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2012 Update to New Jersey's Statewide Greenhouse Gas Emission Inventory

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2012 Update to New Jersey's Statewide Greenhouse Gas Emission Inventory

Background

This report updates New Jersey's estimated total greenhouse gas (GHG) emissions as reported in New Jersey's *Statewide Greenhouse Gas Emission Inventory,* last issued November 2012 for year 2009[1], with emissions estimates for 2010, 2011, and 2012. This report, which will hereafter be referred to as the 2012 inventory, also discusses aspects regarding progress towards achieving the 2020 and 2050 greenhouse gas limits established by New Jersey's Global Warming Response Act (GWRA) (see N.J.S.A. 26:2C-43).

As stated in the GWRA, the 2020 limit is a quantity equal to the 1990 emissions total (baseline), which has been estimated to be 125.6 million metric tons of carbon dioxide equivalent ($MMTCO_2e$)[2] and the 2050 limit is a quantity 80 percent less than the 2006 emissions. The 2006 emission has been estimated to be 127.0 $MMTCO_2e$, so the 2050 limit is 25.4 $MMTCO_2e$.

New Jersey's first GHG inventory pursuant to the GWRA was finalized in November 2008 and included 1990 estimated emissions, estimated emissions for 2004 and projections out to 2020.[3] The first biennial report was completed in November 2009 and included estimated greenhouse gas emissions for 2005 through 2007.[4] The second biennial report was completed in May 2011 and included estimated greenhouse gas emissions for 2008.[5]

It is extremely important to note the context for this report. This report follows methods that were employed for previous statewide GHG emissions inventories conducted in previous years in the State of New Jersey. The same methods were used in this report to ensure consistency in the inventory from year-to-year. While the benefit of having a

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[1] Statewide Greenhouse Gas Emission Inventory for 2009.
http://www.nj.gov/dep/sage/docs/ghg-inventory2009.pdf

[2] "Carbon dioxide equivalent" represents the conversion of all emitted compounds, which includes methane and other gases, to the equivalent quantity of carbon dioxide. The global warming potential (GWP) values provided by the AR4 of Intergovernmental Panel on Climate Change (IPCC) were used. See IPPC AR4, 2007, Climate Change 2007: Working Group I: The Physical Science Basis, Technical Summary, Chapter TS 2.5, available at http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ts.html (accessed 5/9/12). The AR4 global warming potentials were used to make these 2010, 2011, and 2012 inventories more directly comparable to earlier inventories, including the 1990 baseline inventory, for which these potentials were also used without having to re-do all the earlier inventories. Were the new values used, the carbon dioxide equivalent of some gases would change slightly, because the value provided in AR5 is somewhat different.

[3] The report "New Jersey Greenhouse Gas Inventory and Reference Case Projections" is available at http://njedl.rutgers.edu/search_results?query=GHG+inventory accessed 3/17/15

4 New Jersey Statewide Greenhouse Gas Emissions Inventory Update: 2005, 2006, and 2007 Estimates. http://www.nj.gov/dep/sage/docs/inventory-05-06-07.pdf

[5] Statewide Greenhouse Gas Emission Inventory for 2008.
http://www.nj.gov/dep/sage/docs/ghg-inventory2008.pdf

temporally consistent method for the statewide emissions inventory is critically important, we do recognize that use of these methods does present some limitations. These limitations could be addressed in a more comprehensive analysis of sources of GHG emissions in New Jersey. This analysis could include:

- Addressing long-standing challenges to inventorying emissions at a state level including accounting for life cycle contributions of GHG emissions (for example, emissions created from out-of-state extraction of energy sources) as well as out-of-state emissions associated with in-state activities (e.g. air travel); and
- Considering improved analytical methods for a statewide inventory by comparing methods used for this statewide inventory with GHG emissions analyses that have been conducted by the three Metropolitan Planning Organizations in New Jersey as well as with methodologies in place for conducting community and municipal level GHG emissions inventories in New Jersey.

Methods

As with previous statewide inventories, the 2012 inventory is largely based on fuel use data obtained from the Energy Information Administration (EIA). [6,7] These data are typically not available or made public for any year until approximately one and one-half years after the end of a given year. Details on methods used to estimate releases from these data are discussed in the report "New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990-2020" (Inventory and Projections) dated November 2008.[8] Certain improvements were subsequently made to these methods and are discussed in the first and second biennial reports referenced above. Minor additional improvements to the methods made for the 2012 inventory are noted in Appendix A.

Statewide Greenhouse Gas Emissions for 2010, 2011, and 2012

In 2010, total statewide estimated greenhouse gas emissions were estimated to be 112.7 million metric tons of carbon dioxide equivalent ($MMTCO_2e$). The estimated emissions for 2011 and 2012 were 111.7 and 104.6 $MMTCO_2e$, respectively. Figure 1 (below) presents the greenhouse gas emissions for each sector for 2012.

As in earlier years, the top three sectors for greenhouse gas emissions in New Jersey are transportation, electricity generation and combined fossil fuel use for residential, commercial and industrial facilities. Transportation continues to be New Jersey's largest source of greenhouse gas emissions, accounting for approximately 46.3 $MMTCO_2e$, which is 41 percent of gross statewide greenhouse gas emissions. Electricity generation is New Jersey's second largest sector of greenhouse gas emissions, releasing approximately 20.9 $MMTCO_2e$ (~19 percent) of statewide emissions. Fossil fuel used in residential, industrial and commercial sectors, mainly for heating, had combined releases of 32.4 $MMTCO_2e$, contributing 29 percent of gross statewide emissions. Gross statewide emissions do not include the 7.9 MMTCO2e that were estimated to be sequestered by

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[6] http://www.eia.gov/state/seds/, downloaded July 10, 2014
[7] http://www.eia.doe.gov/oiaf/1605/coefficients.html, accessed June 30, 2010
[8] http://www.nj.gov/globalwarming/home/documents/pdf/20081031inventory-report.pdf

growth of the state's forests and other vegetation, including the accumulation of carbon in the associated undisturbed soils.

