avoid mitigation that may reduce emissions locally but increase emissions elsewhere by more than the local reduction). For that reason, as well as to inform NJTPA regional stakeholders of the full merits of all GHG mitigation options, the following estimates were developed, whenever possible:

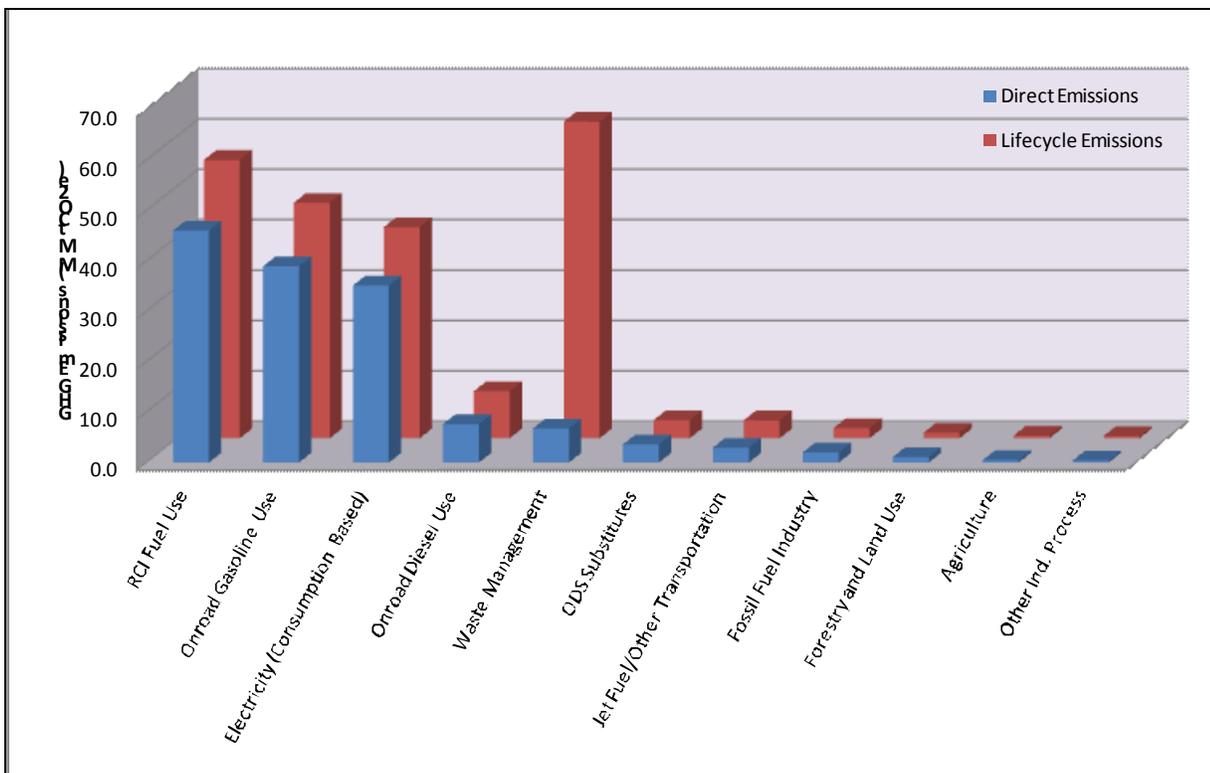
- *Direct GHG emissions;*
- *Consumption-based GHG emissions; and*
- *Energy-cycle GHG emissions.*

A consumption-based approach plus energy-cycle emissions might best fit the needs of mitigation planners, enabling the comparison of the full costs and benefits of proposed actions. However, the state I&F, the U.S. Environmental Protection Agency (EPA) national inventory, and many existing city/county efforts are developed primarily on the basis of direct emissions, and some mitigation benefits goals may be better measured on that basis. Furthermore, direct emissions are the only way to prepare inventories that can be added together cumulatively without double counting

emissions, and thus enable the more precise accounting needed for regulatory applications such as emissions trading. The project approach recognizes the need to maintain consistency with these other efforts.

For example, the gross emissions (not including emission sinks) in the State of New Jersey in 2005, presented in Figure 1 below, demonstrate the importance of lifecycle emissions accounting.<sup>1</sup> The direct emissions in 2005, presented in blue, were approximately 145 million tons carbon dioxide equivalent (MMtCO<sub>2</sub>e). After accounting for the upstream GHGs associated with the activities represented in the inventory (fuel consumption, electricity consumption, waste management), a different picture emerges. By factoring in upstream emissions, the 2005 consumption-based plus energy-cycle emissions (shown in the figure as “lifecycle” emissions), presented in red, increased to about 217 MMtCO<sub>2</sub>e. While lifecycle emissions are higher than direct emissions across nearly all sectors, the most noticeable change is in the scale of the waste management sector emissions. On a consumption basis, the emissions from solid waste management now rival those of the typical prominent sectors (electricity consumption, RCI fuel consumption, and transportation fuel consumption).

**Figure 1. State of New Jersey 2005 I&F comparison: direct vs. consumption + energy-cycle basis.**



It is important to note that the consumption-based emissions shown here do not represent a full estimate that captures emissions from all goods and services consumed in the state; but it does address important sources likely to be considered under ensuing regional to municipal-scale mitigation analyses as well as energy-cycle emissions.

All source/sink sectors were included in the direct emissions inventory; however, given the resource limitations of the project, consumption-based emissions did not include the embedded emissions associated with all materials manufactured outside of the region for use within the region, with the exception of fuels. For example, emissions associated with production of steel and cement outside of the NJTPA region were not included. However, the embedded emissions for materials that enter the solid waste stream were included within the consumption-based estimates for the waste management sector. When available data and resources allow, the inclusion of the embedded emissions for consumed materials that do not end up in the solid waste stream would further benefit mitigation policy assessments.

Detailed descriptions of the methodologies used for each sector can be found in the NJTPA I&F Protocol.<sup>2</sup> Brief descriptions of the emission sources and technical approach for each sector are given below.

### **Residential, Commercial, and Industrial Fuel Use**

Direct Emissions. Direct RCI sector emissions result from the use of fuels for building heat and hot water and for industrial processes, including utility gas, fuel oil, coal, wood, and solar. According to the New Jersey I&F, the fuel most commonly used by the RCI sector for space and water heating and for industrial processes is pipeline natural gas. Three utility companies provide pipeline natural gas to the NJTPA region. Data on annual consumption of natural gas by zip code of the metered location or by MCD, separated by customer type (RCI), was obtained from the companies. Detailed information on the RCI sector consumption of fuels other than natural gas, most importantly fuel oil, is not easy to obtain. However, for the residential sector, the 2000 Census data and the American Community Survey (2006-2008) include estimates of the number of households in a geographic area using each fuel type (utility gas, fuel oil, coal, wood, solar, etc.).<sup>3</sup> The residential use of fuels other than natural gas was estimated using this information along with the data on natural gas consumption, as reported by the utilities.

