2022

NJ Greenhouse Gas Emissions Inventory Report Years 1990-2019

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

CONTENTS

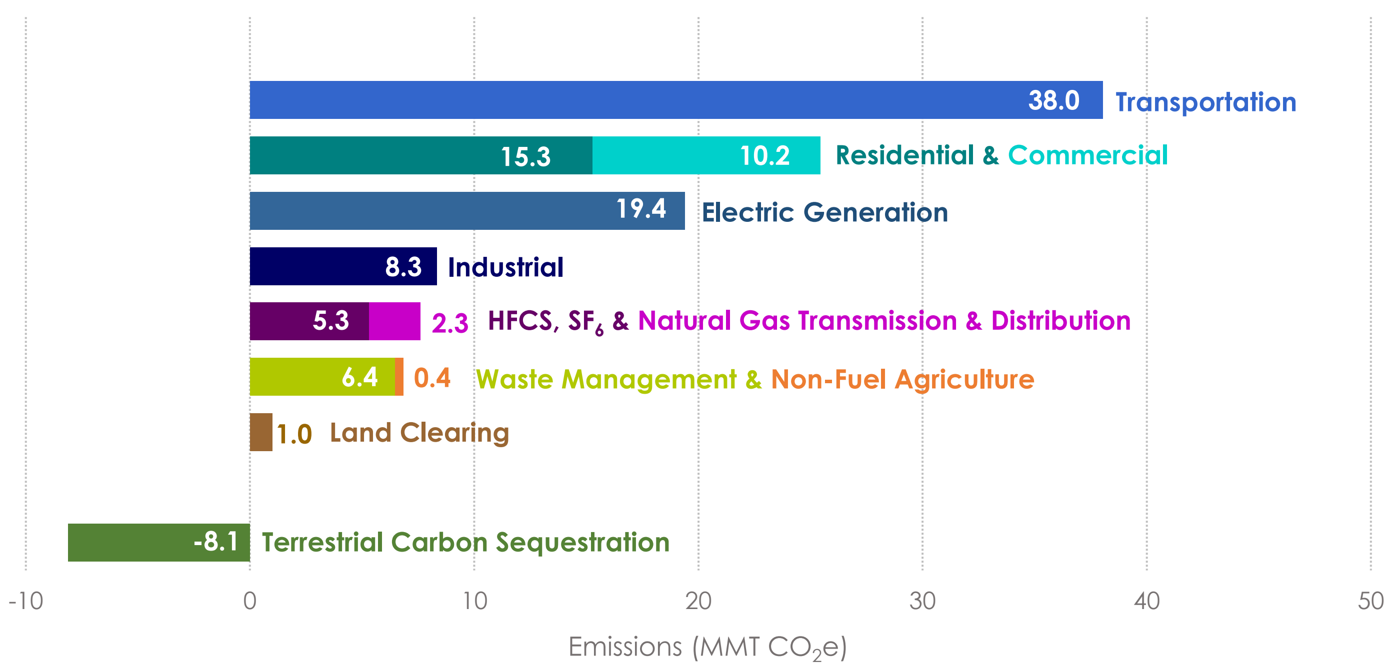
EXECUTIVE SUMMARY

The New Jersey Greenhouse Gas Inventory Report serves as the foundation of the State's strategy to mitigate climate change. It is designed to identify the sources of greenhouse gas emissions in the state, measure progress in reducing those emissions and make this information accessible to decision makers to inform climate policy. This report provides the most up-to-date estimation of annual emissions from 1990, and 2005-2019. New Jersey uses an inventory scope and framework consistent with international and national greenhouse gas inventory practices.

CURRENT STATEWIDE GREENHOUSE GAS EMISSIONS

In 2019, statewide gross emissions were 106.6 million metrics tons of carbon dioxide equivalent (MMT CO_2e) when calculated using GWP_{100} (Figure ES-1). Energy consuming sectors were the largest sources of emissions (85%), resulting from fossil fuel combustion from transportation, electric generation, residential and commercial, and fuel-consuming industrial activities. Non-energy emissions accounted for the remaining 15% of emissions and are associated with a variety of processes such as the release of greenhouse gases from sectors using or producing halogenated gases, sulfur hexafluoride, natural gas transmission and distribution, waste management and other industrial processes. Approximately 8% of 2019 emissions were removed via carbon sequestration from New Jersey natural work lands, such as forests and wetlands, resulting in a net emission total of 98.5 MMT CO_2e.

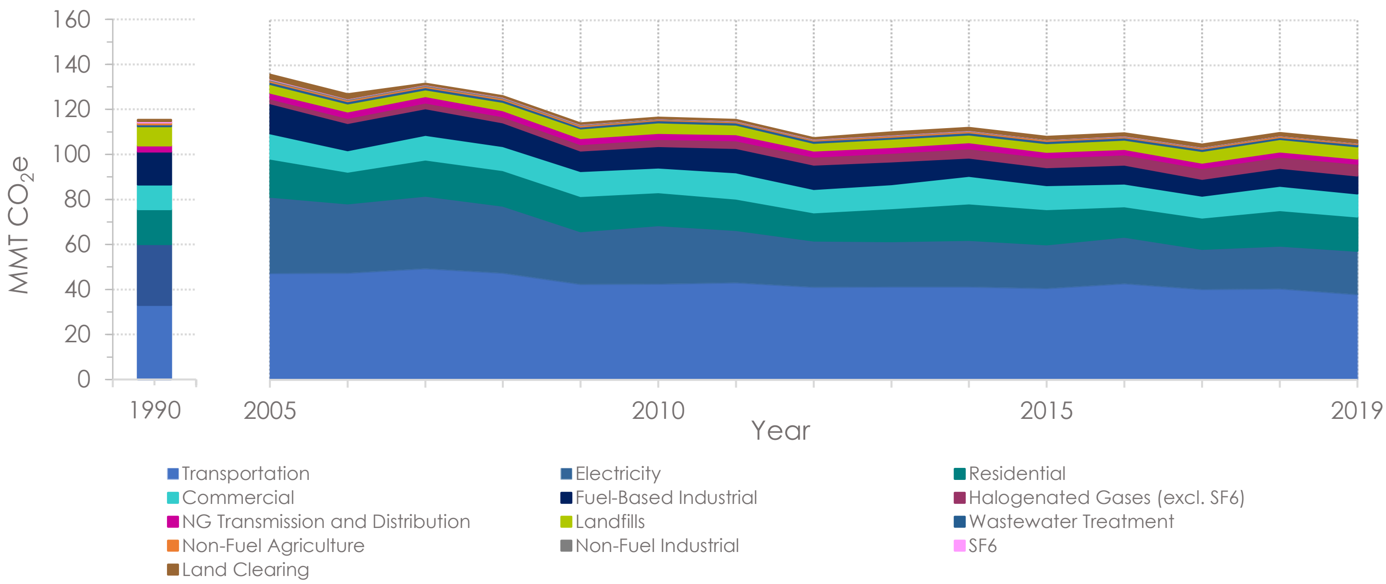
Figure ES-1. 2019 Emissions by Sector (GWP_{100})



TRENDS IN GREENHOUSE GAS EMISSIONS, 1990-2019

New Jersey's net emissions have dropped, from 111.4 million metric tons (MMT) per year CO_2-equivalent (CO_2e) in 1990 to 98.5 MMT CO_2e in 2019 (Figure ES-2). This equals a 12% reduction over the 30-year timeframe. The general pattern of annual decreases seen since 2005 continued in 2019, with a small 3.3 MMT CO_2e year-on-year reduction from 2018. The reductions that have taken place over the last thirty years, have for the most part occurred because of emerging new technologies with inherent economic benefits. For example, aging coal-fired power plants have been almost entirely displaced in New Jersey by highly-efficient combined-cycle natural gas systems. The low cost of natural gas afforded by the development of the Marcellus Shale in nearby states has also facilitated this transition. Similarly, improvements in passenger vehicle fuel efficiency realized over the past 30 years have contributed to the overall emission reductions; however, much of these improvements have been offset by increased consumer demand for larger trucks and sport utility vehicles (Figure ES-2).

Figure ES-2. Greenhouse Gas Emissions for 1990 and 2005-2019 (GWP_{100}). [1]



BLACK CARBON INVENTORY

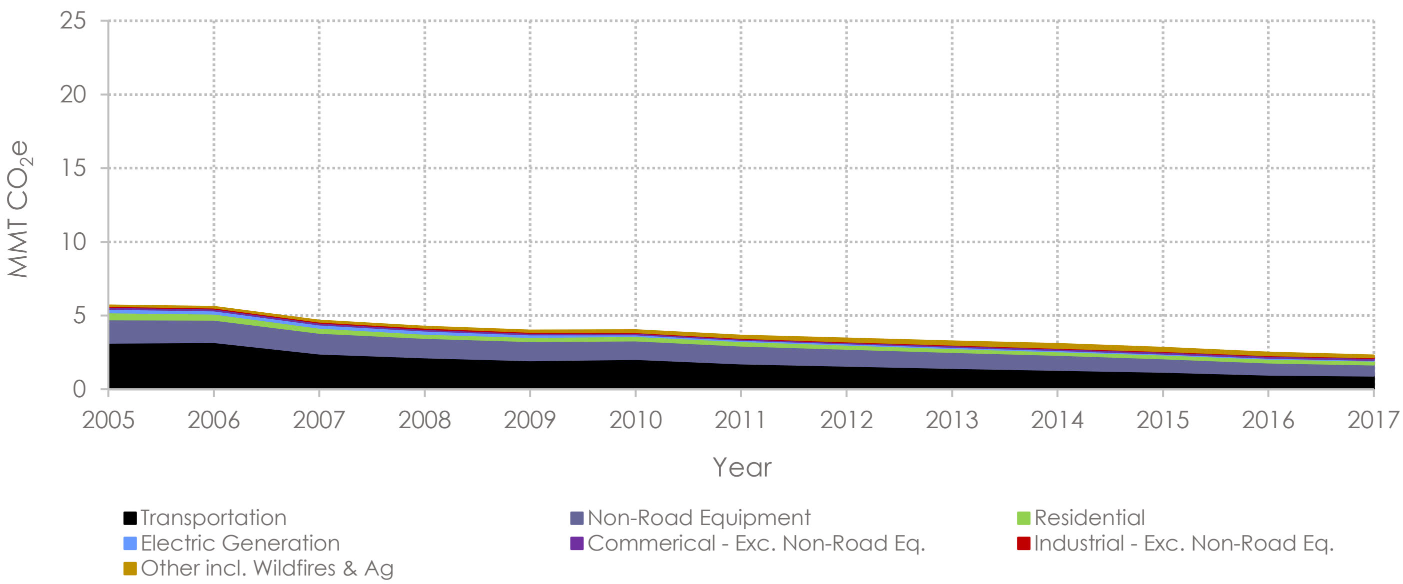
For 2022, this report includes expanded reporting of black carbon. Black carbon, or soot, is a subset of fine particulate matter ($PM_{2.5}$). It is an airborne particle left by the incomplete combustion of fuels and is closely associated with adverse respiratory impacts when inhaled. As such, it has been a long-standing focus of DEP regulatory efforts. Black carbon also creates a climate impact because its dark color absorbs light and thereby contributes to atmospheric warming. It also settles on the earth, where it can accelerate the melting of snow, and when airborne can alter cloud formation. In 2017, the most recent year for which full data is available, total black carbon emissions in the State were 2.3 MMT CO_2e based on GWP_{100}.

Diesel engine exhaust is the single largest source of black carbon emissions in the State, as reflected in estimated emissions for the transportation sector and from non-road equipment (Figure ES-3). However, federal regulations mandating cleaner engines, coupled with other transitions in the state, have resulted in consistent downward trends such that black carbon emissions today are less than half those seen in 2005. With the

[1] Gross emissions, not adjusted for terrestrial carbon sequestration.

anticipated adoption of electric vehicles and the expansion of renewable energy, black carbon emissions are expected to drop still further over the coming years. Black carbon from in-state electric generation comprises less than 2% of all New Jersey black carbon emissions.

Figure ES-3. Black Carbon Emissions 2005-2017 (GWP_{100}) [2]



GLOBAL WARMING POTENTIALS

For the first time, the New Jersey Greenhouse Gas Inventory Report incorporates the legislative requirement (P.L. 2019 c.319) to report emissions utilizing both the standard 100-year Global Warming Potentials (GWP_{100}) and short-term 20-year GWPs (GWP_{20}). Estimates utilizing a GWP_{20} prioritize the impact of short-lived climate pollutants such as methane, nitrous oxide, and hydrofluorocarbons. Utilizing GWP_{20} reorders the sources of GHG emissions, identifying methane from waste management and halogenated gases as larger contributors to climate change compared to commercial and industrial emissions. While the use of GWP_{20} highlights the value of reducing short-lived climate pollutant (SLCP) emissions in the near term by making their impact appear larger, the IPCC recognizes that this approach overestimates the potential benefits of SLCP reductions. The UNFCCC and IPCC have not established any suitable timeframes for SLCPs other than 100 years. With these limitations in mind, estimated emissions based on GWP_{20} are presented in this report alongside GWP_{100} emissions to assist policymakers and the public in recognizing the disparate impacts of SLCPs compared to CO_2 and long-lived greenhouse gases.