Figure 1

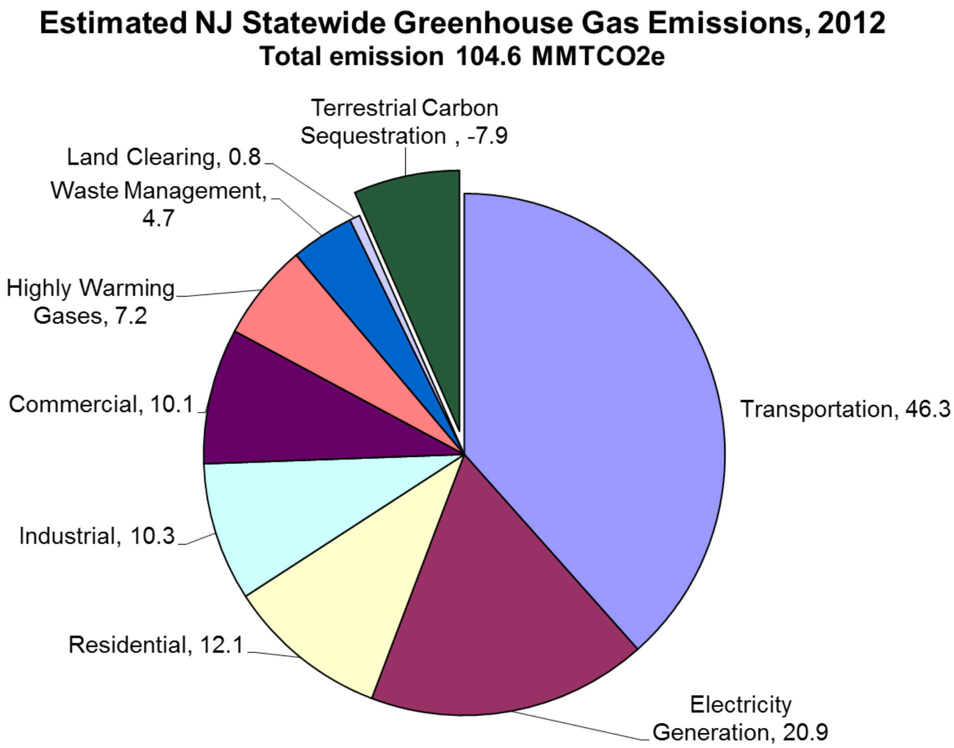


Table 1: Estimated New Jersey Statewide Greenhouse Gas Emission Million Metric Tons Carbon Dioxide Equivalents

Table 1: Estimated NJ Statewide greenhouse gas emissions

Sector	1990	2005	2006	2007	2008	2009	2010	2011	2012	Notes
Commercial	10.7	10.8	9.2	10.6	10.2	10.8	10.6	11.3	10.1	
Industrial	19.8	17.3	16.3	15.9	13.9	10.6	9.1	10.3	10.3	
Residential	15.2	16.3	13.7	15.6	14.9	15.2	14.2	13.6	12.1	
Transportation										
on-road gasoline	28.9	38.0	38.1	39.0	38.2	37.3	36.8	36.1	35.3	
distillate (primarily on-road diesel)	5.6	10.8	10.8	11.4	9.9	7.9	8.9	10.2	8.7	
jet fuel	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	*1
residual (primarily marine)	1.0	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	*2
other	0.4	0.3	0.3	0.3	0.3	0.3	0.5	0.5	0.4	
Electricity										
In-state electric	12.4	19.8	18.5	22.7	19.1	15.0	17.7	15.7	15.1	*3
Imported electric	14.1	13.1	11.7	11.9	10.0	7.7	7.7	6.8	5.2	
MSW incineration	na	0.8	0.8	1.0	0.8	0.8	0.7	0.7	0.6	
Halogenated gases (ex. SF6)	0.0	3.0	3.2	3.2	3.3	3.4	3.9	4.0	4.1	*4a
SF6	1.0	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.1	*4a
Industrial non-fuel related	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	*4
Agriculture	0.6	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	*4
Natural gas T&D	2.5	2.4	2.6	2.6	2.6	2.5	2.5	2.5	2.5	*4b
Landfills, in-state	11.7	3.6	3.5	3.5	3.4	3.3	3.3	3.2	3.2	
out-of-state	2.6	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	*7
industrial	1.1	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	
POTWs	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	*5
Released thru land clearing	0.6	1.7	1.7	0.8	0.8	0.8	0.8	0.8	0.8	*8
Total gross emissions, MMT	129.6	142.2	134.6	142.6	131.6	119.8	120.6	119.7	112.5	
Sequestered by forests	-4.0	-7.6	-7.6	-7.9	-7.9	-7.9	-7.9	-7.9	-7.9	*6
Total net emissions MMT CO2eq	**125.6**	**134.6**	**127.0**	**134.7**	**123.7**	**111.9**	**112.7**	**111.7**	**104.6**	

All numbers are estimates; uncertainty of totals is likely in range of plus or minus 5 percent

*1 set equal to 1 MMT in effort to account for in-state only
*2 estimated to represent in-state only per methods of NJ GHG Inventory & Reference Case Projections 1990-2020, NJDEP, Nov. 2008, assumed same 2006 thru 2012
*3 1990 value from NJ GHG Inventory & Reference Case Projections 1990-2020, NJDEP, Nov. 2008, includes MSW incineration.
*4 2005 value from NJ GHG Inventory & Reference Case Projections 1990-2020, NJDEP, Nov. 2008; 2006 thru 2009 assumed equal to 2005. 2010, 2011, and 2012 Agr. from NJDEP
*4a based on U.S. data from EPA, apportioned to NJ based on population for HFCs, based on elec. use for SF6
*4b Through 2009, based on pipeline data from US DOT. 2010 through 2012 assumed the same as 2009.
*5 earlier values have been adjusted; assumed equal to newly-calculated value for 2008 & 2009; 2010 thru 2012 from NJDEP
*6 all values updated per latest NJDEP calculations
*7 values from 2009 on are assumed equal to 2008 and 2007.
*8 values for 2008 thru 2012 based on carbon release rate with development as calc'd for 2007, but apportioned to number of building permits issued for a given year
Note issues with the transportation methodology described in notes in "CO2_EIA_based" worksheet

Notes to table 1: "MSW" stands for municipal solid waste, "SF6" stands for sulfur hexafluoride, "T&D" stands for transmission and distribution, "MMT" stands for million metric tons, "POTW" stands for Publicly Owned Treatment works, and "CO2eq" stands for carbon dioxide equivalents (see earlier note on carbon dioxide equivalents).