The point source and area source GHG inventories from the New Jersey Department of Environmental Protection (NJDEP) will be used in conjunction with the natural gas consumption data within the commercial and industrial sub-sectors to estimate the direct fuel consumption, without double-counting any sources. When consumption of each fuel by geographic area and subsector is calculated, the emission factors from The Climate Registry General Reporting Protocol will be used to calculate direct emissions.<sup>4</sup>

Consumption-Based Emissions. Since emissions from direct fuel use occur at the point of consumption, the direct emissions and consumption-based emissions are the same for fuel use in the RCI sector.

Energy-Cycle Emissions. Energy-cycle emissions associated with fuel extraction, refining, and transportation were included for all fuels. Energy-cycle emissions include emissions from fuel extraction, transport, and delivery (upstream emissions). The factor that accounts for the upstream emissions will be developed using the Greenhouse gas, Regulated Emissions and Energy use in Transport (GREET) model.<sup>5</sup>

Forecast Method. Plan 2035 Appendix B data for the Business as Usual (BAU) scenario were used to estimate and project the population growth and population distribution changes for the future analysis years. The consumption of electricity and of fuels for heat and hot water was projected using demographic data.

### **Electricity**

Direct Emissions. Direct electricity emissions are associated with the use of fuels for electricity production occurring at the point of combustion. The NJDEP point source GHG emissions inventory was used in developing the emissions resulting from electricity production in the NJTPA region. The NJDEP inventory was developed for all of New Jersey using annual emissions statements. We selected those point sources that were engaged in power production and were located in the NJTPA region for the NJTPA inventory. EPA's Clean Air Markets Database (CAMD) and the Emissions & Generation Resource Integrated Database (eGRID) information were used to verify facility locations and to cross check the information reported to NJDEP.<sup>6</sup>

Consumption-Based Emissions. To fully capture the potential of mitigation efforts targeted at reducing consumption, it was important to develop the consumption-based inventory. The direct emissions associated with electricity generation as well as emissions associated with imported electricity were allocated by electricity consumption to the customers in the RCI sector to produce consumption-based emissions.

Based on the New Jersey I&F for 2005, 26 percent of the electricity consumed in the State is imported. The emissions resulting from electricity consumed in the NJTPA region include both the

emissions from electricity generated within the region and the emissions imported into it. Four utility companies and one rural cooperative deliver electricity to the NJTPA region. Annual consumption data were requested from each of these companies by geographic area (zip code at metered location, or MCD) and by customer type – residential, commercial, industrial, and municipal.

Once electricity consumption is available for the entire NJTPA region, direct emissions will be estimated using the eGRID2007 emission factor for the RFCE subregion.<sup>5</sup> The eGRID emission factor is based on 2005 data. While in the future the use of verified utility-specific emission factors could be used, at this time the eGRID factor provides the best estimate for a region-wide factor, and is also suggested as the best factor to use in absence of utility-specific information in The Climate Registry General Reporting Protocol. Since emissions from electricity generation would be controlled in the future on a regional basis, such as the existing Regional Greenhouse Gas Initiative (RGGI) or potential future Federal programs, this is the most appropriate approach for consumption-based emissions.

Energy-Cycle Emissions. For the energy-cycle analysis, emissions from energy lost through transmission and distribution were included. Based on eGRID, the transmission and distribution loss in RFCE subregion is 6.41 percent. This figure is consistent with the default factor for Eastern U.S. recommended in The Climate Registry (TCR) *Electric Power Sector Protocol for the Voluntary Reporting Program*.<sup>7</sup> The energy-cycle inventory also accounted for the emissions associated with fossil fuel production and transport. The electricity module of the GREET model was used to develop a factor that accounts for the energy cycle emissions. The input to the GREET model was the RFCE subregion energy source mix in 2005, as reported in eGRID2007.

Forecast Method. As for the RCI fuel use sector, consumption of electricity *Plan 2035* Appendix B data for the BAU scenario. While the emission factors or fuel mix associated fuel use are not expected to change significantly over the forecast period, the emission factors associated with electricity consumption are expected to decrease as a result of the Renewable Portfolio Standard (RPS), RGGI, and the goals of the New Jersey Energy Master Plan. By 2020, the state's goal is to produce 22.5 percent of its electricity from renewable resources.<sup>8</sup> The goal was included the NJTPA inventory forecast, by adjusting the RFCE source mix for 2005 to account for the increase proportion of renewables in the mix, while maintaining the relative proportions of fossil fuels (mainly oil and gas) and nuclear energy. It was assumed that the RFCE source mix would be comparable to the New Jersey source mix in 2020.

## **Transportation – Highway Vehicles**

Direct Emissions. The highway vehicle analysis estimates emissions from both privately owned vehicles and commercial trucking. All emissions within the 13 county North Jersey region are included. Emissions come from fuel combusted in vehicles, including both diesel and gasoline fuels, as well as less common fuels such as ethanol and compressed natural gas. This fuel combustion results in emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. Data on direct onroad emissions was provided by AECOM. The emissions associated with onroad transportation cover all of the GHGs for all highway vehicle travel that occurs within the NJTPA region and exclude the portion of a trip's emissions that might occur outside the region. The direct GHG emission estimates for highway vehicle travel link the location of the vehicle emissions assigned to the county with the associated roadway.

The NJTPA travel demand model was used as the primary data source for disaggregated activity estimates, and EPA's recently released MOVES model was used as the primary source of GHG emission factors. Post processing of travel model outputs, and integration with MOVES, relied on AECOM's PPSUITE software which has already been linked to the North Jersey Regional Transportation Model – Enhanced (NJRTM-E).

The NJTPA travel demand model, coupled with PPSUITE and MOVES, were used to develop GHG emission estimates for 2006, 2020, 2035, and 2050. These estimates were developed using MOVES2010, with most parameters updated to reflect local conditions and programs.

Consumption-Based Emissions. A separate consumption-based accounting of emissions for onroad was also developed. These emissions were expressed at the MCD level, but unlike the direct estimate, emissions were not broken down by road type or vehicle type. Consumption-based estimates

are also provided for the years 2006, 2020, 2035 and 2050, and interpolated for the intervening years. Activity for the consumption-based emission estimates include half of the vehicle miles traveled from every trip either originating or ending in the selected MCD. Thus, these can be considered to be trips that the municipalities or counties have some control over and could apply mitigation measures to reduce these emissions.