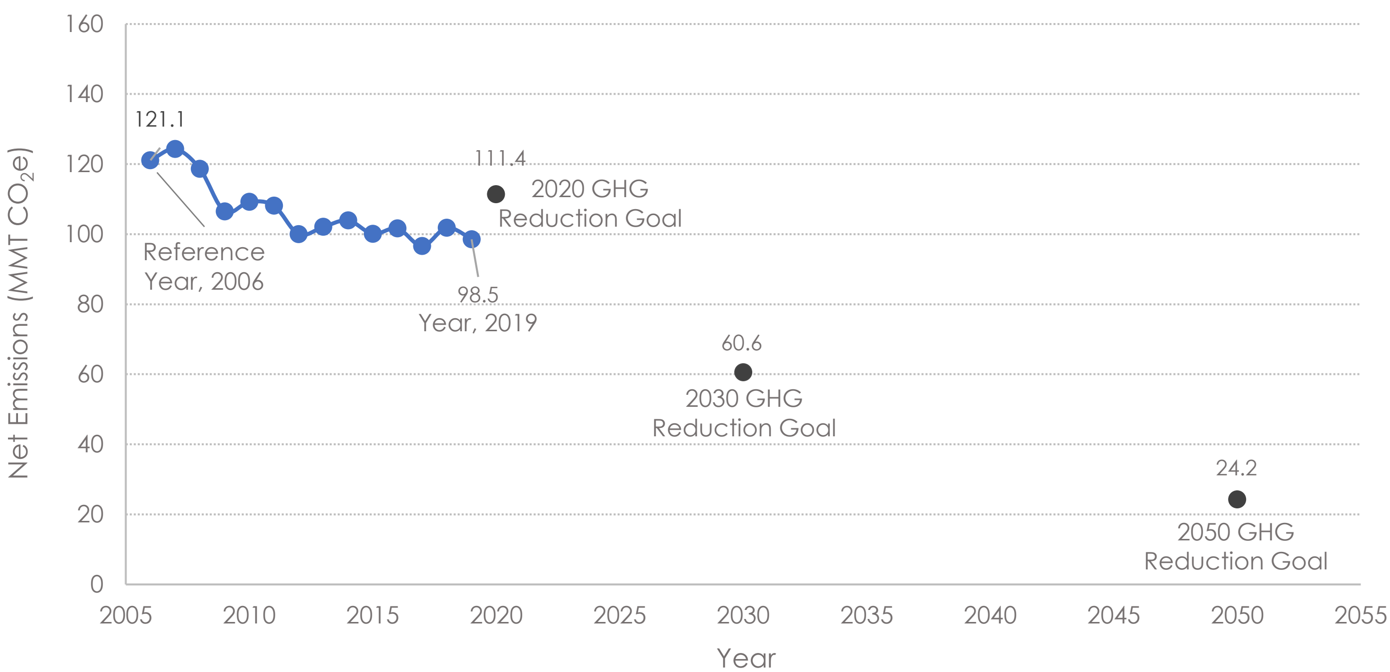
[2] GWP_{20} values (not shown) are 3.5 times greater.

1.0 INTRODUCTION

The New Jersey Global Warming Response Act (GWRA) (P.L. 2007, c.112, as amended 2019) requires that a comprehensive greenhouse gas inventory report be prepared by the Department of Environmental Protection every other year, and that updated estimates be provided during each of the intervening years. This report is the tenth in the series, the first was released in 2008 and the most recent, a mid-cycle update, was released in February of 2021.[3] This inventory report extends emissions estimates to 2019 and includes recalculated emissions for 1990 and 2005 through 2018, applying updated data and methods of analysis. Further, it includes a detailed analysis of emissions by sector, a review of greenhouse gas emissions trends and a discussion of the steps the state is taking to reduce its emissions.

Periodic inventory updates provide vital information for assessing the State's progress towards meeting its greenhouse gas emission limits. The State of New Jersey has established a series of greenhouse gas emission reduction goals (Figure 1). Specifically, the GWRA calls for the state, no later than January 1, 2020, to reduce greenhouse gas emissions to, or below, the level of emissions in 1990. Based on the assessment presented here, the state achieved that goal eleven years early. The GWRA also requires the State to reduce its statewide greenhouse gas emissions to at least 80% below 2006 levels by January 1, 2050. More recently, Governor Phil Murphy's Executive Order 274 established an interim target of reducing total greenhouse gas emissions to 50% of 2006 levels by 2030. An accurate assessment of greenhouse gas emissions is essential to achieving these targets to identify the specific levels of emissions to be reached and to evaluate the effectiveness of the policies applied.

Figure 1. New Jersey Emissions and Greenhouse Gas Reduction Goals



[3] An archive of the previous inventory reports is available on can be found at https://www.nj.gov/dep/aqes/ghginventoryarchive.html

1.1 INVENTORY STRUCTURE AND PROCESS

New Jersey uses an inventory scope and framework consistent with international and national greenhouse gas inventory practices. This inventory provides estimates of anthropogenic greenhouse gas emissions within New Jersey, and also those associated with imported electricity and exported waste. Biogenic (natural) sources are not included in the inventory. The inventory includes estimates for:

- Carbon Dioxide (CO_2);
- Methane (CH_4);
- Nitrous Oxide (N_2O);
- Fluorinated gases with high global warming potentials (High-GWP) which includes hydrofluorocarbons (HFCs) and sulfur hexafluoride (SF_6);
- Estimates of Carbon Sequestration from natural and working lands; and
- Separate, detailed inventory for Black Carbon.

These emissions are organized into four overarching sections, with further sector breakdowns within each, listed below in Table 1. Emission estimates are recalculated for all years to maintain a consistent time-series following IPCC recommendations for developing greenhouse gas inventories. Thus, emissions levels in this report differ from those in previous inventory editions. The methods applied are summarized in Appendix B. Emissions are calculated using both United Nations standard 100-year Global Warming Potentials (GWP_{100}) and short-term 20-year GWPs (GWP_{20}) as required pursuant to P.L. 2019 c.319.[4] Estimates utilizing a GWP_{20} prioritize the impact of short-lived climate pollutants such as methane, nitrous oxide, and hydrofluorocarbons. However, since CO_2 is the reference gas, GWP_{20} estimates are nearly identical to those based on GWP_{100} for emissions from combustion processes since they emit few if any short-lived pollutants. Therefore, in this report when the two estimates are nearly identical only the 100-year estimate is provided. Full tabular results based on both GWP_{20} and GWP_{100} are included in Appendix A. An overview of GWP is included in Appendix C. The following discussion breaks down the state's emissions trends and provides context for each of the source categories.

Table 1. Section Descriptions

SECTION	SECTORS/ACTIVITIES INCLUDED
Energy Emissions	Emissions of all greenhouse gases resulting from fossil fuel combustion from transportation, electric generation, residential and commercial buildings, and fuel-consuming industrial activities.
Non-Energy Emissions	Emissions associated with the release of greenhouse gases from sectors using or producing halogenated gases, the electric transmission and distribution system (using sulfur hexafluoride as insulator); the natural gas transmission and distribution system; agriculture (enteric fermentation, manure and soil management), waste management, industrial processes other than fuel consumption, and natural land clearing.
Carbon Sequestration	Estimates of removal of carbon dioxide from the atmosphere through sequestration on forests, wetlands, and agricultural lands.
Black Carbon	Emissions associated with combustion of fossil and biogenic materials.

[4] With the exception of black carbon, GWP values used in this report were taken from IPCC AR4, *Climate Change 2007 - The Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the IPCC, 2007, Table 2.14, pages 212-213. GWP values for black carbon were from Section 12.1 of T. C. Bond, et al., Bounding the role of black carbon in the climate system: a scientific assessment. J. Geophysical Research, Vol 118, pp. 5380-5552, 2013. Use of GWP_{100} values from AR4 Table 2.14 is required for national emissions estimates submitted to the IPCC under international conventions and is used here to allow comparison of New Jersey emissions estimates with those developed at the national and international levels.

2.0 TRENDS IN GHG EMISSIONS

2.1 STATEWIDE TRENDS

Total estimated net greenhouse gas emissions for 2019 were 98.5 MMT CO_2e when calculated using GWP_{100} (Figure 2; tabular data is in Appendix A, Table A-1), and 122.0 MMT CO_2e when calculated using GWP_{20} (Figure 3; Table A-3). A recalculation of 1990 data found estimated emissions of 111.4 MMT CO_2e based on GWP_{100}, and 134.5 MMT CO_2e based on GWP_{20}. Because emissions decreased to below 1990 levels before January 1, 2020, (based on GWP_{100} or GWP_{20}), it can be concluded that the state has achieved the first reduction goal of the GWRA. The significance of reaching this milestone is made clear by comparing the state's current situation with what was projected under business-as-usual conditions in the 2008 Greenhouse Gas Inventory Report. In that scenario, the absence of state action would have resulted in emissions of 159.9 MMT CO_2e by today (using GWP_{100}).[5] The state has therefore managed to keep emissions 38% below that projected amount.

As with previous inventory years, the four leading sectors of GHG emissions in 2019 were transportation, residential, and commercial fossil fuel use, and electric generation based on GWP_{100} (Figure 4). Specifically, transportation remained as the largest source of GHG emissions at 38.0 MMT CO_2e, or 39% of the net statewide emissions. The residential and commercial sectors combined totaled 26% of net statewide emissions. While the electric generation sector accounted for 19.4 MMT CO_2e, or 20% of net statewide emissions. Carbon captured by the state's natural sinks remained at 8.1 MMT CO_2e in 2019, "offsetting" 8% of the gross statewide GHG emissions.[6] Using GWP_{20}, the second greatest contributor was highly warming gases,[7] which accounted for 16% of net emissions (Figure 5). Transportation, electricity generation, residential fuel use and commercial fuel use accounted for 31%, 16%, 13% and 8% of net emissions, respectively, using GWP_{20}.

While keeping emissions growth in check has been successful, the challenge is now to drive emissions rapidly downward. The 80% reduction below 2006 emissions mandated under the GWRA for 2050 establishes a goal of 24.2 MMT CO_2e (GWP_{100}). A 50% reduction by 2030 translates to an emissions limit of 60.6 MMT CO_2e by that year. If New Jersey were to continue the rate of decrease observed from 2006 through 2019, it would only reach the 80% mark more than a decade beyond the 2050 deadline. Recognizing the need for assertive action, the State has published detailed emissions reduction pathways in both the 2019 Energy Master Plan[8] and 2020 GWRA 80x50 report.[9] Future releases of this inventory report will document the degree to which these plans are successfully implemented.

[5] The corresponding figure using GWP_{20} would be approximately 221 MMT CO_2e.

[6] The carbon sequestration value relies on statewide land use and land cover data. Values remains constant at 2015-year levels awaiting publication of new data.

[7] The category shown as highly warming gases in Figures 3 and 4 includes halogenated gases, sulfur hexafluoride, emissions from non-fuel agricultural activities, and emissions from natural gas transmission and distribution. Emissions from waste disposal also consist largely of methane, a highly warming gas, and are accounted for in a separate category. Combined, highly warming gases and waste management represent 15% of emissions using GWP_{100} and 31% using GWP_{20}.

[8] NJBPU, 2019 New Jersey Energy Master Plan, Pathway to 2050. https://www.state.nj.us/emp/index.shtml

[9] NJDEP, New Jersey's Global Warming Response Act 80x50 Report, 2020. https://www.nj.gov/dep/climatechange/mitigation.html

Figure 2. Greenhouse Gas Emissions for 1990 and 2005-2019 (GWP_{100}) [10]