Trends and Progress Toward 2020 and 2050 Limits

This section briefly discusses recent trends in greenhouse gas emissions and progress toward achieving the 2020 and 2050 statewide greenhouse gas limits. Trends for specific sectors are discussed, including key related data for specific sectors, where appropriate.

- *Statewide Progress in meeting 2020 and 2050 limits*

Table 1 above presents estimated statewide greenhouse gas emissions for 1990 (the 2020 limit) and 2005 through 2012. The statewide greenhouse gas limit for 2020 is to stabilize emissions to the level of 1990, which, as noted above, is 125.6 MMTCO2eq. Since 2008, statewide greenhouse gas emissions have been consistently below the 2020 limit.

The statewide greenhouse gas limit for 2050 is 80 percent less than the 2006 level (127 $MMTCO_2e$) of statewide greenhouse gas emissions, or 25.4 $MMTCO_2e$. To achieve this limit, current greenhouse gas emissions must be reduced by approximately 75%; the 2012 emissions, at 104.6 $MMTCO_2e$, are 79.2 $MMTCO_2e$ above the 2050 limit.

The state's greenhouse gas emissions in 2012 were nearly seven percent lower than the average emissions of the three previous years, 2009, 2010, and 2011. A decrease of this degree in just one year might suggest that the state is well on the road to achieving the 2050 limit. However, data from the NJ State Climatologist indicate that 2012 had an unusually warm winter and an unusually cool summer,[9] which meant that less fuel was combusted and less electricity used for both heating and cooling by the residential, commercial, and industrial sectors. Figures 2 and 3, which show heating and cooling degree days,[10] illustrate the unusual mildness of 2012 regarding both parameters.

Potential reasons for the 2012 decline in statewide Greenhouse Gas Emissions

1) Natural gas, which emits less GHG per unit of energy, replaced coal in some electricity generating plants. Natural gas also replaced some uses of heating oil in residential and commercial facilities, which also lowered GHG emissions.

2) 2012 had a relatively warm winter, which lessened the combustion of fuels for heating. The year also had a relatively cool summer, which lessened the need for electricity for cooling. Both of these reductions led to lower GHG emissions.

3) Energy efficiency measures, both those encouraged by State policies and those resulting from a long-standing trend apparent at the national level, lowered energy use and GHG emissions.

4) Although relatively small in effect, a trend of more electricity production from photovoltaic sources continued, resulting in less generation from fossil fuel sources, lowering GHG emissions.

[9] New Jersey State Climatologist, 2014, Monthly Mean Temperatures in New Jersey From 1895-2014, http://climate.rutgers.edu/stateclim_v1/data/njhisttemp.html,

[10] Heating degree days (HDD) and cooling degree days (CDD) are measurements that reflect the demand for energy needed to heat or cool a building. Heating degree days are typically calculated as the difference between a day's average temperature and 65º F, if that day's average was below 65º F. Cooling degrees are the difference between a day's average temperature and 65º F if the average temperature was above 65º F. For this analysis, monthly mean temperatures, as provided by the NJ State Climatologist (see footnote above) were used.

Figure 2.

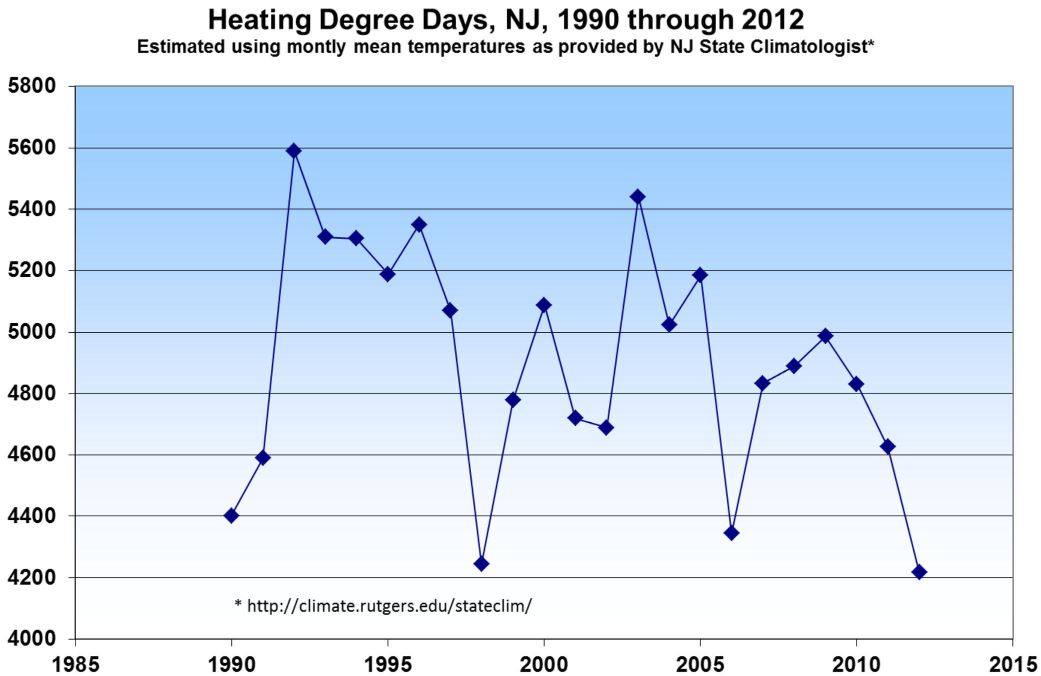
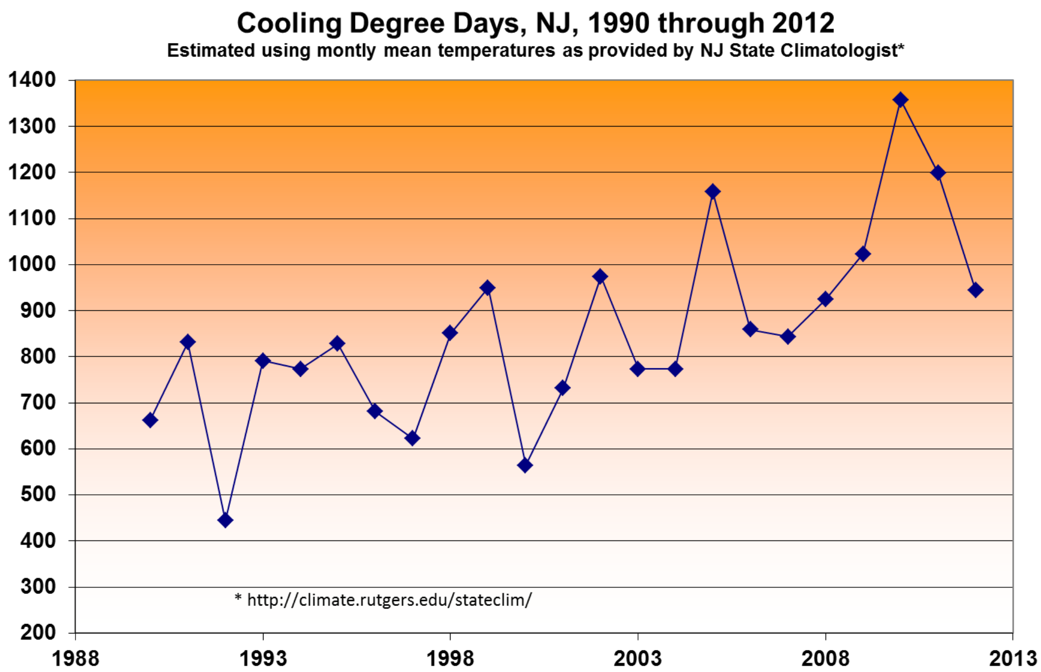