Energy-Cycle Emissions. Energy-cycle GHG emissions within the onroad sector are associated with the production, refining and transport of diesel fuel and residual oil. Argonne National Laboratory's GREET model is used to estimate the full life-cycle emissions of both gasoline and diesel fuels in this analysis. The GREET model allows analysis for any year between 1990 and 2020. The percentage increase from direct to energy cycle emissions is held constant throughout the analysis, because no information is available on any change in energy cycle emissions over the forecast period.

Forecast Method. Emissions for futures years were estimated as described above.

## **Transportation – Aviation**

Direct Emissions. The geographic boundary for this analysis included all public use airports within the NJTPA area. There is one military airport in the North Jersey area (Naval Air Engineering Station Lakehurst), but it was not included in the GHG inventory because information for military flights was not available. The organizational boundary includes all aircraft operations up to 3000 feet.

Aircraft emission estimates were developed based on estimates from two different sources: the PANYNJ GHG emission inventory for calendar year 2006 (for Newark and Teterboro airports), and EPA 2008 National Emissions Inventory (NEI) landing-takeoff (LTO) data (for all other applicable airports).

Information from PANYNJ was used for Teterboro and Newark airports because it included aircraft type information for all flights taking place. These aircraft types were then assigned emission rates based on their engines, which provides a much more exact method than an estimate based on average emissions from LTOs.

Emissions estimates for non-Port Authority airports in North Jersey were estimated based on NEI data. This data source provides 2008 LTO data for all 24 airports in North Jersey. Of these airports, less than 1 percent have aircraft/engine information reported in the NEI. Where this information was reported, emissions were estimated based on Federal Aviation Administration Emissions and Dispersion Modeling System (EDMS) data. Where no aircraft/engine information is available, emissions were based on a representative aircraft.

Consumption-Based Emissions. A separate consumption-based accounting of emissions from the aircraft sector was not developed for this project due to limited need for local-scale GHG planning for airports.

Energy-Cycle Emissions. The GREET model was used to determine the energy-cycle emissions for aviation fuel consumption. Energy-cycle emissions factors from GREET were compared with direct emissions factors from TCR. The GREET model does not have an energy-cycle emissions estimate specifically for aviation fuels, so diesel fuel was used as a surrogate. This produced a 24.8 percent increase in emissions when energy-cycle emissions are considered.

Forecast Method. Aviation emissions were projected from 2006 through 2030 using general aviation and commercial aircraft operations projections data from the Federal Aviation Administration's Terminal Area Forecast System.<sup>9</sup> Forecast year estimates were 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) 2010.<sup>10</sup>

## **Transportation – Marine Vessels**

Direct Emissions. The Commercial Marine Vessels (CMV) category covers all the major marine emissions categories, including Ocean Going Vessels (OGVs), harbor boats, towboats, dredging boats, ferry boats, excursion vessels and government boats. Small, privately owned vessels are not included in the commercial category, and instead counted under nonroad engines/vehicles. Only emissions occurring within the three-mile demarcation line of the shore are included in this analysis. This is

consistent with the boundary used for the ozone nonattainment area State Implementation Plan (SIP) emission inventory and the PANYNJ GHG inventory. Emissions 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<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O, primarily from the combustion of diesel fuel. Other fuels, such as residual oil, are used on occasion in some types of OGVs, but our information indicates that diesel fuel is the primary fuel used at North Jersey terminals.

The majority of CMV activity data was obtained from the appendix of the Port Authority sponsored CMV study that evaluated 2000 calendar year vessel activity in the New York City harbor. This detailed port study provided a more accurate estimate of overall CMV activity and emissions than could be achieved with a top down approach. This report provided activity data for the 2000 calendar year in kilowatt hours (kWh) and horsepower hours (hp-hr) for main and auxiliary engines, and metric tons of fuel for boilers for the entire ozone non-attainment area.

Emissions estimates were made based on estimated total activity of OGVs, harbor boats, towboats and dredging boats. Ferries, excursion vessels and government boats were a much smaller number of vessels, and these were estimated based on their individual activity data and horsepower. All emissions estimates were then grown to 2006 levels based on estimated growth in the Starcrest report for port-wide ship calls by vessel type.

In the case of OGVs, emissions were allocated by county based on the terminal they would eventually use. All other vessels emissions were allocated to counties according to the percentage of time spent in that county.

Consumption-Based Emissions. To be consistent with handling of the aircraft sector, no consumption-based allocation of emissions was performed.

Energy-Cycle Emissions. Energy-cycle GHG estimates were developed for commercial marine vessels by adding the upstream GHG emissions associated with fuel extraction, processing and transport for the diesel fuel consumed by CMVs. This estimate comes from the GREET model's estimate of full life cycle emissions for diesel fuel. Accurately estimating the upstream GHG emissions associated with fuel extraction, processing and transport can be difficult for the CMV sector, because little information is available on the energy-cycle emissions associated with diesel for marine use. In this analysis, the energy-cycle emissions estimate for onroad diesel fuel is used as a surrogate.

Forecast Method. CMV emissions were forecast through 2050 using estimates of total domestic and international shipping fuel consumption from the AEO 2010. The AEO does not estimate emissions beyond 2035, so the growth factor for 2020-2035 was held constant through 2050.

## **Transportation – Rail**

Direct Emissions. Passenger rail (light rail, heavy rail, commuter rail) include inter-city rail (Amtrak), NJ TRANSIT, and PATH. NJ TRANSIT and PATH annual ridership, energy, and fuel consumption data were available from NJ Transit and from the Port Authority of New York and New Jersey. Detailed ridership data for Amtrak were available from the National Association of Railroad Passengers, and energy consumption data for Amtrak was available from the Transportation Energy Data Book.<sup>11</sup> GIS estimates of route length were prepared. Direct emissions were calculated based on train schedules, allocating the emissions based on the location of each line.

Freight is transported in New Jersey by 14 short line railroads, two regional railroads and three national railroads. Collecting detailed data for all freight rail would require a significant effort and not all detailed data is readily available. However, the ton-miles of freight for the region is available from NJTPA. The emissions for the region were estimated based on the ton-miles for originating and culminating in each county, but data at the township level is not available. Due to the complexity of obtaining such data, and since little use of this information could be made at a township level, freight estimates were only applied at the county (subregion) level.