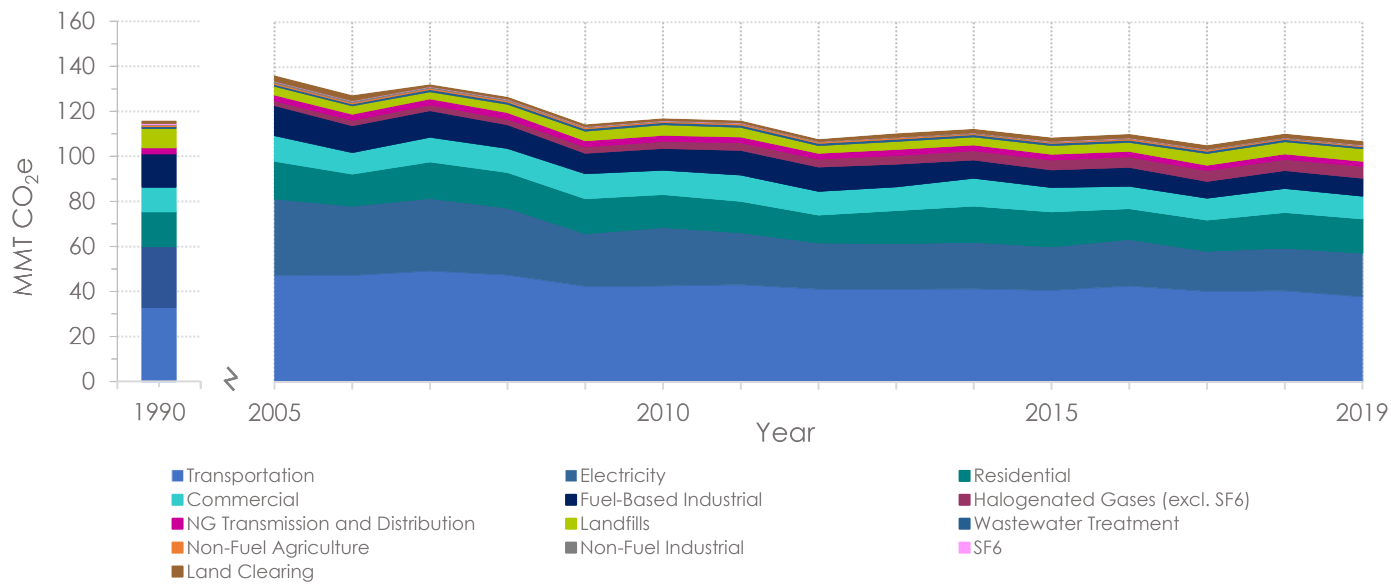
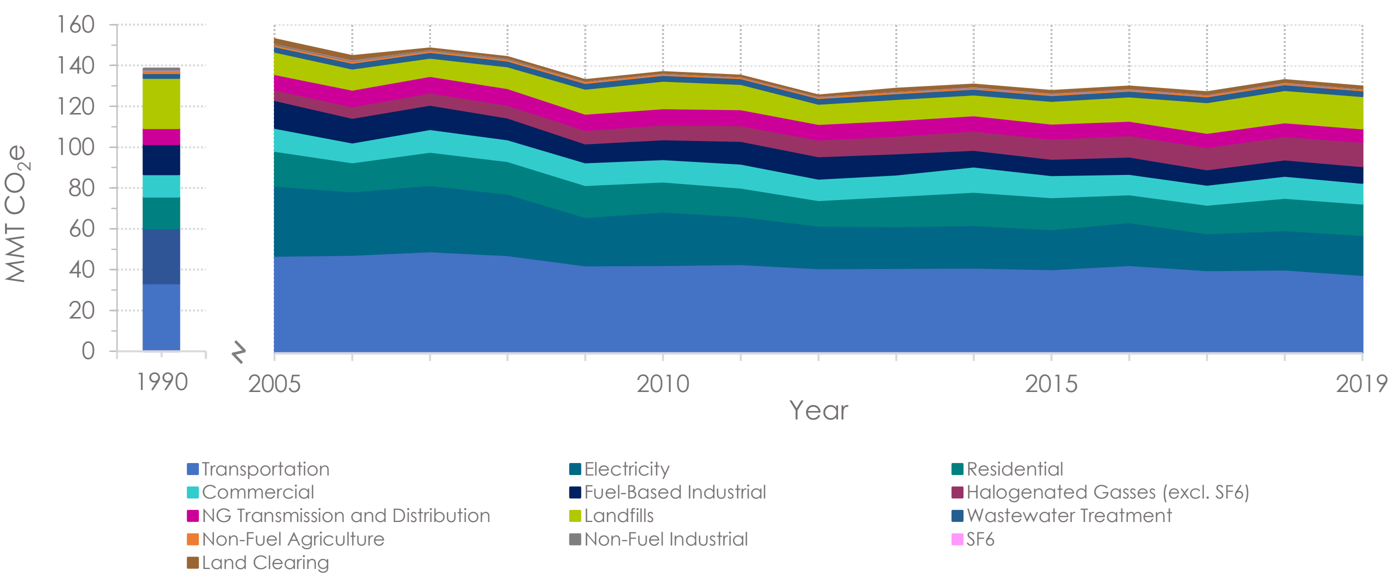


Figure 3. Greenhouse Gas Emissions for 1990 and 2005-2019 (GWP_{20}) [11]



[10] Gross emissions, not adjusted for terrestrial carbon sequestration.
[11] Gross emissions, not adjusted for terrestrial carbon sequestration.

Figure 4. 2019 Emissions by Sector (GWP_{100})

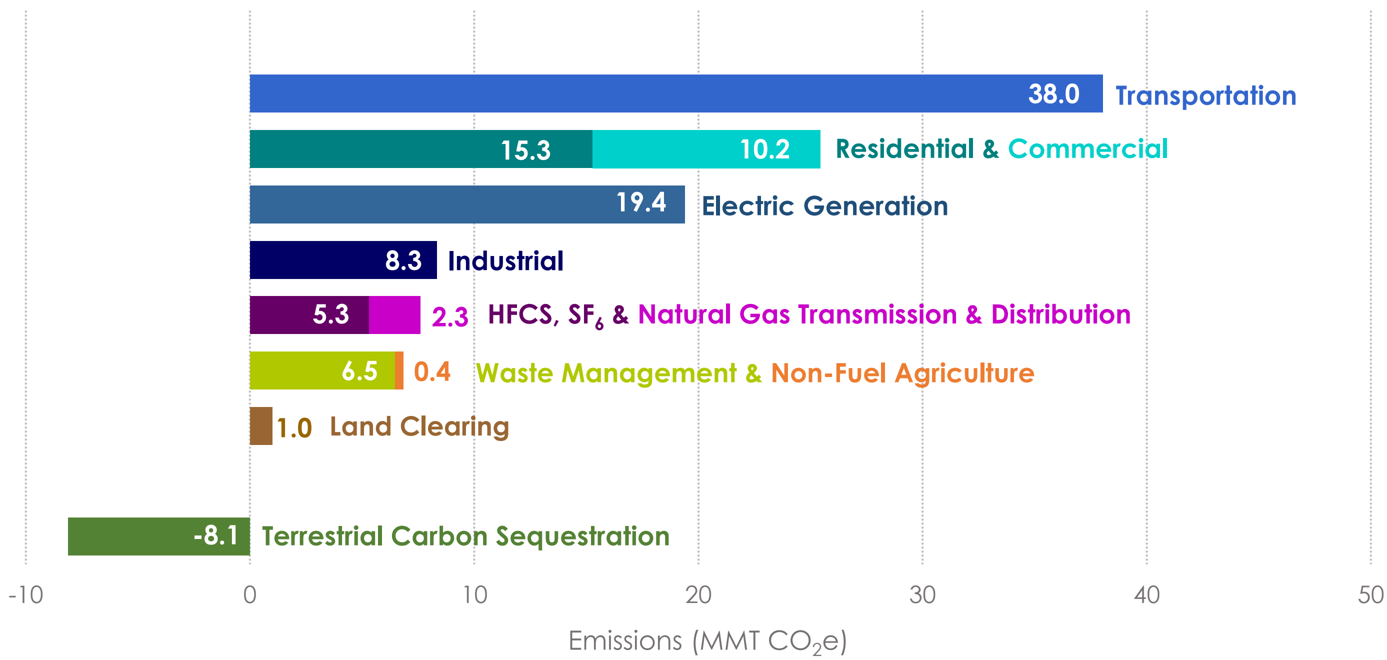
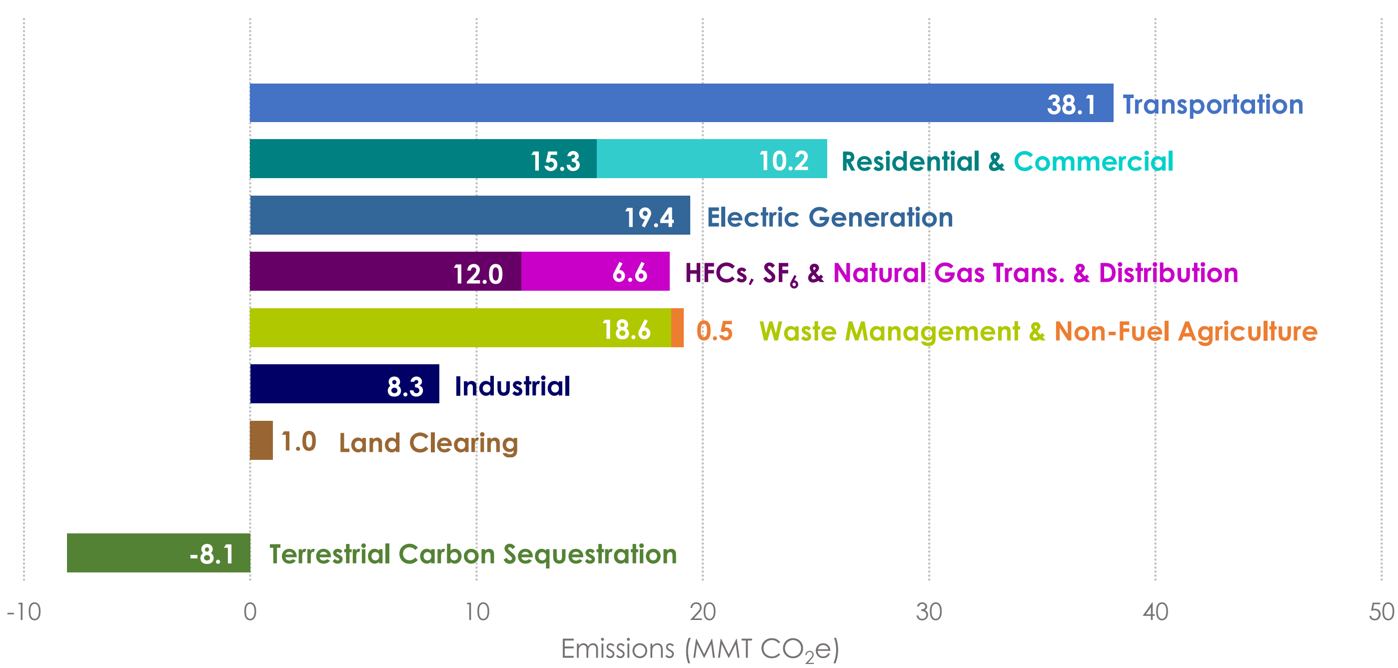


Figure 5. 2019 Emissions by Sector (GWP_{20})



2.2 NATIONAL AND GLOBAL TRENDS

New Jersey's climate mitigation efforts are only one part of the world-wide response to global warming. Placed in context, New Jersey is responsible for 1.6% of national emissions and 0.3% of worldwide emissions (Table 2). On a per capita basis, New Jersey in-state emissions averaged 12 metric tons CO_2e per resident between 2016 and 2019.[12] This was slightly more than half the national average of 20 metric tons per resident, and about double the international average of 5 metric tons per resident. However, it should be noted that New Jersey residents benefit from emissions-generating activities outside the state, and some of the observed discrepancies between state and national rates are due to goods and services imported from outside state boundaries. The figures cited above do not account for these consumption-based transfers, with the exception of New Jersey's inclusion of emissions from out-of-state solid waste disposal and imported electricity.[13]

Table 2. Comparison of New Jersey with the United States and the World[14]

	Gross Emissions (MMT CO_2e, GWP_{100})			NJ as Percent of		Emissions per Capita (MT CO_2e/person)		
Year		U.S.	World	U.S.	World	NJ	US	World
2016	109.7	6,520	35,452	1.7%	0.3%	12.1	20.2	4.8
2017	104.7	6,520	35,926	1.6%	0.3%	11.5	19.9	4.8
2018	109.9	6,483	36,646	1.7%	0.3%	12.0	20.4	4.8
2019	106.6	6,671	36,703	1.6%	0.3%	11.5	20.0	4.8

[12] Based on GWP_{100}.

[13] National totals also include some wide-scale emissions such as those from passenger aircraft at cruising altitude that are not included in the New Jersey estimates.

[14] US emissions from Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2019. USEPA EPA430-R-21-005, 2021, https://www.epa.gov/ghgemissions/natural-gas-and-petroleum-systems-ghg-inventory-additional-information-1990-2019-ghg. Global emissions from P. Friedlingstein, et al., 2021 Global Carbon Budget. Global Carbon Project, https://www.globalcarbonproject.org/carbonbudget/21/data.htm. US and global populations from US Census Bureau, https://www.census.gov/data-tools/demo/idb/#/country. New Jersey population for 2010 and 2020 from US Census Bureau, with intervening years estimated by interpolation. https://www.census.gov/data/tables/time-series/dec/popchange-data-text.html

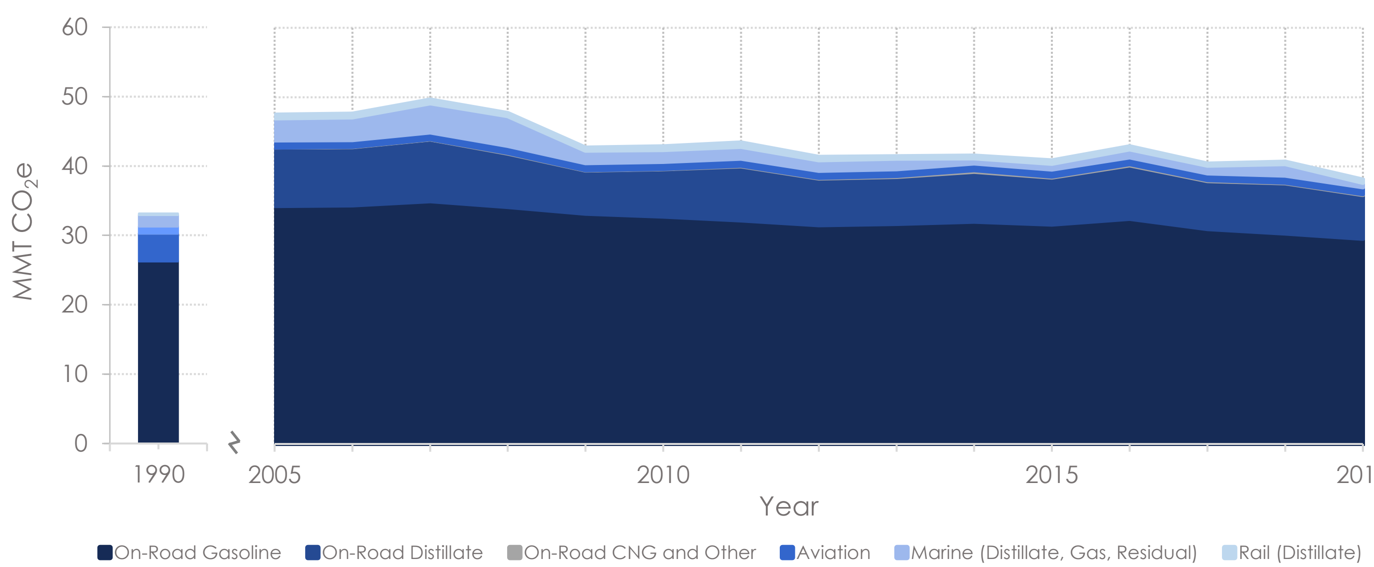
3.0 ENERGY EMISSIONS

3.1 TRANSPORTATION

The transportation sector consists of activities that move people and goods from one location to another.[15] Familiar examples of emissions sources in this sector include autos, trucks, and other on-road vehicles; non-road modes of transport include trains, subways, cargo ships and passenger ferries. Other sources of mobile emissions such as construction equipment and forklifts are included in estimates for the sectors in which they are used. For example, construction equipment emissions are accounted for in the industrial sector while forklift truck emissions are listed in either the commercial or industrial sector, depending on the type of business.