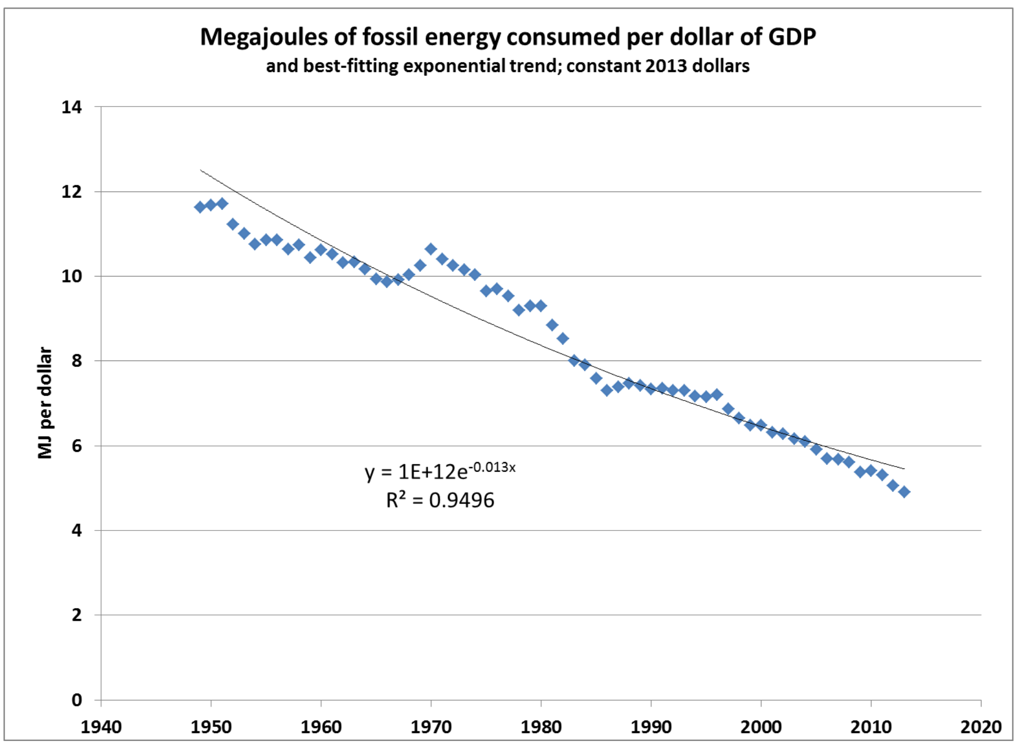
Figure 3



Another reason for the decrease in emissions in 2012, and for the lowered emissions of 2009 through 2011 as compared to earlier years, is that the use of coal for electricity generation has been sharply reduced as coal consumption in New Jersey has been replaced by natural gas. This is shown by the fuel use data obtained from the Energy Information Administration (see references above). Prior to 2009, coal combustion for electricity production accounted for approximately 10 MMTCO2e per year. In the years 2009 through 2011, this emission declined to the range of 5 to 7 MMTCO2e. By 2012, coal combustion accounted for just 2.4 MMTCO2e. During the same period, MMTCO2e emissions from natural gas combustion by the electric power sector grew, but only by about 4 MMTCO2e, for a net reduction in the range of 4 MMTCO2e.

Finally some of the decrease in recent years is likely due to increased efficiency of energy use by the residential, commercial, and industrial sectors. Increased efficiency in energy use is a long-standing trend, apparent at the national level, as shown in Figure 4, which shows energy consumed in the U.S. per unit of gross domestic product (GDP)[11] for the years 1950 through 2013.