Consumption-Based Emissions. Consumption-based emissions were developed using the same data as direct emissions. Consumption-based emissions, including electric rail, were allocated to the station areas based on ridership origin and destination, allocating half of the emissions associated with

each rider's share of the emissions (based on passenger-miles) to the origin and destination stations (50 percent to each).

Energy-Cycle Emissions. As with other Transportation sub-sectors, energy-cycle emissions were based on results of the GREET model.

### **Transportation - Nonroad**

Direct Emissions. The latest version of EPA's NONROAD model (NONROAD2008a) was used to calculate CO<sub>2</sub> emissions and fuel consumption for non-road engines in all sectors, encompassing non-highway mobile engines. NONROAD provides the best estimate available for emissions down to the county level. Sectors include recreational, construction, industrial, lawn and garden, agricultural, commercial, logging, airport ground support equipment, mining, oil field, railway support equipment, and marine recreational. Emissions were then allocated to the applicable sector (e.g., agriculture, residential, construction, etc.), not included as an aggregate within the Transportation sector. The model was run according to the latest procedures and assumptions used by NJDEP in SIP preparation, in consultation with NJDEP. The model included estimates of all equipment used, load factors, and hours of operation for the various vehicle and fuel types and all sectors.

Consumption-Based Emissions. For the Nonroad subsector, consumption-based emissions are the same as direct emissions.

Energy-Cycle Emissions. As with other Transportation sub-sectors, energy-cycle emissions were based on results of the GREET model.

Forecast Method. The EPA NONROAD model forecasts future year emissions based on built-in assumptions regarding engine technologies and fuels (including current Federal regulations regarding future year engine manufacturing and fuel quality), as well as economic and population growth assumptions. The growth assumptions were reviewed and compared with the assumptions in *Plan 2035* and with the growth assumptions for each sector. In cases where specific projections were available, the sector projections for each county were used. For example, growth in the agricultural sector use of non-road engines was assumed to be the same as the projected growth in the sector as a whole for future years.

### **Industrial Processes & Fossil Fuel Industry**

Direct Emissions. Industrial Process (IP) emissions include CO<sub>2</sub>, CH<sub>4</sub>, SF<sub>6</sub>, HFCs, PFCs, and N<sub>2</sub>O released as by-products from industrial activities, excluding combustion of fuels and electricity use (which are included in the RCI and Electricity sector). Also included in this sector are CH<sub>4</sub> emissions released from the distribution of natural gas and crude oil refining.

This sector comprised approximately two percent of the New Jersey State GHG emissions in 2000, and about 5.0 percent of New Jersey's gross GHG emissions projected for 2020. Also, many of the traditional IP sources, including some larger ones such as cement, iron, and steel production, 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.

Detailed data regarding the manufacturing output and usage of all of the substances included in this sector within the NJTPA region are not available, and the level of effort required to produce such data was considered to be far beyond the benefit of quantifying the small amount of IP emissions expected. Furthermore, it is unlikely that actions to mitigate these emissions can be taken at the local level. Therefore, the approach for the industrial process sector was 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).

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, subregions, and MCD levels, and to forecast future emission levels.

The release of SF<sub>6</sub> from electric power transmission and distribution was estimated for the NJTPA region and further allocated down to the subregion 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 was 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 MCD 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 MCD 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. Other compounds were allocated based on manufacturing employment levels.

Consumption-Based & Energy-cycle Emissions. Many of the process emissions themselves are a portion of the lifecycle emissions for the industrial sector as a whole, and refinery and natural gas distribution emissions are a portion of the energy-cycle emissions. Note that many substances may be part of a ‘lifecycle’ analysis at the point of consumption. However, this analysis focused only on energy-cycle emissions. Therefore, the IP sector treated direct and consumption-based emissions as one and the same, and no energy-cycle emissions are associated with IP emissions.

Forecast Method. For ODS substitutes, population projections were used to forecast future emission levels. Other compounds were forecast into the future based on the New Jersey I&F state-wide growth rates.

## **Agriculture**

Direct Emissions. Overall, the agriculture sector covers non-fuel combustion emissions associated with production of crops and livestock management. Emissions from agricultural nonroad engines were also allocated to the Agriculture sector (see a description of nonroad estimates under the Transportation – Nonroad section above). Given the relatively small contributions from the agricultural sector, state-level estimates from the New Jersey I&F were allocated down to the county and municipal level based on data from the U.S. Department of Agriculture’s (USDA’s) 2007 Census of Agriculture (COA)<sup>12</sup> and each MCD’s fraction of agricultural land use<sup>13</sup> as described in the I&F Protocol.<sup>1</sup>

Consumption-Based Emissions. Full consumption-based accounting for the agriculture sector would involve estimating the GHGs embedded within the agricultural products consumed by NJTPA residents and food service establishments. This type of analysis was beyond the scope of this project; however, it would have obvious benefits in mitigation planning (e.g., sourcing of locally produced agricultural products).

Energy-Cycle Emissions. Important energy-cycle GHG emissions within the agriculture sector are associated with the production and transport of synthetic fertilizers. One of the common GHG mitigation options in the crop production sector is nutrient management programs, where reductions in nitrogen are applied leading to reductions in direct emissions of N<sub>2</sub>O, as well as, a reduction of energy-cycle GHG emissions. Energy-cycle GHG estimates were developed by allocating state-wide fertilizer consumption from the New Jersey I&F to each county, as was done for the direct crop-related emission estimates above. An energy-cycle component for each source category was then developed for each county using the total synthetic nitrogen applied and an upstream emission factor from the scientific literature.<sup>14</sup>

Forecast Method. Emissions were forecast based on agricultural growth factors from NJDEP’s State I&F.

## **Solid Waste Management**

Direct Emissions. The direct emission sources for the solid waste sector are solid waste landfills, waste combustion, and composting operations. Composting operations also represent a carbon sink. Therefore, while composting is listed as a “source” of CO<sub>2</sub> in this report, composting actually creates a net carbon “sink,” resulting in negative values for composting CO<sub>2</sub> emissions, even after consideration of the CH<sub>4</sub> and N<sub>2</sub>O emissions. While it is possible that some of the waste generated in a municipality or county could be recycled within that same municipality/county, the Team has assumed that this does

not occur in the NJTPA region; hence, no direct emissions associated with recycling have been developed.