Total emissions from the transportation sector in 2019 were 38.0 MMT CO_2e (GWP_{100})/38.1 MMT CO_2e (GWP_{20}). This represents a decrease of 9.5 MMT CO_2e from 2006 levels, but an increase of 4.9 MMT CO_2e over 1990 levels, using GWP_{100}. These shifts were dominated by changes in on-road emissions and can be attributed to the transition of the passenger vehicle fleet to larger models and the application of federal performance standards (Figure 6; Tables A-1 and A-3).

Figure 6. Transportation Sector Emissions by Mode of Transport (GWP_{100})



On-Road Transportation

Total on-road emissions rose from 30.3 MMT CO_2e in 1990 to a high of 44.0 MMT CO_2e in 2007 (GWP_{100}).[16] Emissions then slowly dropped at an average rate of 0.66 MMT CO_2e per year, reaching 36.1 MMT CO_2e in 2019 (Figure 7;). Throughout this period, the proportion of emissions attributed to gasoline averaged 82%, with only small deviations. In 2019, on-road gasoline contributed 29.7 MMT CO_2e, or 82% of the on-road total. The balance of on-road emissions were nearly all from diesel fuel. Compressed Natural Gas (CNG) and other fuels contributed 0.1 MMT CO_2e in 2019. Emissions from the electric generation used to supply power to electric vehicles is not included in this total but is counted as part of the electric generating sector.

By far, the vehicle types contributing the greatest share of emissions in 2019 were gasoline-powered passenger vehicles, including sedans, pickup trucks, and SUVs, at 27.1 MMT CO_2e (Figure 8; Tables A-5 and A-6). Diesel-

[15] USEIA, https://www.eia.gov/tools/glossary/index.php?id=T

[16] Emissions estimates are based on GWP_{100}. Estimates based on GWP_{20} are within 0.1 MMT CO_2e of the GWP_{100} values. Totals listed in the text may not agree exactly with sums of the numbers shown in the tables in Appendix A due to rounding of estimates in the tables.

powered medium- and heavy-duty vehicles followed at 4.8 MMT, while gas-powered medium- and heavy-duty vehicles contributed 2.5 MMT CO_2e.

Figure 7. On-road transportation greenhouse gas emissions by fuel type (GWP100)

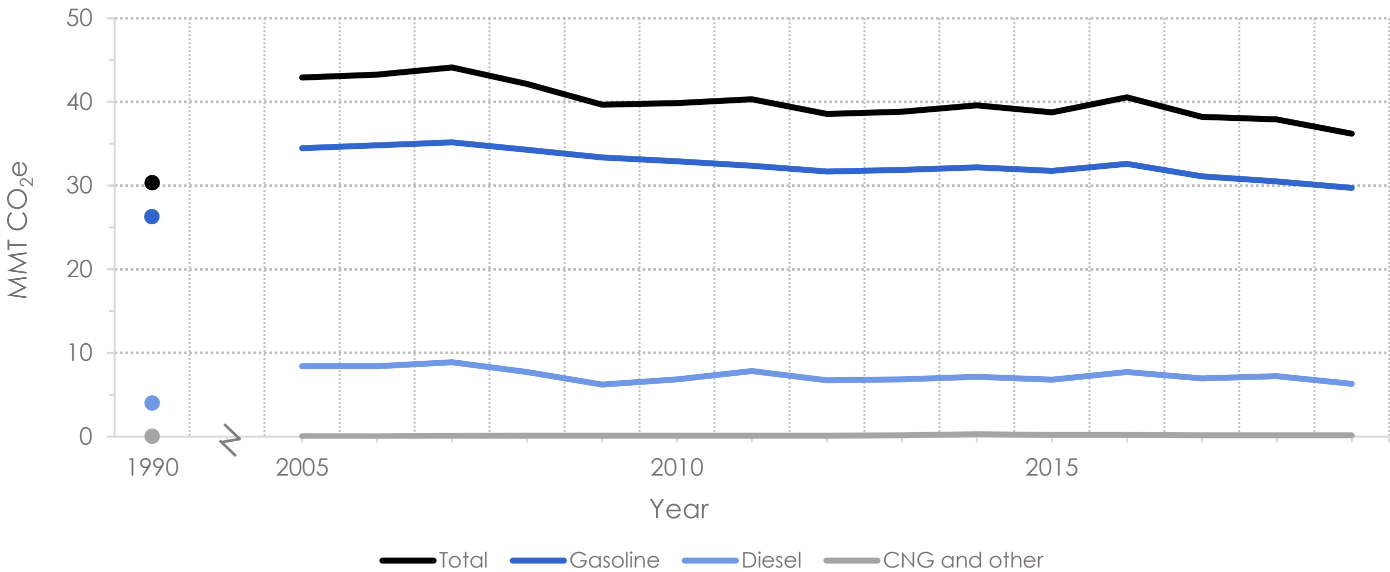
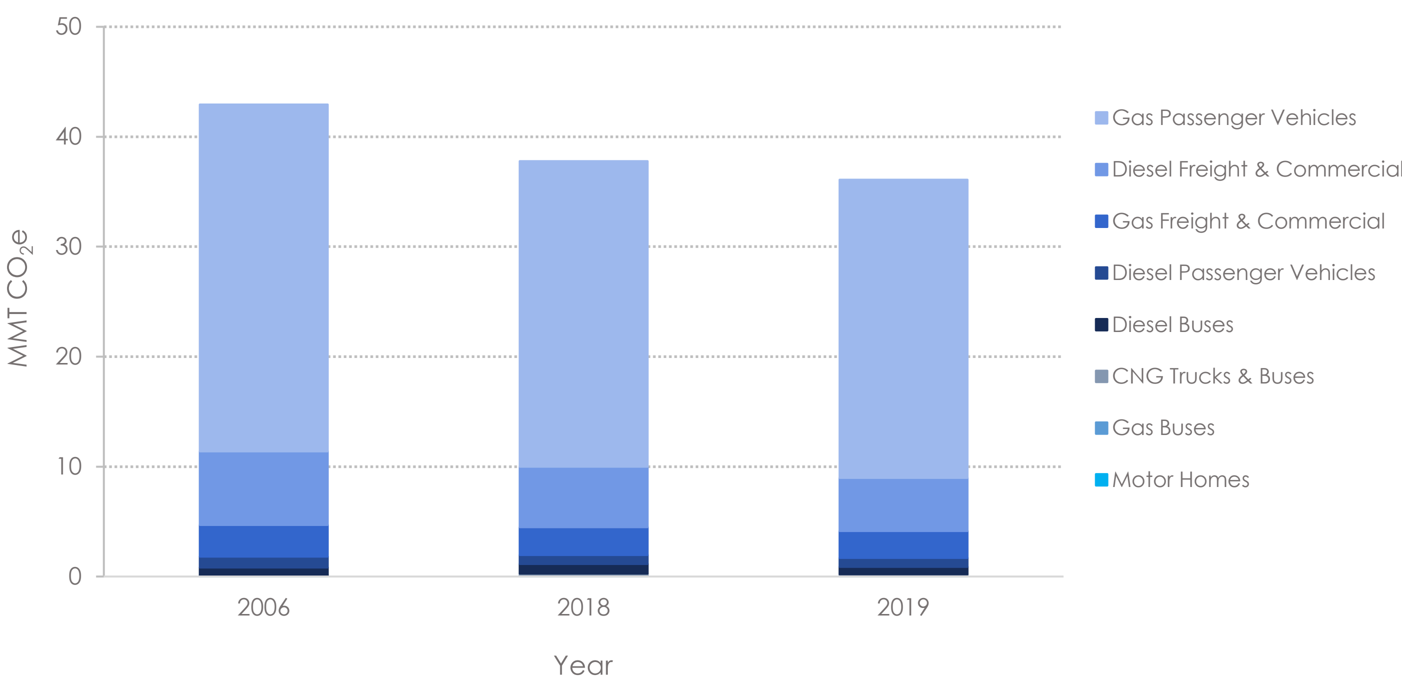


Figure 8. On-road emissions by vehicle category (GWP100)



Aviation

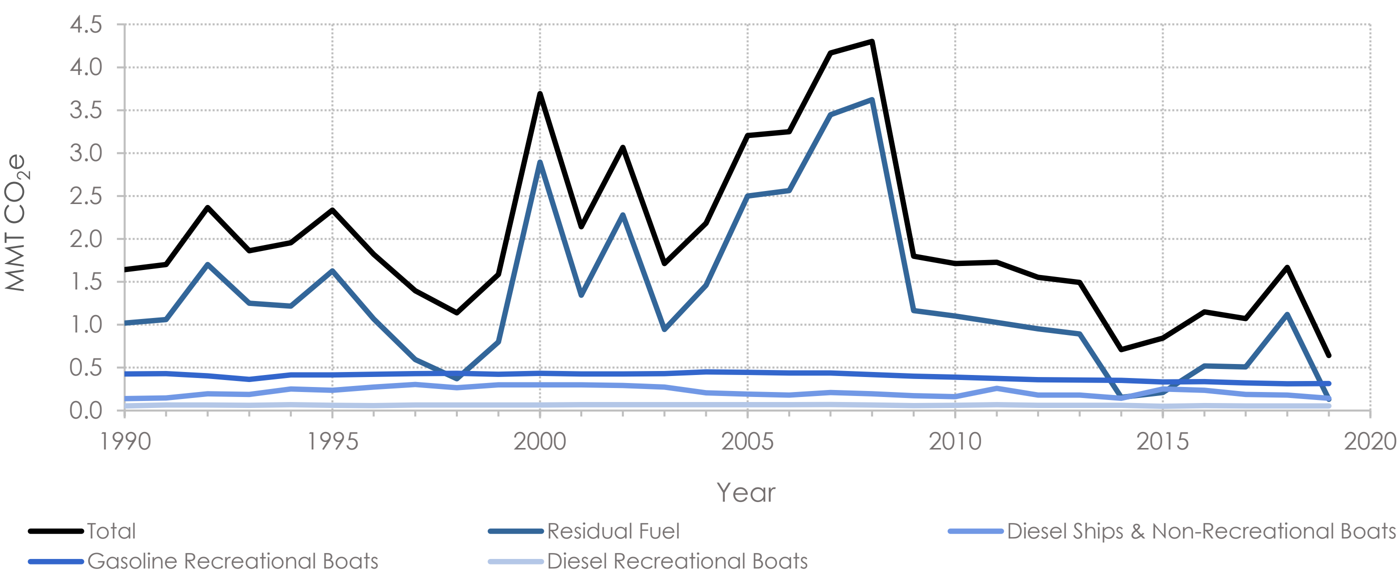
New Jersey is home to forty public airports, including Newark Liberty International Airport, one of the busiest in North America. In 2019, Newark Liberty served more than 46 million passengers.[17] In-state emissions from aviation are estimated to be approximately 1.0 MMT CO_2e for all years, based on either GWP_{100} or GWP_{20}. This estimate is in close agreement with the 2017 USEPA National Emissions Inventory (NEI) which found that in-state aviation emissions totaled 0.8 MMT CO_2e for that year.[18]

Marine Transportation

Marine transport includes large ocean-going ships, recreational watercraft, and regional transport such as passenger ferries. Three types of fuel are commonly used, residual oil, distillate (diesel), and gasoline. For ocean-going ships, the largest part of their emissions take place outside the territorial waters of the United States. These international emissions are not included in the state's emissions estimates in accordance with IPCC guidelines.