Figure 4



[11] Gross domestic product (GDP) is the market value of all officially recognized final goods and services produced within a country in a year, or over a given period of time. GDP data, from http://www.bea.gov/national/xls/gdplev.xls, adjusted to constant 2013 dollars using cost price indicator data from http://stats.bls.gov/cpi/cpifiles/cpiai.txt. Energy use data from U.S. DOE/EIA, http://www.eia.gov/

Clearly, continued moderation of the weather, even if it should occur, cannot reduce the energy use of the residential, commercial and industrial sectors by the approximately 75 percent below 2012 emissions needed to reach the 2050 limit. A continuation of the switching from coal and heating oil to natural gas would lead to additional reductions. However, this switching alone cannot achieve nearly the degree of emissions reduction necessary to achieve the 2050 limit, because the total GHG emission from combustion of coal and heating oil in the state in 2012 totaled only approximately 5 MMTCO2eq of the approximately 80 MMT CO2eq reduction needed from current levels. Continued progress in energy efficiency also holds promise. However a closer examination of the data indicates that this source of reductions, too, is likely to be far less than will be needed to reach the 2050 limit. The current rate of improvement in energy efficiency in the U.S., in terms of energy used per unit of GDP, is about 1.3 percent per year (see Figure 4). This is approximately equivalent to the yearly increase in GDP in recent years. Overall, energy use has not decreased significantly due to increased efficiency. Assuming that similar rates of improvement in efficiency and growth in GDP exist in New Jersey, a significant reduction in GHG emissions through increased efficiency cannot be expected unless either the rate of efficiency improvement accelerates dramatically, GDP growth ceases, or both.

More progress in a number of the major sectors is needed to achieve the 2050 limit. These sectors are discussed below, starting with the largest sector, transportation.

- *Transportation*

Greenhouse gas releases from transportation remained the largest contributor to statewide greenhouse gas emissions, with a total of 46.3 $MMTCO_2e$ in 2012. A modest reduction trend appears to be evident, with total emissions from on-road gasoline and on-road diesel taking place from 2011 to 2012, even though vehicle miles traveled,[12] which had showed an earlier decline likely due to the recession, rebounded somewhat. See Figure 5. New federal motor vehicle miles per gallon standards[13] that require increased fuel economy to the equivalent of 54.5 mpg for new cars and light-duty trucks by Model Year 2025 are expected to result in a further decline in emissions from this sector. However, it is virtually certain that additional steps will be necessary. Even if the entire car and light truck fleet averaged 54.5 mpg by 2050, and VMT did not increase, an overall reduction from this source of no more than approximately 60 percent could be expected, since the fleet average mpg today is in the range of 20 mpg[14] Additional steps necessary to reach the 2050 limit will likely include extensive electrification of the fleet, provided that the electricity is generated from low- and zero-carbon sources.

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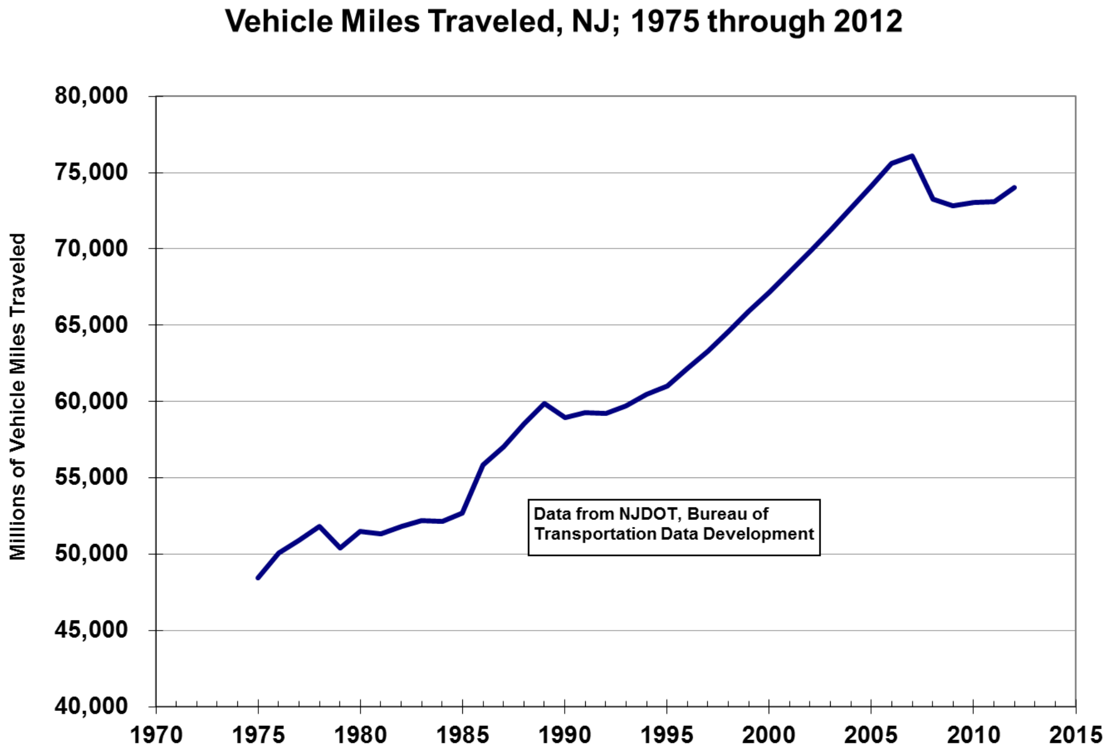
[12] http://www.state.nj.us/transportation/refdata/roadway/pdf/hpms2008/prmvmt_08.pdf

[13] National Highway Traffic Safety Administration, 2012, Obama Administration Finalizes Historic 54.5 mpg Fuel Efficiency Standards, http://www.nhtsa.gov/About+NHTSA/Press+Releases/2012/Obama+Administration+Finalizes+Historic+54.5+mpg+Fuel+Efficiency+Standards , accessed 11/10/14

[14] U.S. Department of Transportation, Bureau of Transportation Statistics, 2014, Table 4-23: Average Fuel Efficiency of U.S. Light Duty Vehicle, http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/html/table_04_23.html, accessed 11/10/14