NJDEP provided a list of the mid-size and large landfills in New Jersey, including the estimated CH<sub>4</sub> emissions, as predicted by the first-order decay (FOD) equation. There are over 300 small closed landfills in New Jersey. However, these sites were not included in this study due to lack of data and the small contribution to emissions that these sites represent. NJDEP also provided the Team with a list of composting facilities in New Jersey, including the location of each facility and the type of feedstock composted. The amount of compost feedstock was multiplied by the emission factors to yield the emission estimates for each facility. Emissions from residential open burning were based on a per-capita burning rate for brush waste, leaf waste, and municipal solid waste biomass and the 2006 population for each county.<sup>15</sup>

Consumption-Based Emissions. Consumption-based emissions from this sector are associated with solid waste landfill disposal, composting, waste transportation, and waste combustion. In order to prepare the base-year inventory and reference case projection for the solid waste sector consumption-based and energy-cycle emissions, it was necessary to complete a historical and projected municipal solid waste management profile. The Team sent a survey to each county waste management director requesting the amount of waste generated that was disposed of in-county 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. Seven counties provided data. For all other counties, the NJDEP data for waste disposed and diverted was used to create the waste management profile.

The annual estimates for waste generated within a county that was disposed at landfills in the years 1990 to 2050 – regardless of the geographic location of those landfills – was estimated using the EPA LandGEM model, which applies the FOD equation.<sup>16</sup>

As an example for emissions due to out-of-county landfill disposal, Morris County provided the Team with the amounts of waste disposed at landfills in Pennsylvania. The distances were calculated using Google Maps and a weighted average ton-miles distance was calculated. EPA's WARM model provides an emission factor for tCO<sub>2</sub>e per ton-mile, which was multiplied by the weighted average from Morris County (average ton-miles per ton of waste). The WARM default assumption (based on 20 ton-miles) is used as the emission factor for transportation to in-county landfills.

The default emission factor from WARM for waste transportation was used for both recycling and composting. For composting, the same emission factors applied in the direct emissions analysis were applied for the consumption-based accounting. However, the consumption-based accounting practice multiplies the tons of compost feedstock generated in each county (as predicted by the waste management profile), regardless of where the feedstock is actually composted.

The method for calculating waste combustion emissions, for which the sole source is residential open burning, is the same as for the direct emissions inventory.

Energy-Cycle Emissions. The sources of energy-cycle emissions include:

- *Landfill Disposal energy-cycle emissions:* include the embedded energy of the waste disposed at landfills, based on the current mix of recycled and virgin materials that comprise the waste stream;
- *Recycling energy-cycle emissions:* these are based on the embedded energy of the current mix of the waste stream, less the virgin input portion of the embedded emissions due to the fact that the materials that are being recycled will be replacing the necessary extraction of virgin materials. Therefore, the net embedded emissions from recycling are equal to the process energy and non-energy and upstream material transportation emissions that result from the recycling process;
- *Composting energy-cycle emissions:* there are no composting energy-cycle emissions accounted for in this study, as there has been no literature identified by the Team which provides factors for the embedded energy of yard and food waste (e.g., that occurring during lawn/garden maintenance or food production); and

- *Waste Combustion energy-cycle emissions*: the embedded emissions of waste combustion (residential open burning in NJTPA) represent the current input mix of embedded emissions in the portion of the residential waste combusted that is not yard or food waste.

This study does not attempt to assess the downstream GHG benefits that result from landfill gas utilization for energy generation and the application of compost to soils that increases soil carbon retention and replaces fossil-based fertilizers as soil nutrients. Also, the energy-cycle embedded energy in transportation fuels used to transport raw materials to manufacturing facilities, or to transport the generated waste to the landfill, recycling, or composting site.

Emission factors for embedded emissions within materials that are landfilled, recycled, or combusted were drawn from WARM. The emission factors, which are based on process energy, non-energy process emissions, and emissions from the transportation of raw materials and manufactured goods, are dependent on the waste composition data provided (either county data or New Jersey statewide composition). While it is believed that food and yard waste do retain embedded energy (such as energy to remove yard waste or process food that results in residuals), there are no sufficient studies available at the time of this report's publication. Therefore, the energy-cycle emissions attributed to composting are zero. Note that the down-stream emissions associated with fuel combustion at composting facilities, as well as for landfill operations equipment, are captured in the top-down industrial fuel combustion emission estimates and cannot be broken out separately based on available data.

Forecast Method. For direct emissions, the forecast MSW landfill emissions are based on the application of the FOD equation to the waste emplacement data for each landfill provided by NJDEP. This method assumes constant annual waste disposal at open landfills until the year they are anticipated to close. The composting emissions forecast is based on the average annual growth in waste composted between 2000 and 2006 in the state of New Jersey. The waste combustion (residential open burning) emissions are based on population growth projections through 2050 for each MCD.

The forecast for consumption-based emissions were based on each county's average annual per-capita generation growth rate for 1995-2006. A key assumption is that the disposal, recycling, and composting rates for the most recent data year available were applied throughout the forecast period (i.e., meaning no change in solid waste management under business as usual conditions through 2050). Energy-cycle emissions were forecasted in the same manner as the consumption-based accounting emissions.

## **Wastewater Treatment**

Direct Emissions. Direct emissions from the wastewater treatment (WWT) sector include CH<sub>4</sub> and N<sub>2</sub>O emissions from municipal and industrial wastewater treatment facilities. These are process emissions only. Any fuel combustion-related emissions in the WWT sector are included within the industrial/commercial fuel combustion sector totals. Municipal WWT emissions were estimated using the population-based methods from the state I&F and recommended by EPA in the draft Regional Guidance to estimate emissions. County-level emissions were developed by applying CH<sub>4</sub> and N<sub>2</sub>O emission factors to the population for each county. The county emissions were then allocated to each municipality with one or more WWT plants based on the average daily volume treated provided by NJDEP. As with the state I&F, emissions from industrial wastewater treatment were not estimated due to the lack of data for this sub-sector and its likely small contribution to regional GHG emissions.

Consumption-Based Emissions Total regional consumption-based emissions from the wastewater sector do not differ from direct emissions; however, the geographic allocation differs between direct and consumption-based accounting. Direct emissions are associated with the location of wastewater treatment plants, while consumption-based emissions are associated with the residential and non-residential generators of wastewater. MCD-level consumption-based emissions were estimated by applying CH<sub>4</sub> and N<sub>2</sub>O emissions factors to MCD-level population data.

Energy-Cycle Emissions Energy-cycle emissions from wastewater treatment include the emissions associated with the electricity usage at wastewater treatment plants, as well as the upstream potable water system. A separate estimate of energy-cycle emissions was developed for this project due

to its importance in subsequent GHG mitigation planning; however, these emissions will overlap with electricity consumption emissions for the commercial/industrial sectors. The emission estimates for WWT energy-cycle emissions were modeled using methods described below, while those for commercial/industrial consumption are based on the actual electricity usage reported by NJTPA utilities. Therefore, the user of the estimates presented here needs to understand that these estimates overlap and adjustments will be needed when they are used along with those from the broader commercial/industrial sectors.