Since 1990, marine emissions have varied widely (Figure 9; Table A-7), starting at 1.6 MMT CO_2e in 1990, reaching a high of 4.3 in 2008, and then falling to 0.6 MMT in 2019.[19] However, much of the variability seen in these emissions estimates may be attributed to the limitations of using fuel sales data as a proxy for actual emissions activity. Residual fuel in particular may be purchased elsewhere and brought to the state, or sold here and then used later when the ship is away from the state. Fluctuations therefore reflect market processes as well as changes in underlying activity.

Figure 9. Marine Emissions (GWP_{100})



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[17] Port Authority of New Jersey (PANJ), 2019 Airport Traffic Report, https://www.panynj.gov/content/dam/airports/statistics/statistics-general-info/annual-atr/ATR2019.pdf, Accessed on June 3, 2022.

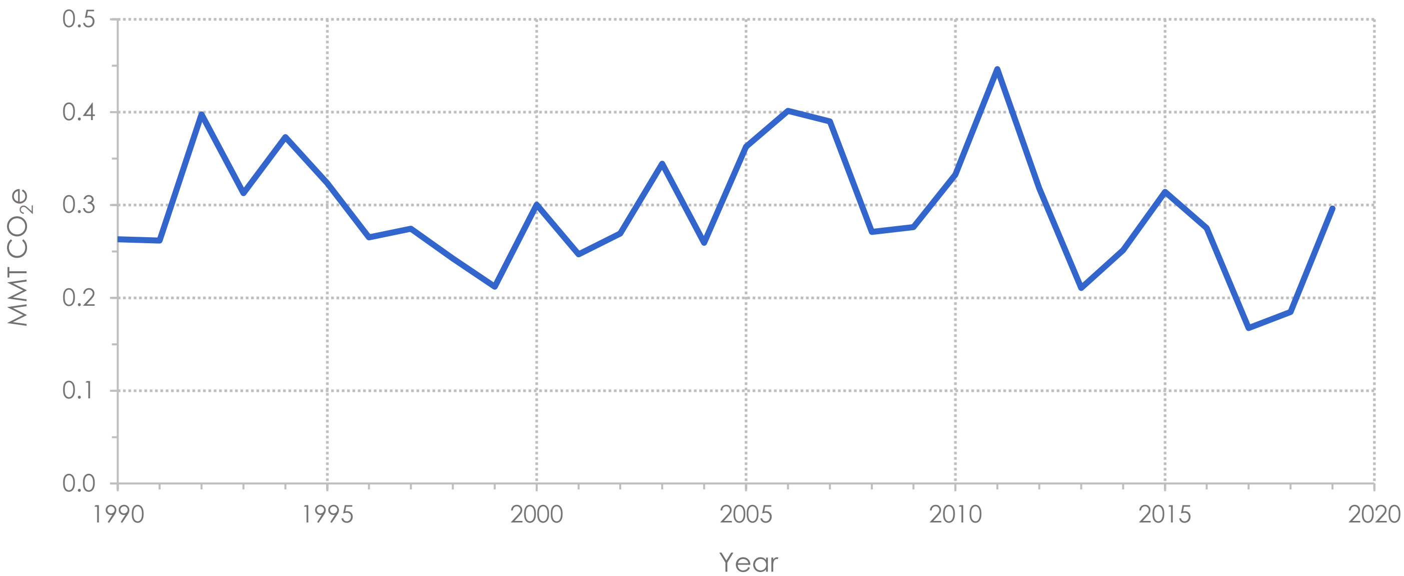
[18] Sum of CO_2 emissions for SCC codes 2275050011, 2275050012, 227506001, 2275060012, 2275020000 and 2275001000. https://gaftp.epa.gov/air/nei/2017/data_summaries/2017v1/2017neiJan_facility_process_byregions.zip

[19] Emissions estimates are based on GWP_{100}. Estimates based on GWP_{20} are within 0.1 MMT CO_2e of the GWP_{100} values.

Rail Transportation

NJ Transit operates the state's public transportation system and has more than 500 miles of track, 166 rail stations, and provides almost 90 million passenger trips a year.[20] With respect to emissions, electrified rail service is well-established in the state, but considerable traffic still relies on diesel-powered locomotives. This is especially true for freight transport. Diesel-powered rail emissions remained relatively stable from 1990 through 2019, fluctuating between 0.2 and 0.4 MMT CO_2e across all years (Figure 10; Table A-8).[21] Fossil-powered rail freight and passenger transportation accounted for 0.3% of New Jersey's gross emissions in 2019.

Figure 10. Estimated New Jersey Rail GHG emissions from Diesel Fuel (GWP_{100})



State Action: Transportation

New Jersey's strategy to reduce greenhouse gas emissions from the transportation sector includes a suite of legislated commitments, regulatory actions, incentive programs, and partnerships. Together these efforts have primed New Jersey for an equitable and electric future.

Enacted in 2019, the Electric Vehicle Law[22] outlined a goal for the State to have 330,000 electric vehicles registered by the end of 2025 and 2 million by the end of 2035. To reach this level of adoption, the law also sets goals for the installation of publicly accessible charging stations, and for the State to lead by example by electrifying 25% of the light duty non-emergency State-owned fleet by 2025. Through the Northeast States for Coordinated Air Use Management (NESCAUM) New Jersey reenforced the commitment for electric transportation by signing onto two Zero-Emission Vehicle Memorandum of Understandings (ZEV MOU). The ZEV

[20] https://www.njtransit.com/careers/railroad-careers/

[21] Emissions estimates are based on GWP_{100}. Estimates based on GWP_{20} are within 0.1 MMT CO_2e of the GWP_{100} values.

[22] P.L. 2019 c.362

MOUs are pledges to reach at least 3.3 million zero-emission vehicles across signatory states by 2025[23] and make at least 30 percent of all new medium- and heavy-duty vehicle sales be zero emission vehicles by 2030.[24]

Through the New Jersey Protecting Against Climate Threats (NJ PACT) regulatory reform effort, 2021 also marked the Department's adoption of the Advanced Clean Truck and Fleet Reporting Rules. The adopted rules (N.J.A.C. 7:27-31) require each truck manufacturer selling medium- and heavy-duty vehicles in New Jersey to increase the number of electric vehicles sold in the state over time. In addition, the Fleet Reporting Rule (N.J.A.C. 7:27-33) sets a one-time reporting requirement to gather information about the in-state operation of fleets of vehicles over 8,500 pounds.

New Jersey has established incentive programs to meet the milestones of the EV Law and ZEV MOU. The Charge Up New Jersey Electric Vehicle Incentive Program,[25] New Jersey Zero Emission Incentive Program,[26] and Clean Fleet Electric Vehicle Program,[27] all provide funds for businesses, schools, government agencies and residents to make the switch.

Complementary programs have also been established to support the deployment of charging stations. This includes the It Pay$ to Plug In[28] and the Electric Vehicle Tourism Program.[29] More recently, the Board of Public Utilities announced the Multi-Unit Dwelling Electric Vehicle Charger incentive program which supports the purchase and installation of eligible Level-Two EV charging equipment for multi-unit dwellings.[30] The program will award $1,500 toward the purchase of a dual-port, networked Level-Two EV charging station and fifty percent of the cost, up to $5,000, for make-ready expenses. Additional funds are available for multi-unit dwellings in overburdened communities.

Additional support to drive the future of clean transportation can be seen through the State's assistance to municipalities and businesses. The State has created electric vehicle educational resources and streamlined the process to approve local charging stations by issuing a model ordinance. Outreach and consumer awareness has been highlighted through programs such as Destination Electric, a program that recognizes charging friendly towns and businesses[31], as well as the PlugStar EV Training and Certification Program that trains and certifies car dealerships to sell electric vehicles[32].

[23] Northeast States for Coordinated Air Use Management, Topics, Zero-Emission Vehicles, State Zero-Emission Vehicle Programs Memorandum of Understanding, https://www.nescaum.org/documents/zev-mou-10-governors-signed-20191120.pdf/. Accessed on February 3,2022.

[24] Northeast States for Coordinated Air Use Management, Topics, Zero-Emission Vehicles, Multi-State Medium- and Heavy-Duty Zero Emissions Vehicle Memorandum of Understanding, https://www.nescaum.org/documents/mhdv-zev-mou_12-14-2021.pdf/. Accessed February 3, 2022.

[25] New Jersey Board of Public Utilities, Charge Up New Jersey Program, https://chargeup.njcleanenergy.com/. Accessed on January 24, 2022.

[26] New Jersey Economic Development Authority, New Jersey Zero Emission Incentive Program, https://www.njeda.com/njzip/ . Accessed on January 24, 2022.

[27] New Jersey Board of Public Utilities, Electric Vehicle Incentive Programs, Clean Fleet EV Incentive Program, https://njcleanenergy.com/ev. Accessed on January 24, 2022.

[28] New Jersey Department of Environmental Protection, Air Quality, Energy & Sustainability, Drive Green, It Pay$ to Plug In, https://www.drivegreen.nj.gov/plugin.html. Accessed on January 24, 2022.

[29] New Jersey Board of Public Utilities, Electric Vehicle Incentive Programs, EV Tourism, https://njcleanenergy.com/ev. Accessed on January 24, 2022.

[30] https://www.nj.gov/bpu/newsroom/2022/approved/20220126.html

[31] New Jersey Department of Environmental Protection, Air Quality, Energy & Sustainability, Drive Green, Destination Electric, https://www.drivegreen.nj.gov/destinationelectric.html. Accessed on February 3, 2022.

[32] New Jersey Department of Environmental Protection, Air Quality, Energy & Sustainability, Drive Green, PlugStar, https://www.drivegreen.nj.gov/. Accessed on February 3, 2022.

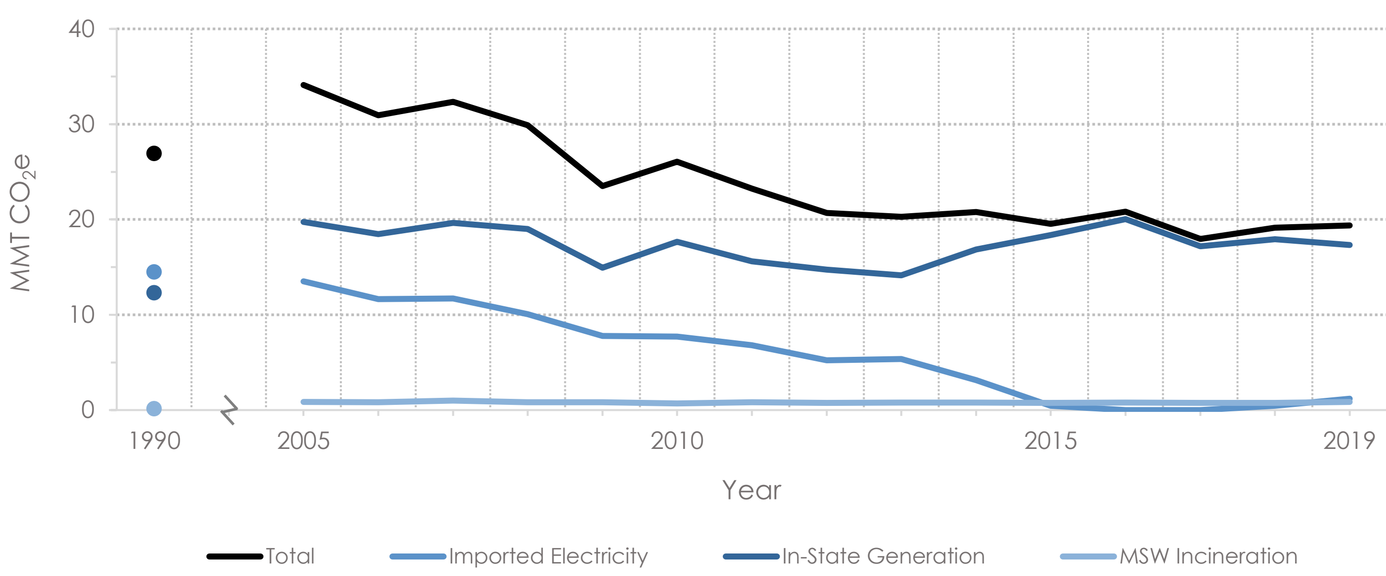
Altogether the State's actions have led to an accelerated rate of adoption. In 2021, New Jersey's inventory of electric vehicles included nearly 49,000 plug-in electric vehicles.[33] This represents a 63.1% increase from almost 30,000 plug-in electric vehicles in 2019. According to 2021 preliminary data from NESCAUM, plug-in electric vehicles represent 3.7% of light-duty sales.

3.2 ELECTRIC GENERATION

Electric generation, which includes dedicated in-state generation; energy from in-state resource recovery facilities; and emissions from electricity imports, has consistently ranked as the state's second largest source of emissions after transportation. In 2019, emissions for the sector were 19.4 MMT CO_2e,[34] a decrease of 14.7 MMT CO_2e below peak 2005 emissions of 34.1 MMT CO_2e (Figure 11; Table A-9). With respect to in-state generation (including resource recovery), emissions have dropped from 20.6 MMT CO_2e in 2005 to 18.2 MMT CO_2e in 2019, while at the same time in-state power output increased from 39,968 GWh to 73,542 GWh.[35] These shifts were largely due to reduced reliance on coal-heavy energy resources, expanded in-state capacity from high-efficiency combined-cycle natural gas systems, and surging growth in renewable energy. In particular, the greater availability of clean in-state resources has nearly eliminated reliance on electric imports, which tend to come from facilities with higher emissions rates.