Figure 5



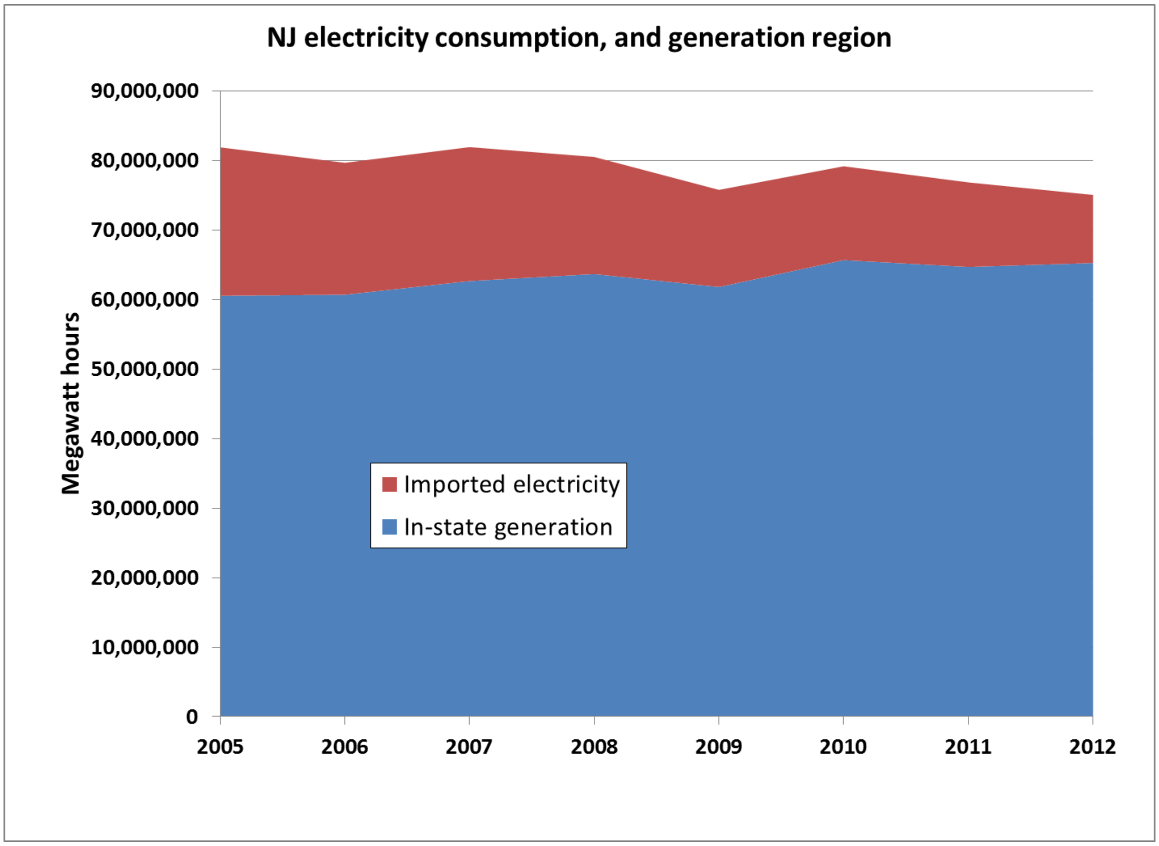
- *Electricity Generation*

Electricity generation accounted for a smaller percentage of total gross emissions in 2012 than in earlier years. Much of this decrease, as discussed above, is a result of switching from coal to natural gas. Also, both the quantity of electricity consumed in the state and the portion of that electricity imported has declined in recent years. The decline in amount of electricity imported has been especially important in the overall emissions reduction, because production of imported electricity is more carbon-intensive than electricity production in-state. Emissions from the generation of imported electricity are estimated using the most recent emission factor available from the PJM grid.[15] For 2012, this emission factor was approximately 0.53 metric tons CO_2e/MWh (about 1100 lbs/MWh). In-state generation, because of the high percentage of virtually zero-carbon nuclear power in the mix, had an emission factor in 2012 of only about 0.23 metric tons CO_2e/MWh (about 510 lbs/MWh), based on emissions data provided by NJDEP's

[15] PJM is a regional transmission organization (RTO) that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia, including NJ. Yearly emission factors were provided by NJDEP (Steve Jenks, NJDEP, personal communication, August, 2014) based on data made available by PJM.

Emissions Statement program,[16] electricity consumption data from US DOE, and Energy Information Administration's State Electricity Profiles.[17] See Figure 6.

Figure 6



Trends would indicate that the decline in electricity use evident from 2008 to 2009 is very likely due to the recession. However, the decline since 2010 is not associated with a decrease in economic activity, since New Jersey's gross domestic product (GDP) increased during this period.[18] See Figure 7. An increase in energy efficiency, as well as milder than usual demands for both heating and cooling in 2012, as noted above, are likely reasons for the decline of electricity consumption since 2010.