Energy-cycle GHG estimates were developed by applying emission factors for the electricity consumption associated with treatment of wastewater and potable water to county-level water treatment plant flow rates provided by NJDEP. The emissions were allocated to MCDs based on population. The emission factors were based on estimates of electricity consumed in WWT in a study conducted for the New York State Energy Development Authority (NYSERDA) for WWT in that state.<sup>17</sup> The electricity consumption estimate was then combined with the consumption-based emission factor for electricity use from EPA's eGRID2007 which includes grid losses. The upstream energy-cycle emissions associated with fuels used to generate the electricity were also added.

Forecast Method. Direct emission associated with WWT plants were forecasted based on county-level population growth. Consumption-based emissions were projected based on MCD-level population growth.

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

Direct Emissions. This sector includes net CO<sub>2</sub> flux from both forested lands and urban forests. Hence, the CO<sub>2</sub> flux in any given area could represent a net source or a net sink. Also included are emissions of N<sub>2</sub>O from non-agricultural fertilizer application (often captured within a category referred to as settlement soils).

For forest land, estimates of net CO<sub>2</sub> sequestration/emission were developed using county-level estimates of forest carbon stocks and carbon sequestration rates derived from the U.S. Forest Service (USFS) and National Council for Air and Stream Improvement (NCASI) Carbon On-Line Estimator (COLE)<sup>18</sup> and municipal-level estimates of forest acreage from DEP for 1986, 1995, and 2002 (2007 data were not available in time for use in this inventory). For urban forests, the Team developed the urban forest sequestration estimates from the bottom-up using the urban area for each municipality developed above from the NJDEP LULC data, USFS urban tree canopy cover data,<sup>19</sup> and a region-specific urban forest carbon accumulation rate.<sup>20</sup> For non-farm fertilizer application were, state-level estimates from the EPA SIT Land Use, Land Use Change and Forestry module was allocated down to each municipality using USFS data on urban area available green space (non-tree canopy green space).

Consumption-Based Emissions. As with the agriculture sector, full consumption-based accounting would involve estimating the GHGs embedded within the forest products by NJTPA residents and, and was beyond the scope of this project.

Energy-Cycle Emissions. With the exception of non-farm fertilizer use, there are no energy-cycle GHG emissions in the LULUCF sector (i.e., all of the upstream energy use associated with carbon sequestration is renewable solar during photosynthesis). For non-farm fertilizer use, there are embedded GHGs associated with the manufacturing and transport of commercial fertilizers, as discussed under the agriculture section above. The Team used the same approach and data sources that were used for agricultural fertilizers to estimate the energy-cycle GHG emissions for non-farm fertilizers.

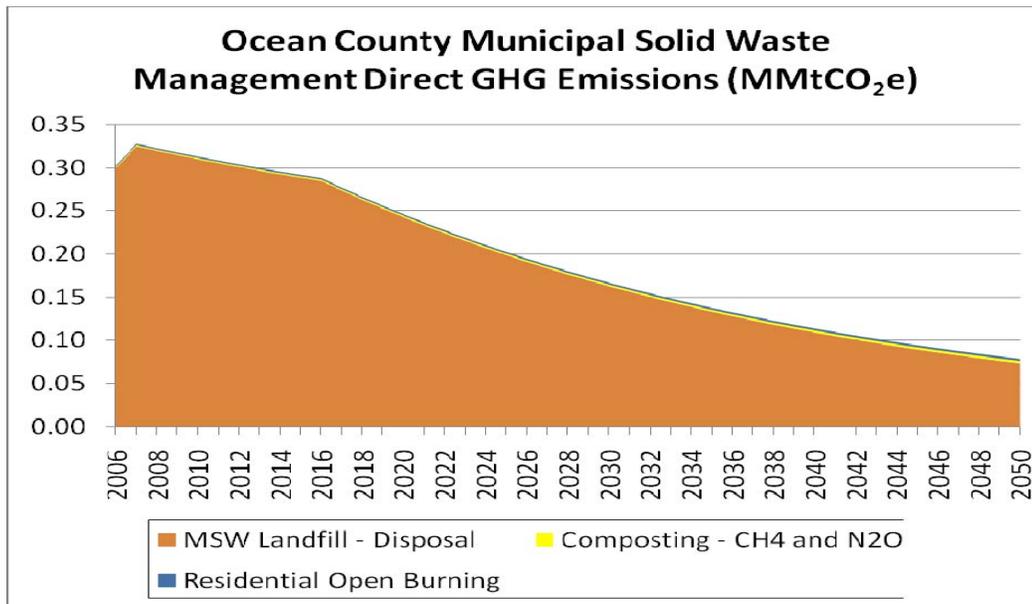
Forecast Method. Carbon sequestration/emission estimates were forecasted based on the historic trends observed in each municipality of growth/decline in forested landscape or urban area, respectively.