In New Jersey's in-state energy mix, the dominant fossil fuel is now natural gas which, combined with nuclear energy, composed 91.2% of in-state electric generation (Figure 12, with incorporated table). Coal continued to decline, while renewable energy output[36] more than quadrupled since 2006. In 2019, renewables generated 4,534 GWh of electric power, or 6.2% of New Jersey's 73,542 GWh of in-state electric power generation.

Figure 11. Emissions from Electricity Generation (GWP_{100})



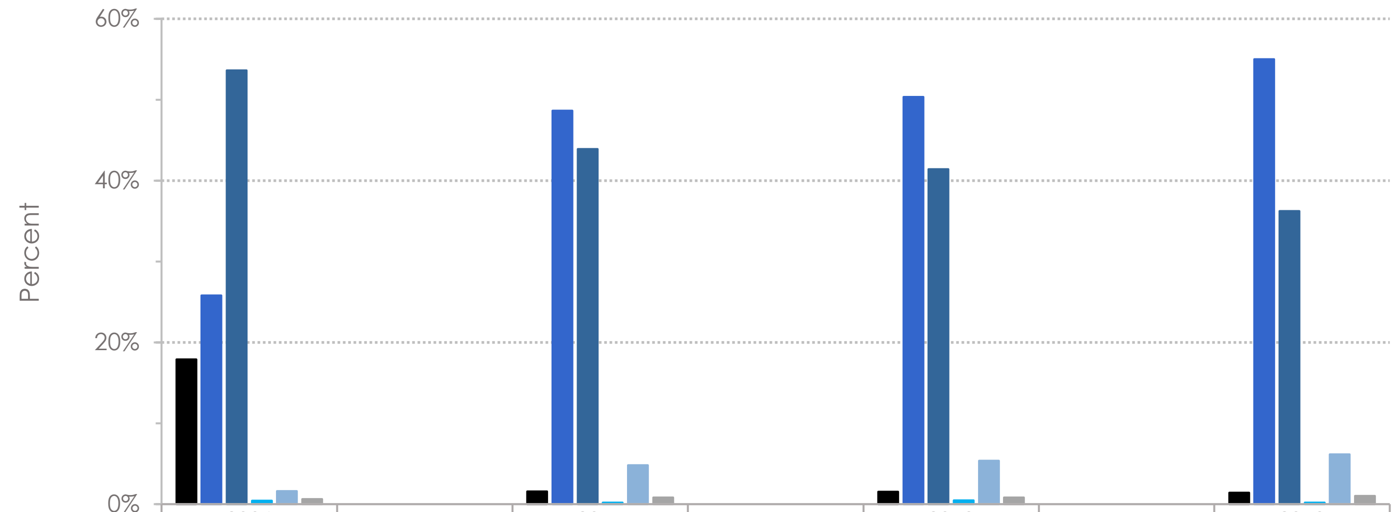
[33] New Jersey Department of Environmental Protection, Air Quality, Energy & Sustainability, Drive Green, New Jersey Plug-in Electric Vehicle Registrations, https://www.drivegreen.nj.gov/dg-electric-vehicles-basics.html. Accessed on January 24, 2022.

[34] Emissions estimates are based on GWP_{100}. Estimates based on GWP_{20} are within 0.1 MMT CO_2e of the GWP_{100} values.

[35] Including behind-the-meter solar photovoltaic. Totals listed in the text may not agree exactly with sums of the numbers shown in the tables in Appendix A due to rounding of estimates in the tables.

[36] Renewables include NJ Class I and Class II renewable energy sources, including but not limited to grid-connected and behind-the-meter solar photovoltaic, wind, hydroelectric, landfill gas, and solid waste resource recovery (biologically-produced component of fuel only).

Figure 12. Percent of In-State Electricity Generated by Major Energy Sources



	2006	2017	2018	2019
Coal	17.9%	1.6%	1.5%	1.4%
Natural Gas	25.8%	48.7%	50.3%	55.0%
Nuclear	53.6%	43.9%	41.4%	36.2%
Petroleum	0.4%	0.2%	0.5%	0.2%
Renewables	1.6%	4.8%	5.4%	6.2%
Others	0.6%	0.8%	0.8%	1.0%

State Action: Electric Generation

New Jersey is pursuing a slate of regulatory mechanisms and incentive programs to accelerate the transition to clean, renewable electric generation. In 2020, New Jersey officially rejoined the Regional Greenhouse Gas Initiative (RGGI). RGGI is a regional market-based cap and investment program among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia to cap and reduce carbon dioxide emissions from the power sector. RGGI regulates fossil fuel power plants that generate carbon dioxide emissions at or above a 25-megawatt capacity. In New Jersey 93 electric generating units at 33 locations currently participate in RGGI. Through the state's participation in RGGI, it has set a regional emissions cap reduction of 30% from 2020 to 2030.

The state has furthered its emission reduction efforts, by proposing an emissions limit on CO_2 from electric generating units, via NJ PACT, its climate focused regulatory effort. These proposed limits will become more stringent over time, ultimately establishing a limit no greater than 1000 lbs/MWh per unit by 2035. This rule will eliminate the dirtiest plants from operating in New Jersey.

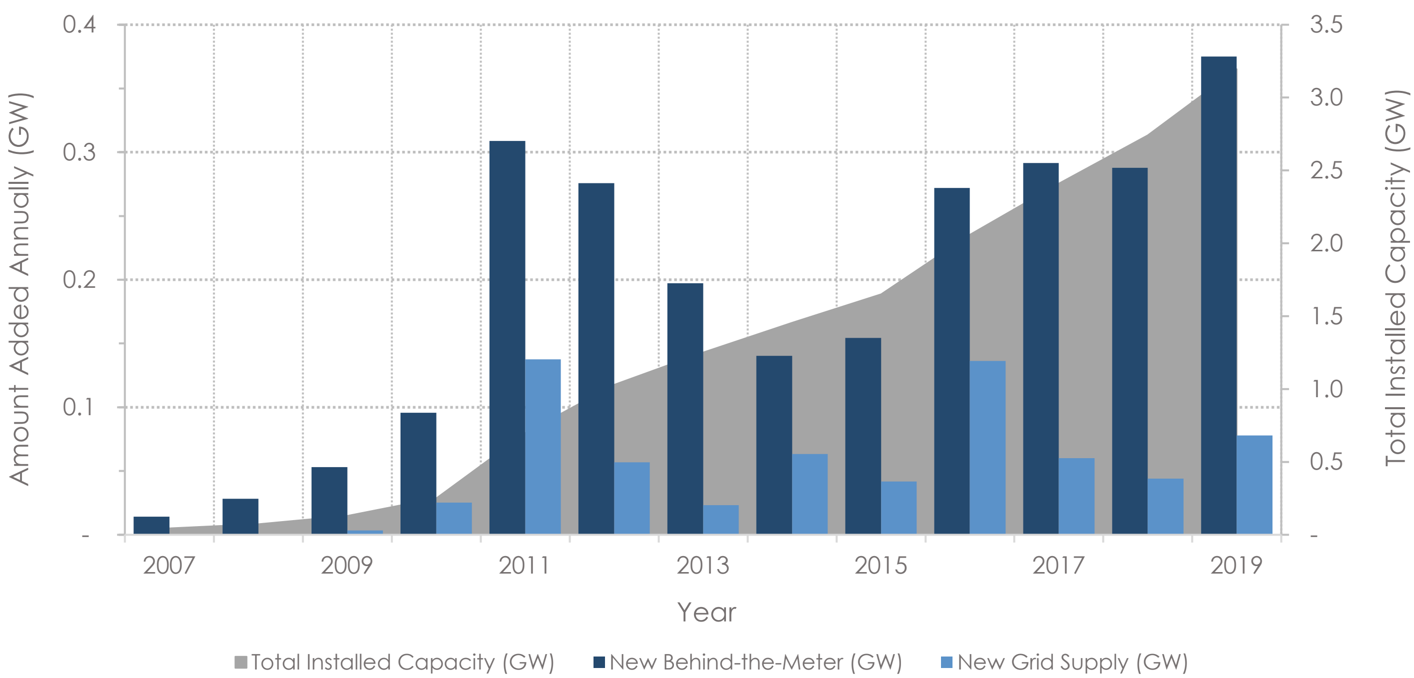
Beyond these regulatory efforts, the state has increased its commitment to New Jersey based renewable energy. In 2019, solar PV accounted for 3.2 GW of in-state installed capacity (Figure 13). In July 2021, Governor Murphy signed the Solar Act of 2021 into law, which directed the BPU to establish a successor program to the solar renewable energy certificate (SREC) program.[37] The law aims to more than double the state's current installed

[37] New Jersey Solar Act of 2021, P.L. 2021, c. 169 (A4554 ACS), https://www.njleg.state.nj.us/Bills/2020/PL21/169_.HTM. Accessed January 24, 2022.

capacity (3.2 GWs) by providing incentives for the development of at least 3.75 GWs of new solar by 2026. Two incentive structures were created, an Administratively Determined Incentive (ADI) for net metered facilities with capacity of 5 MW and less and community solar facilities, and a Competitive Solicitation Incentive (CSI) for grid supply solar facilities and net metered facilities over 5 MW.[38] The ADI program opened on August 28, 2021, and the BPU is in the process of developing the CSI program via stakeholder meetings.

Additionally, New Jersey is committed to siting offshore wind facilities in New Jersey's coastal waters. In 2019, Governor Murphy, via Executive Order 92, committed New Jersey to procuring 7,500 MW of offshore wind capacity by 2035. Since then, BPU has issued two offshore wind solicitation awards, one in July 2019 for 1,100 MW and one in June 2021 for 2,658 MW. These awards total 3,758 MWs, halfway to the 7,500 MW goal; additional solicitations are scheduled for 2022, 2024 and 2026.[39]

Figure 13. New Jersey Solar Photovoltaic Capacity - Annual Growth and Cumulative Total



3.3 RESIDENTIAL SECTOR

Residential single and multi-family housing emissions are associated with space heating, water heating, air conditioning, lighting, refrigeration, cooking, appliances, and other household activities.[40] In 1990, emissions based on GWP_{100} totaled 15.5 MMT CO_2e, rose to 18.5 MMT by 2003, fell to a low of 12.5 MMT in 2012, and ended the period at 15.3 MMT in 2019 (Figure 14; Table A-10).[41] Since the largest greenhouse gas contributor in this sector is carbon dioxide, estimates based on GWP_{20} are nearly identical. Combustion of natural gas accounted for 13.2 MMT in 2019, fuel oil 1.8 MMT, and the balance, propane (0.3 MMT).

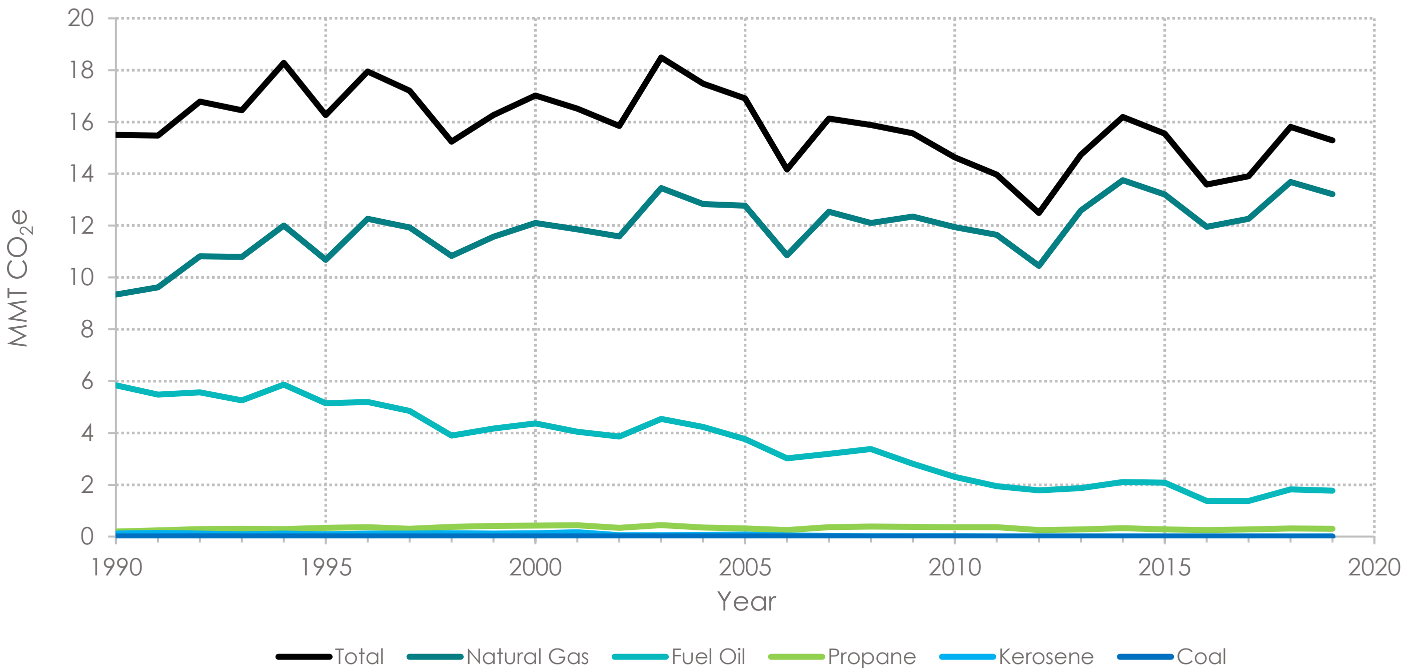
[38] New Jersey Board of Public Utilities, Clean Energy Program, Solar Activity Reports, https://njcleanenergy.com/renewable-energy/project-activity-reports/project-activity-reports. Accessed January 24, 2022.