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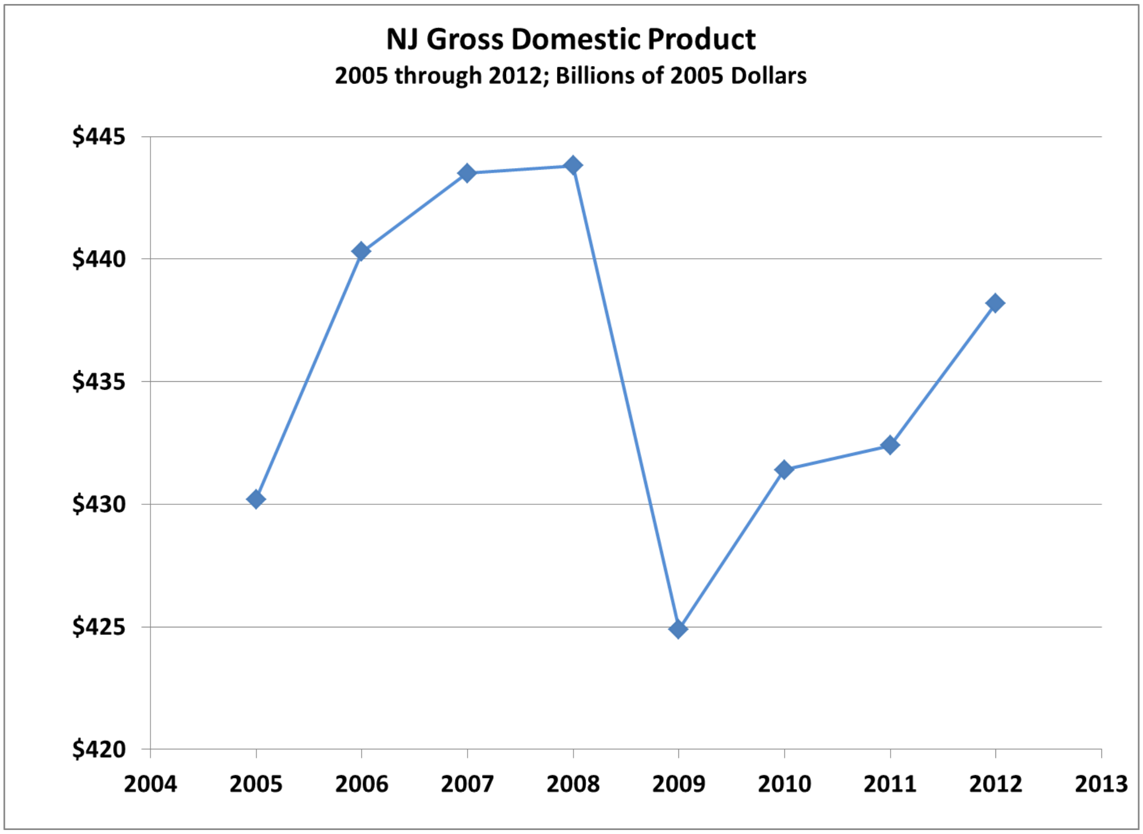
[16] NJDEP, 2014, Emissions Statement Program, http://www.nj.gov/dep/aqm/es/emstatpg.html , data provided by Steve Jenks, NJDEP (personal communication, August, 2014)
[17] USDOE/EIA, 2014, EIA State Electricity Profiles, http://www.eia.gov/cneaf/electricity/st_profiles/new_jersey.html, accessed August, 2014
[18] http://www.eia.gov/state/seds/sep_use/notes/use_gdp.pdf accessed 8/13/14

Figure 7



Another reason for emissions reductions is the increase in electricity produced by solar photovoltaic (PV) systems, although the effect is relatively small. New Jersey is among the leading states in the nation in installation of solar PV capacity. By the end of 2012, the state had 956 MW of installed solar capacity. Assuming a capacity factor of 14.5 percent, this produced about 1.2 million MWh of electricity in 2012, which is about 1.6% of the state's total electricity consumption. Based on the emissions associated with electricity generation, as discussed above, if this amount of electricity had instead been produced by existing sources in-state, or imported from out-of-state sources, it would have added 0.3 to 0.6 MMTCO2e to the state's GHG emission total.

- *Residential and Commercial*

Greenhouse gas emissions from fuel use in the residential sector decreased about 16 percent from 2011 to 2012, and the commercial sector's emissions decreased by approximately 7 percent. As noted above, one reason for this decline is very likely the mild heating and cooling demands presented by the weather of 2012. However, increased energy efficiency is also likely a factor.

- *Industrial*

Greenhouse gas releases from the industrial sector have stayed relatively consistent through the 2009 to 2012 period.

- *Halogenated Gases and Sulfur Hexafluoride (SF_6)*

Halogenated gases are a category of emissions that includes compounds of carbon and fluorine (PFCs) such as carbon tetrafluoride (CF_4), and compounds of carbon, fluorine, and hydrogen (HFCs), such as HFC-134a. As noted in Table 1, above, data on emissions of these compounds are from the USEPA,[19] apportioned to New Jersey based on population. This class of chemicals is used in a variety of industrial and consumer applications. In New Jersey, most of the emissions of halogenated gases are associated with their uses in, and releases from, air conditioning and refrigeration systems. Sulfur hexafluoride (SF_6) is also a halogenated gas but has been treated separately in New Jersey GHG emission inventories due to its specialized uses as an insulating fluid in high voltage electrical equipment. Data on this compound are from the same USEPA source as for the other halogenated gases referenced above, but are apportioned to New Jersey based on electricity use.

Many of this class of chemicals, especially certain HFCs such as HFC-134a, are replacements for chlorofluorocarbons (CFCs). Many of the CFCs have very high global warming potential (GWP), and their continued, albeit slowly declining, presence in the atmosphere contributes significantly to global warming. In addition to exerting a warming effect, CFCs also deplete stratospheric ozone, which protects the earth from dangerous ultraviolet radiation. They have traditionally not been included in GHG inventories because their production has been banned or severely restricted through international agreements.

Like CFCs, all of the halogenated gases included in the GHG inventories have high global warming potential (GWP), which means that relatively small quantities of emissions nevertheless can translate to significant emissions when weighted as carbon dioxide equivalents, as they have been in the NJ GHG emission inventories. Emissions of some of these compounds, such as HFC-134a, are steadily increasing. Should this increasing trend continue, halogenated gases have the potential to offset reductions in emissions from other sectors. Because these gases are industrial and commercial products of some value, curtailing their emissions from leaks, in addition to reducing the state's GHG emissions, could be cost-effective.

It should be noted that a relatively large percentage, in the range of 50%, of emissions of HFC-134a are associated with the motor vehicle sector. Since the mid-1990s, this

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[19] USEPA, 2015, National Greenhouse Gas Emissions Data, http://www.epa.gov/climatechange/ghgemissions/usinventoryreport.html, accessed 1/6/15 and on earlier dates.

compound has been the refrigerant fluid used in motor vehicle air conditioning systems.[20] Leaks of refrigerant fluid from motor vehicles are more difficult to control than are leaks from other air conditioning systems due to vibration and other stresses, including accidents. Substitute compounds have been developed but have not achieved wide usage to date. More comprehensive leak detection and repair could reduce emissions. It is likely that curtailing the sale of HFC-134a in small cans to consumers for do-it-yourself auto repairs would reduce emissions.[21]

Acknowledgements

Thanks to Jorge Reyes, Steve Jenks, and Joe Carpenter of NJDEP, Office of Sustainability and Green Energy, for review of data and text and provision of updated estimates and data. Thanks also to the Michael J. and Susan Angelides Public Policy Research Fund of the Rutgers University Edward J. Bloustein School of Planning and Public Policy for support for development of this report.