### **PRELIMINARY DRAFT RESULTS**

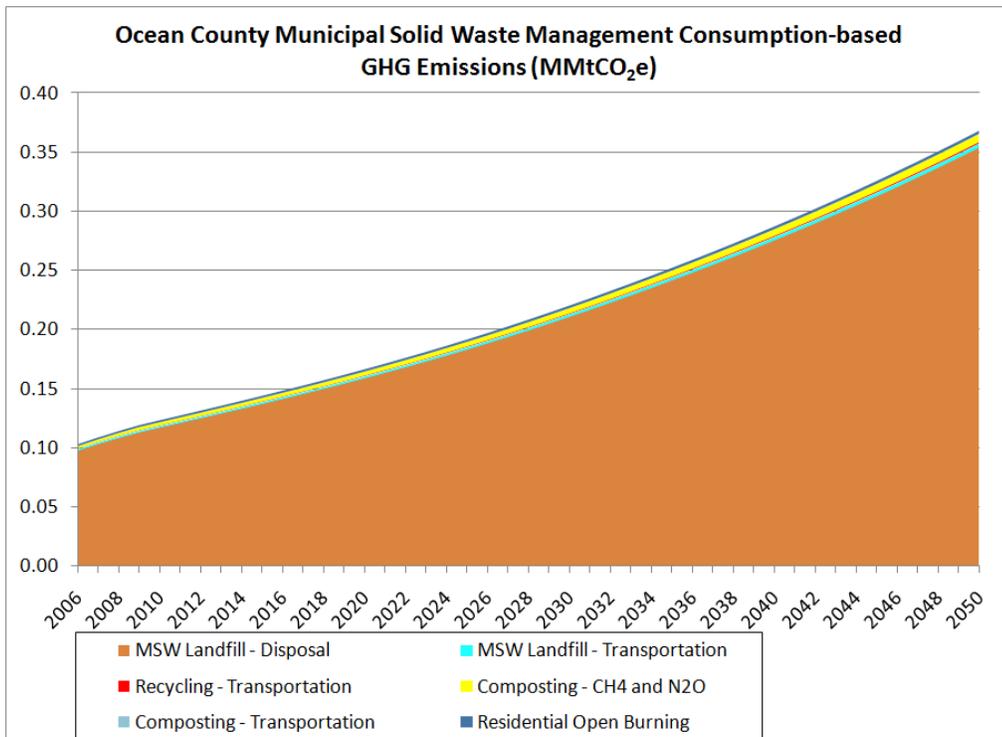
At the time this paper was submitted, final emission estimates were not available. Results presented here are *draft estimates only* and are presented only as examples of how consumption-based accounting and energy-cycle emissions may be important considerations in mitigation planning. Examples of draft emission estimates for the solid waste management and transportation sectors are presented here.

Figures 2 through 4 show solid waste management GHG emissions for Ocean County, New Jersey based on direct emissions, consumption-based emissions, and energy-cycle emissions, respectively. Standard GHG accounting would only look at the direct emissions shown in Figure 2, which capture emissions associated with a single closed landfill (with declining emissions over the forecast period), and small contributions from composting and open burning. The take-away from a GHG mitigation perspective could be that there is little attention needed for the solid waste sector. However, on a consumption basis (Figure 3), the emissions forecast looks quite different. The emissions here are actually increasing over the forecast period because all emissions for solid waste management, regardless of where they occur, are captured (much of the waste generated in Ocean County is exported outside the county for disposal). Finally, in Figure 3, the emissions associated with the embedded energy of the waste generated are shown. These represent order of magnitude increases over either the direct or consumption-based estimates alone. Figure 4 shows all three accounting methods on a single chart. The upshot is that source reduction and recycling programs can have substantial GHG benefits (at relatively low cost); however, emission reductions largely occur outside of the generating jurisdiction. However, if emissions only within the geographic boundaries of the jurisdiction are considered (i.e., standard direct emissions accounting), then these alternative waste management strategies seem unimportant.

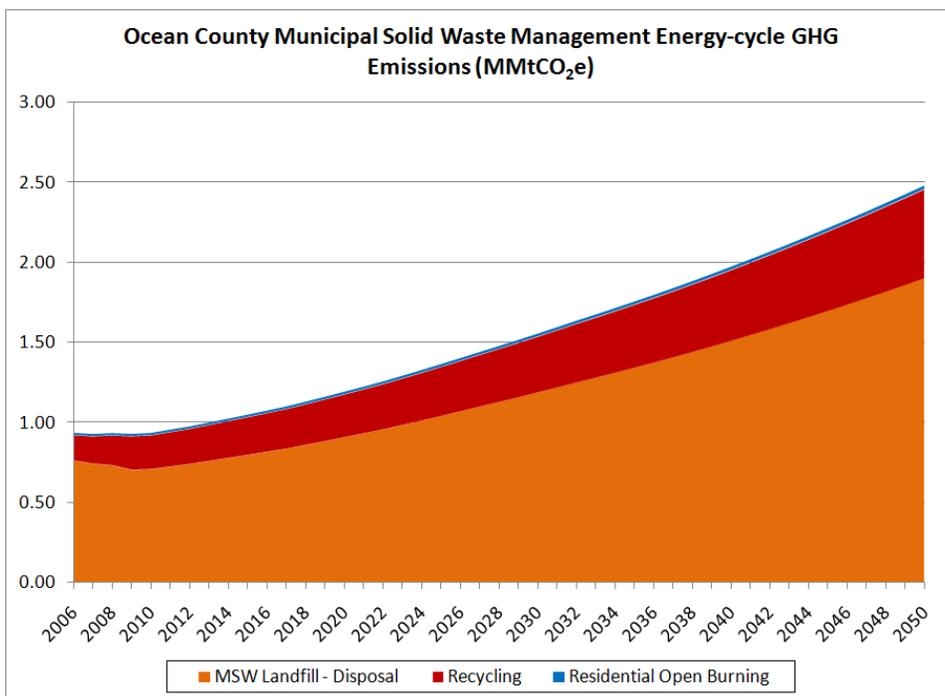
**Figure 2. Sample direct emissions – solid waste management.**