[39] New Jersey Board of Public Utilities, Clean Energy Program, New Jersey Offshore Wind Solicitations, https://www.njcleanenergy.com/renewable-energy/programs/nj-offshore-wind/solicitations. Accessed January 24, 2022.

[40] US Energy Information Agency, Glossary, Residential Sector, https://www.eia.gov/tools/glossary/. Accessed December 7, 2021.

[41] Estimates based on GWP_{20} are within 0.1 MMT CO_2e of the GWP_{100} values.

Figure 14. Residential sector greenhouse gas emissions by fuel type (GWP_{100})



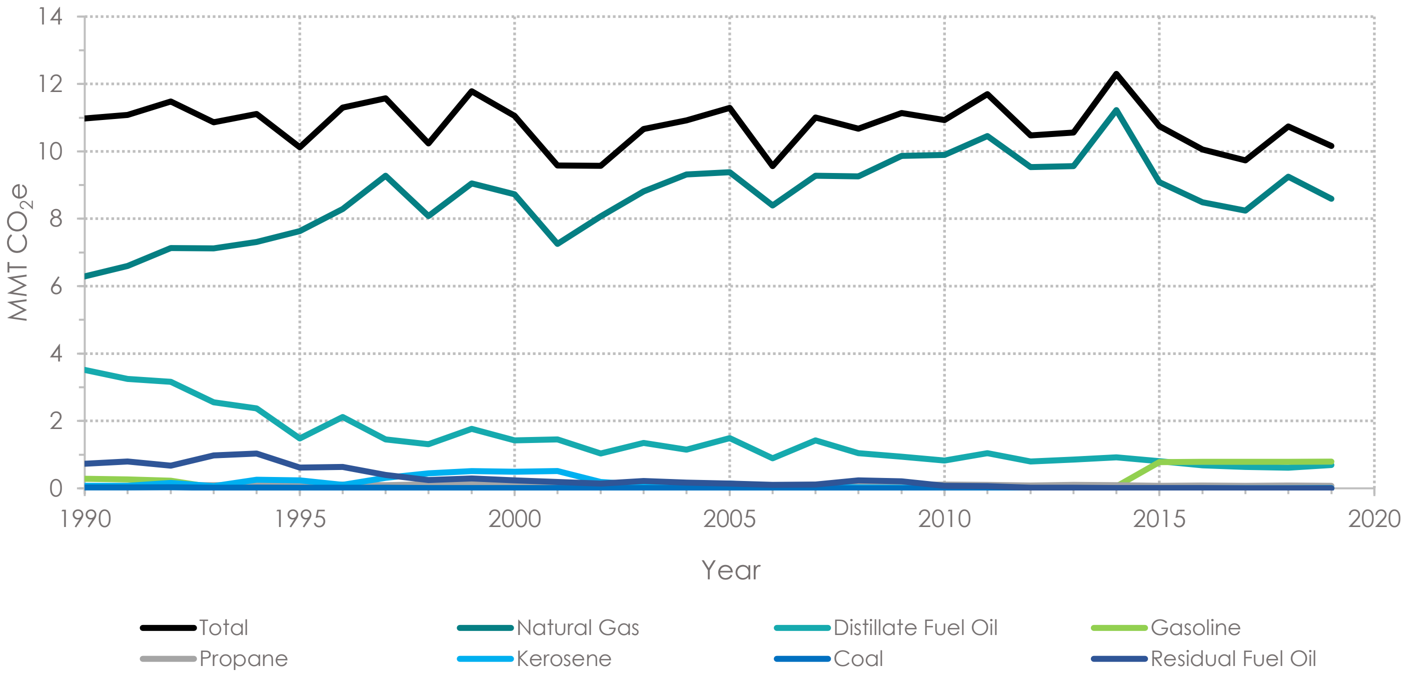
3.4 COMMERCIAL SECTOR

Commercial sector emissions are associated with service-providing facilities, business equipment, government activities, institutional living quarters, colleges, and religious institutions. Examples of sources that may contribute to greenhouse gas emissions in this sector include heating, ventilation, and air conditioning (HVAC), cooking, and production of behind-the-meter electricity that is not fed into the electric grid. Emissions associated with fuel consumption at water and wastewater treatment plants are also included in these estimates. Non-fuel emissions of methane from biological processes at landfills and wastewater treatment plants are discussed later in this report in sections specific to those activities.

Emissions from the commercial sector have been stable since 1990, beginning the period at 11.0 MMT CO_2e (GWP_{100}).[42] Values reached a low of 9.6 in 2006, climbed to a high of 12.3 in 2014, and fell back to 10.2 in 2019. (Figure 15, Table A-11). Emissions from fuel oil declined, and were matched by comparable increases from natural gas, the changeover being essentially complete before 2005.

[42] Estimates based on GWP_{20} are within 0.1 MMT CO_2e of the GWP_{100} values.

Figure 15. Commercial sector greenhouse gas emissions by fuel type (GWP_{100})



STATE ACTION: BUILDINGS

Decarbonizing the building sector requires improving energy efficiency, adopting electric technologies (such as cold-climate heat pumps) and implementing modern construction standards. New Jersey has begun in earnest to tackle building emissions through legislation, regulation, and strategic partnerships to deploy the latest technologies and building codes.

Key pieces of legislation that has put New Jersey on a path to reduce emissions from the building sector include, the Clean Energy Act (P.L. 2018, c.17), the Low Carbon Concrete Law (P.L.2021, c.278) and the Appliance Standards Law (P.L. 2021, c.464).

Signed in 2018, the Clean Energy Act (P.L. 2018, c.17) established a benchmarking requirement for commercial buildings over 25,000 square feet. Beginning in May 2023, owners and operators of commercial buildings that meet this threshold will be required to benchmark their building's energy and water use. Benchmarking allows building owners and operators to measure and analyze their respective facilities' energy use and compare their performance to other types. This data can help inform future capital improvements and encourage facilities to improve their energy efficiency.

On November 8, 2021, New Jersey Governor Phil Murphy signed legislation (P.L.2021, c.278) that requires builders to offer concrete products that utilize carbon footprint-reducing technology. The law establishes tax credits, sales tax exemptions, and where feasible requires state agencies to procure concrete products that use carbon footprint-reducing technology.

Signed in 2022, the Appliance Standards Law (P.L. 2021, c.464) established minimum efficiency standards for several categories of residential and commercial appliances such as faucets, toilets, commercial ovens, and computers. Beginning January 18, 2023, this law will prohibit the sale of appliances in New Jersey that do not meet the specific efficiency standards.

NJDEP has also pursued a regulatory agenda to reduce emissions from buildings. The buildings component of the recent NJ PACT stationary source proposal[43] seeks to replace large boilers (1 to 5 million BTUs) fired by fossil fuels with electric boilers when they reach the end of their useful lives. Boilers of this size typically are used in commercial, industrial, and institutional properties, which could include office buildings, manufacturing facilities, schools, or hospitals; the rule also includes boilers in apartment buildings. Additionally, the NJ PACT rule bans the sale and use of No. 4 and No. 6 fuel oil in New Jersey.

New Jersey is also slated to adopt the 2021 International Energy Conservation Code (IECC).[44] The 2021 IECC is an important vehicle for achieving the state's greenhouse gas emission reduction goals, most importantly because it requires a zero-energy building envelope. A zero-energy building envelope saves energy from the bottom up, where the foundation, walls, windows, doors, and roof all work together to reduce the amount of energy needed to heat/cool the building. Once completed, a well-designed zero-energy building will produce as much renewable energy as it uses.

Additional efforts on building decarbonization includes the BPU initiated Zero Energy/Carbon Emissions Building Collaborative.[45] This collaborative, managed by the Northeast Energy Efficiency Partnerships (NEEP) and Rutgers Centers for Green Building, is engaging key stakeholders in the development, adoption, and implementation of a building code roadmap for New Jersey. The roadmap will integrate best practices and programs to set and achieve zero energy/carbon emissions building energy codes. The effort is aligned with the New Jersey Global Warming Response Act 80x50 report and the 2019 NJ Energy Master Plan.

3.5 INDUSTRIAL SECTOR

The industrial sector includes activities that produce, process, or assemble goods, agriculture, and building construction as well as mining, and fossil-fuel production.[46] Emissions arise from energy use, such as from powering manufacturing equipment, tractors, logging equipment, and fishing boats (as opposed to boats used for transportation). Emissions can also originate from fuel used for electric generation where that generation is fully "behind the meter" and does not feed the larger electrical grid. Categories of industrial emissions that are unrelated to fuel consumption, for example emissions from farming practices and industrial process chemistry,[47] are included in the inventory report as separate categories, distinct from fuel consumption.

Emissions from fuel consumption in the industrial sector have fluctuated as activities have shifted over time. Emissions were 14.8 MMT CO_2e in 1990,[48] but dropped to a low of 7.5 MMT CO_2e by 2017.[49] Emissions for both 2018 and 2019 were 8.0 MMT CO_2e (Figure 16, Table A-12). Emissions from combustion of natural gas dropped from 4.9 MMT CO_2e in 1990 to between 2.6 and 3.6 MMT CO_2e in recent years. Emissions from still gas, a product generated within refineries and used onsite as a fuel source, have remained between 2.0 and 2.5 MMT CO_2e since 2009 and were the second largest source of emissions in the sector during 2019 at 2.0 MMT CO_2e.

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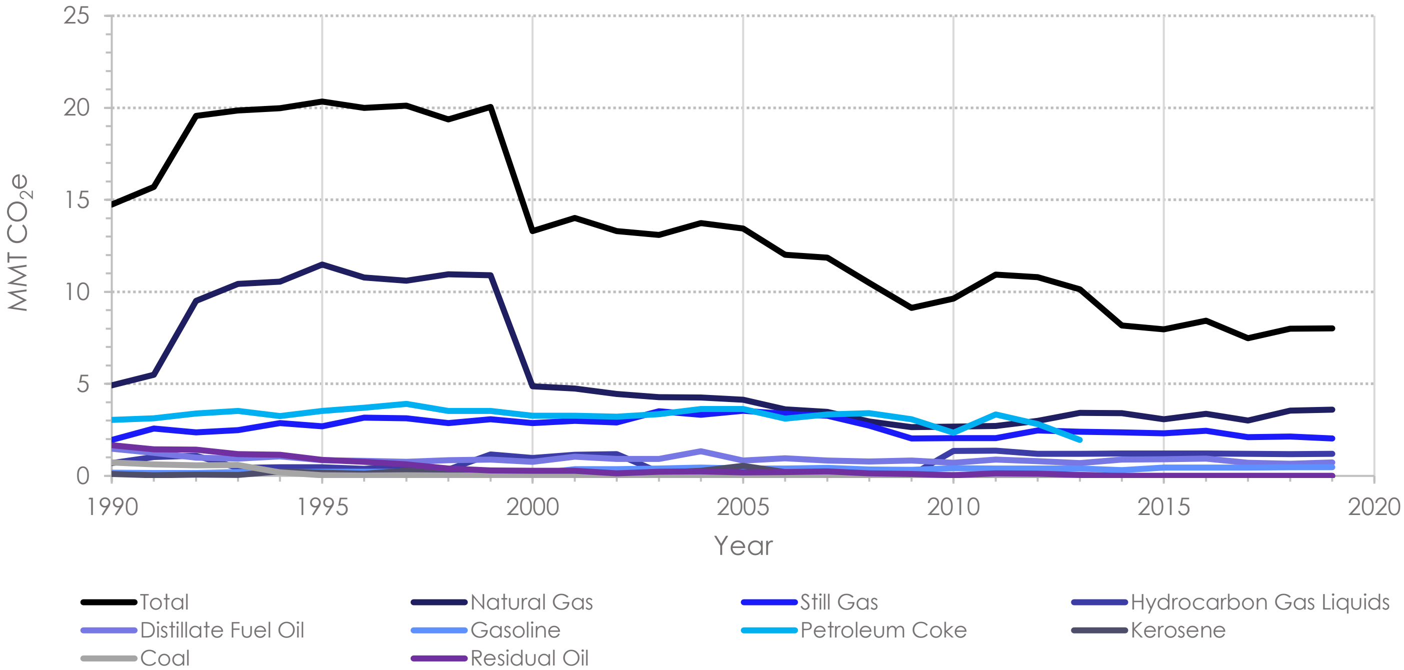
[43] https://www.nj.gov/dep/rules/proposals/20211206a.pdf
[44] https://codes.iccsafe.org/content/IECC2021P2
[45] http://www.broadband.state.nj.us/bpu/pdf/boardorders/2021/20210127/8E%20-%20MOU%20NEEP%20NJ%20ZEB%20Collaborative%20-%20w%20President%20+%20NEEP%20+%20RCGB+DAG.pdf
[46] USEIA Glossary, https://www.eia.gov/tools/glossary/index.php?id=I
[47] Examples of industrial processes that emit greenhouse gas emissions include cement manufacture, lime manufacture, limestone and dolomite use, soda ash manufacture and use, aluminum production, iron and steel production, ammonia production, and urea consumption. Not all of these processes take place in New Jersey.
[48] GWP_{100} basis. Because the fuel-based processes generating these emissions create very few highly-warming gases such as methane, estimates based on GWP_{20} are nearly identical. Additional information is in the appendices.
[49] Emissions estimates are based on GWP_{100}. Estimates based on GWP_{20} are within 0.1 MMT CO_2e of the GWP_{100} values.