[20] Data available from USEPA used for this report are not sufficiently detailed to permit a more precise breakdown of the portion of HFC-134a emissions associated with the motor vehicle sector vs. other sectors, such as residential and commercial refrigeration. It can be argued that HFC-134a emissions should be included in the transportation sector. However, to do this would skew the data, making the emissions from the years since the 1990 baseline year relatively higher, because HFC-134a was not in use in 1990. At that time, CFC-12 was used in motor vehicle air conditioning systems. CFC-12, like all the CFCs, has not been included in this inventory to be consistent with other GHG emission inventories.

[21] http://www.sae.org/events/aars/presentations/2008/albertoayala.pdf, accessed 1-6-15

Appendix A: Changes in Greenhouse Gas Inventory Data and Methods, and Discussion of Some Limitations

There have been some improvements to the estimation methodologies in this latest iteration of the New Jersey GHG emissions inventory. These are noted below. Changes made in previous years are discussed in the inventory reports for those years. Most of these changes have been improvements to some of the smaller emission sectors. The bulk of the emissions continue to be estimated based on fuel use data from EIA and from NJDEP Emissions Statement data; there have been no significant changes to these methods.

Also, several significant limitations of the methodology exist. These limitations apply to earlier inventories as well, so their presence in these updated inventories does not hinder, and in a sense enhances, the ability of these latest inventories to depict trends in emissions over time. Nevertheless, further work to overcome these limitations appears warranted. The limitations apply to jet fuel and residual fuel used in ocean-going ships. Imprecision in data characterizing leaks of natural gas is also a significant limitation. These limitations are discussed below.

- *POTWs*

Revised calculations completed by NJDEP,[22] based partly on the EPA's State Greenhouse Gas Inventory Tool,[23] were used for the 2010 through 2012 estimates.

- *Sequestered by Forests and Other Land-Uses and Released Through Land Clearing*

Since the 2009 inventory, new estimates of carbon sequestration by forests and other land-uses have been calculated based on updated NJDEP Land Use/Land Cover data (latest available 2012 update). The amount of land converted from undeveloped to developed, and the resulting change in carbon released from land clearing has been recalculated based on the updated land use data.[24]

- *Limitations; Jet Fuel and Residual Fuel Used on Ocean-going ships*

As noted above, estimates of fuels consumed in New Jersey are used to estimate the consumption of these fuels as reported by the USDOE EIA. These consumption data are in turn used to estimate GHG emissions from combustion of these fuels. For fuels such as coal and natural gas used to generate electricity, or used to heat residential and commercial facilities, the translation from quantities consumed to GHG emissions is direct and straightforward. Jet fuel and residual fuel used in ocean-going ships are problematic, however, because the estimated quantities of these fuels sold in New Jersey

[22] Reyes, Jorge, 2014, personal communication from Jorge Reyes, NJDEP, August, 2014
[23] http://epa.gov/statelocalclimate/resources/tool.html
[24] Reyes, Jorge, 2014, personal communication from Jorge Reyes, NJDEP, August, 2014

does not reflect the quantity of that fuel actually combusted in the state. Much of the fuel used by jets, and ocean-going ships, is burned in air space or ocean waters well beyond New Jersey's boundaries. Importantly, New Jersey has essentially no control over these emissions. In earlier inventories, a decision was made to include only those emissions of these fuels over which New Jersey could conceivably exert some control with possible future actions, such as electrifying terminals where ships are moored or limiting runway taxiing at airports. There is a high degree of uncertainty over what portion of the emissions of these fuels is in fact potentially amenable to such state control. For this reason, the reported emissions of these fuels, although based on calculations or engineering judgment with some rationale[25] should be considered to be little more than placeholders. Clearly, improvements in the methods will be necessary to better characterize these emission sources. Nevertheless, the consistent use of essentially the same placeholder values over time for these sectors permits a view of trends of the remaining GHG emissions, which the state has a greater potential to reduce.

- *Limitations; Natural Gas Leaks*

Natural gas has a relatively high GWP, in the range of 25 to 30 times that of CO_2 when looked at over a 100-year time frame (see discussion and references above). Because natural gas contains less carbon per unit of energy content than coal and petroleum-derived fuels such as gasoline, diesel fuel, and heating oil, switching from these fuels to natural gas is widely perceived as a strategy to reduce CO_2 equivalent emissions. This strategy becomes less effective and perhaps even harmful from a GHG emissions perspective, however, if a sufficient quantity of natural gas leaks before, or during, combustion. In one study, for example, it was estimated that new natural gas power plants produce net climate benefits relative to efficient, new coal plants only as long as leakage in the natural gas system is less than 3.2% from well through delivery at a power plant.[26] The overall picture of the rate of natural gas leakage from not only the production process, e.g. well drilling and/or hydrofracturing, but also natural gas compression and processing stations and transmission and distribution systems is still not clear, with widely varying emission rate estimates available in the literature.

Leaks from natural gas transmission lines passing through New Jersey have been estimated, based primarily on the type of piping material, and have been included (Natural gas T&D) in the GHG inventories and these updates. However, possible additional emissions from distribution to consumers or elsewhere in the entire system are not included. There is enough uncertainty associated with the natural gas leak rate that emission estimates for this source, like those from jet and residual fuel discussed above, should be considered more as placeholders than firm estimates.

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[25] See the sections "Commercial Marine Vessels" and "Aviation" in New Jersey Greenhouse Gas Inventory and Reference Case Projections.
http://www.nj.gov/globalwarming/home/documents/pdf/20081031inventory-report.pdf

[26] Alvarez, R., S. Pacala, J. Winebrakec, W. Chameides, and S. Hamburg, 2012, Greater focus needed on methane leakage from natural gas infrastructure, *PNAS*, 109, 6435-40