**Figure 3. Sample consumption-based emissions – solid waste management**



**Figure 4. Sample energy-cycle emissions – solid waste management.**



**Figure 5. Sample emissions chart all accounting methods – solid waste management.**

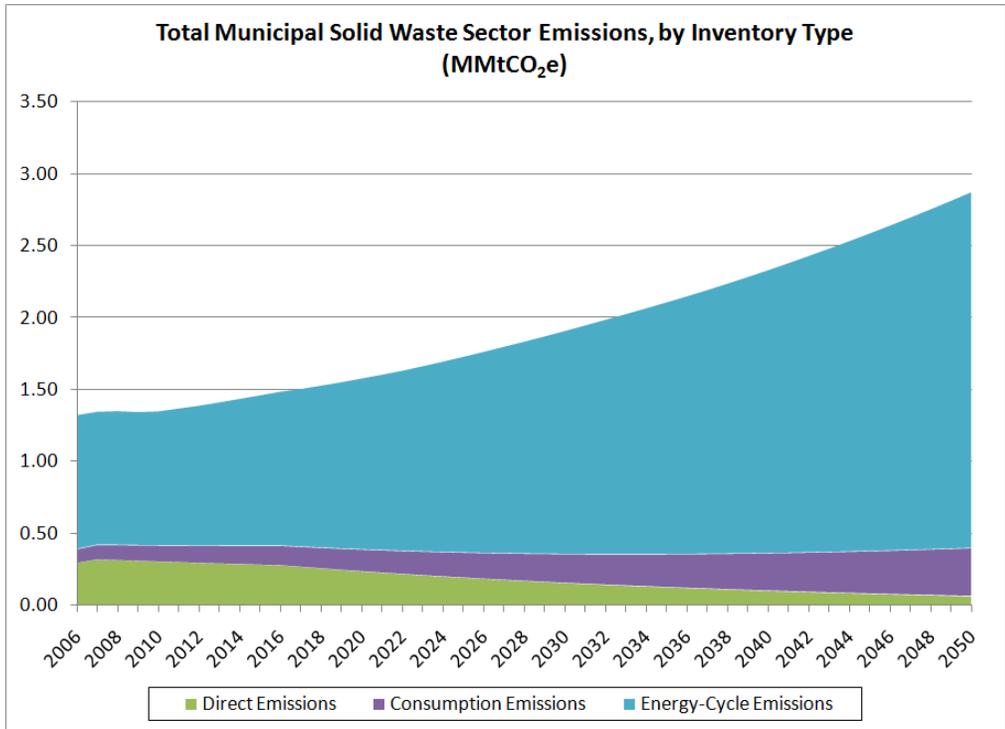


Figure 6 below shows the direct and consumption-based accounting methods applied to the onroad transportation sector. For consumption-based onroad emissions, the concept can be thought of as consuming vehicle trips (instead of with waste above, where packaging/products are consumed to produce waste). The blue colored bars on the chart correspond to the direct emissions forecast for Bergen County, New Jersey (GHG emissions that occur only within the county boundaries). The red colored bars on the chart show the total consumption-based estimates, which were developed by assigning half of the GHG emissions for each trip to the place of origin and the other half to destination.

**Figure 6. Sample emissions chart direct vs. consumption-basis – onroad transportation.**

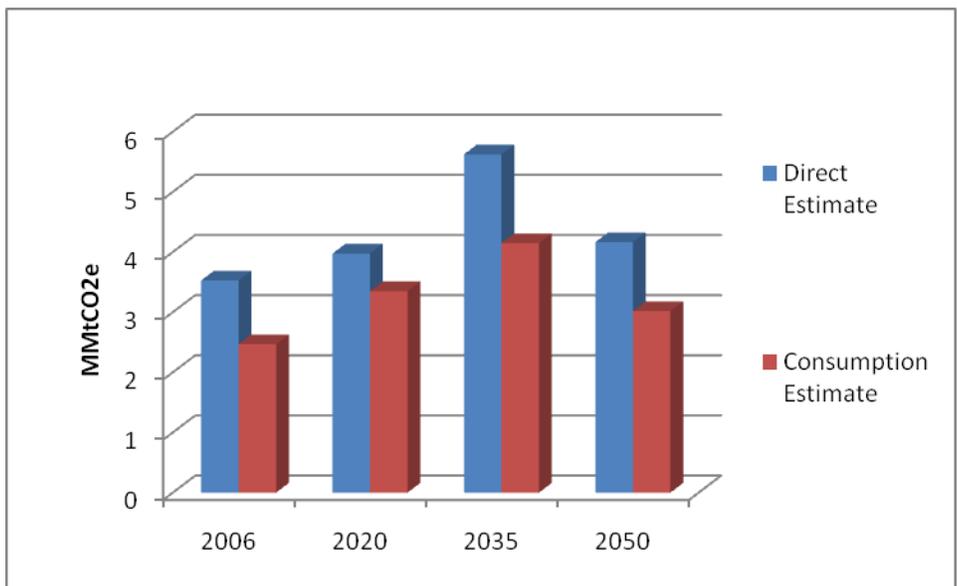
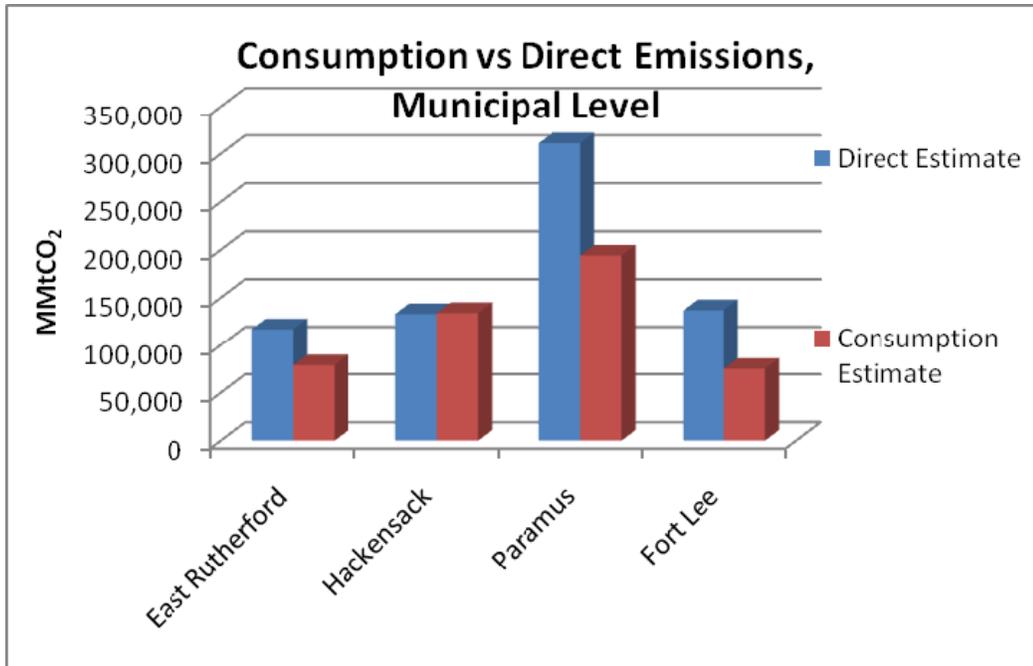


Figure 7 below serves to illustrate the potential differences between direct and consumption based estimates. For some cities, such as Hackensack, the direct and consumption based estimates are

virtually the same. Compare this to Paramus, where the direct emissions estimate is almost double that of the consumption based estimate. This is likely because Paramus has several interstates running through the town towards New York.

**Figure 7. Sample emissions of municipal-level direct vs. consumption-basis – onroad transportation.**



These types of consumption-based analyses are useful in the exploration of onroad mitigation measures such as those designed to reduce vehicle trips (e.g., ride-share programs, mode shift). In Bergen County, the direct and consumption-based estimates are fairly even. However, in a county or municipality where the direct onroad emissions are much larger than the consumption-based estimates, this could indicate that a large portion of the traffic is simply passing through the jurisdiction from other areas (e.g., via an interstate or highway). If this is the case, trip reduction measures are likely to have a much lower impact on the onroad GHG emissions, since they only affect the locally-generated trips.

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**KEY WORDS**

Greenhouse gas, emission inventory, forecast, direct emissions, consumption-based emissions, energy-cycle