Figure 16. Industrial sector fuel greenhouse gas emissions (GWP_{100})



4.0 NON-ENERGY EMISSIONS

4.1 HALOGENATED GASES (EXCLUDING SULFUR HEXAFLUORIDE)

Halogenated gases are compounds containing elements from the halogen group of the periodic table, including fluorine, chlorine, bromine, and iodine. With respect to climate change, hydrofluorocarbons (HFCs) are of the greatest concern because they are widely used and cause substantially more intense global warming than carbon dioxide on a weight per weight basis. On the other hand, HFCs break down relatively quickly in the environment compared to carbon dioxide, and their climate influence therefore decreases rapidly in response to lower emissions. HFCs are most commonly found in refrigeration and air conditioning equipment as well as in products such as foams, spray cans, and fire-fighting systems. Since their introduction in the early 1990s, HFCs have been widely deployed as replacements for ozone-depleting chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).

Since 2005, HFC emissions have gradually increased from 2.2 MMT CO_2e to 5.2 MMT CO_2e (GWP_{100}) in 2019 (Figure 17; Tables A-13). The three largest source types in 2019 were commercial refrigeration (1.8 MMT CO_2e), light-duty motor vehicle air conditioning (0.8 MMT CO_2e) and small commercial air conditioning units (0.6 MMT CO_2e) (Figure 18). Using a 20-year GWP, total HFC emissions rose from 5.2 MMT CO_2e (GWP_{20}) in 2005 to 11.9 MMT CO_2e (GWP_{20}) in 2019, with commercial refrigeration accounting for 4.0 MMT CO_2e (GWP_{20}), light-duty motor vehicle air conditioning 1.8 MMT CO2e (GWP_{20}), and small commercial air conditioning equipment 1.3 MMT CO2e (Figures 19 and 20; Table A-14).

State Action: HFCs

Pursuant to P.L 2019 c.507, New Jersey has established statutory deadlines to phase out many HFCs in a range of applications. However, while this law assures long-term reductions, many applications of HFCs such as refrigeration equipment have long operating lifetimes. The greatest decreases in emissions will therefore occur as older equipment with the potential to leak ages out and is replaced.

In 2021, via NJ PACT, a climate focused regulatory reform effort, the DEP proposed a new Greenhouse Gas Monitoring and Reporting Rule (N.J.A.C. 7:27E)[50], which will in part, collect data on HFC emissions. Non-residential refrigeration systems containing 50 pounds or more of any combination of high-GWP refrigerant will be required to report. Subject facilities must submit an annual Facility Refrigeration System Report that identifies the high-GWP refrigerant(s), its 20-year and 100-year GWP value, and the quantity purchased, charged, recovered, stored, and reclaimed or destroyed in a calendar year. The Department will utilize this information to calculate refrigerant leakage and subsequent emissions from each facility.

Through the United States Climate Alliance, New Jersey also works collaboratively with states and industry stakeholders to coordinate the reduction of HFCs. Efforts include establishing a uniform regulatory landscape to facilitate compliance across state lines, assessing supply chain constraints, and reclamation efforts to recover HFCs at end of life. At the Federal level the American Innovation and Manufacturing (AIM) Act directs the EPA to address HFCs in a threefold approach. The first actions include the phase down of production and consumption of listed HFCs through the HFC Allocation Rule. Additionally, the EPA will act to manage HFCs substitutes, and facilitate the transition to next-generation technologies. New Jersey is actively monitoring and providing comments during the AIM rule development process.

[50] New Jersey Department of Environmental Protection, NJ PACT: Protecting Against Climate Threats, Rule Proposals, Greenhouse Gas Monitoring and Reporting, https://www.nj.gov/dep/njpact/cpr.html#cpr-rule-proposals. Accessed February 4, 2022.

Figure 17. Hydrofluorocarbon emissions by category (GWP_{100})

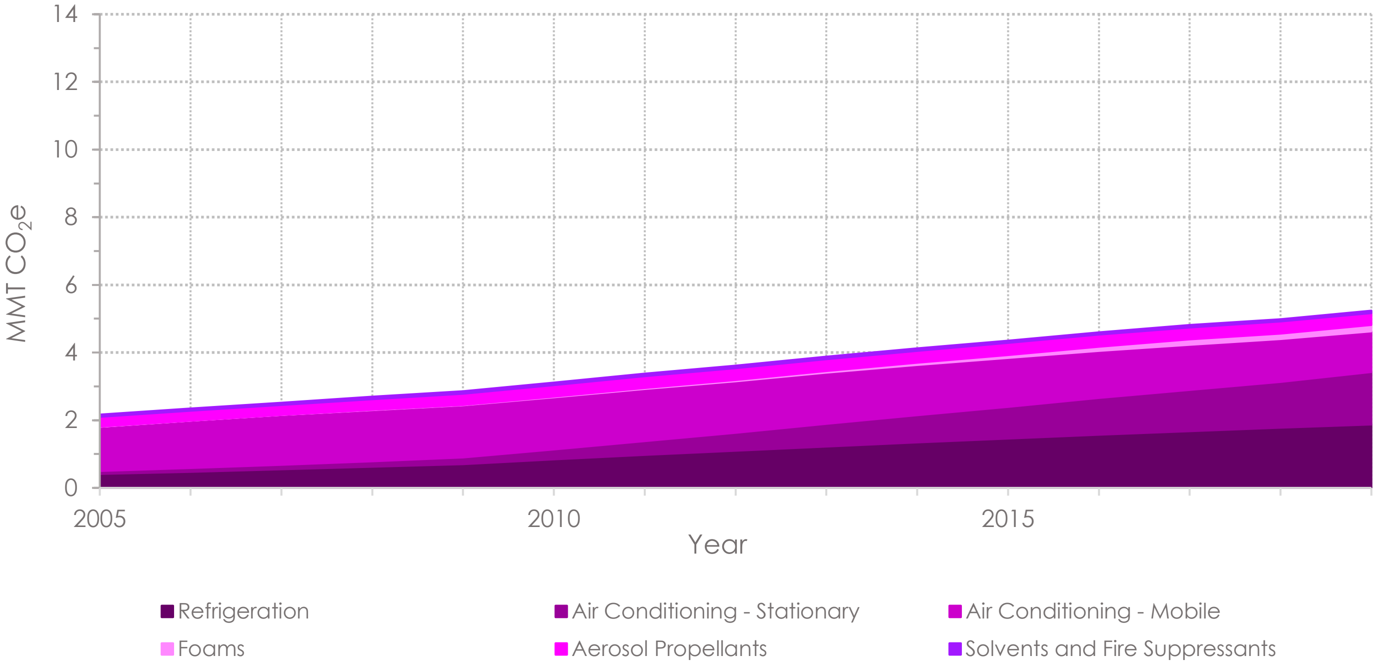


Figure 18. 2019 HFC emissions profile (GWP_{100})

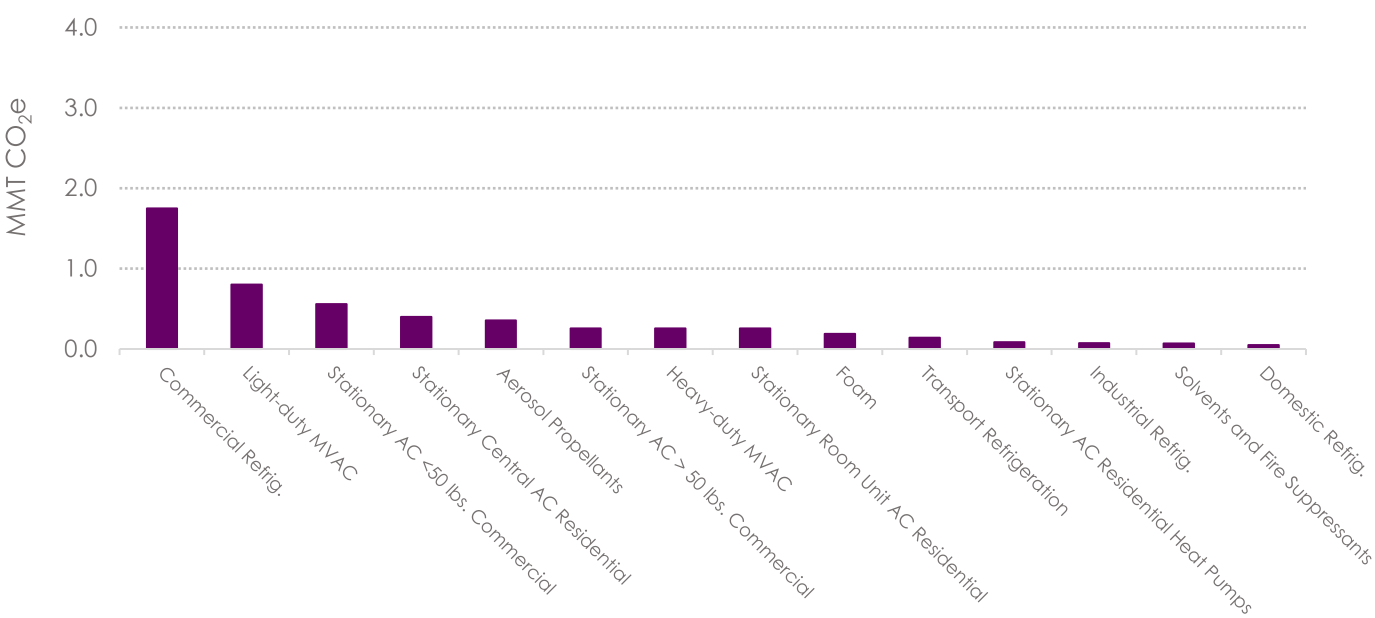


Figure 19. HFC emissions by category (GWP_{20})

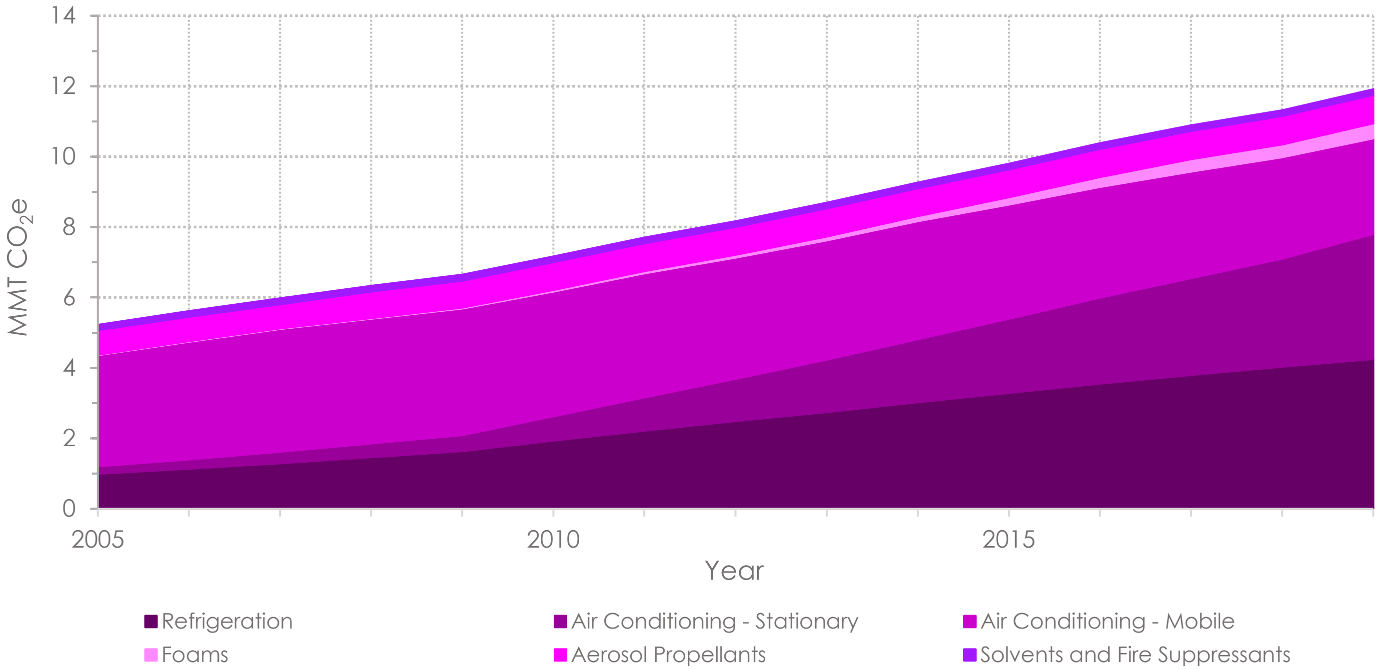
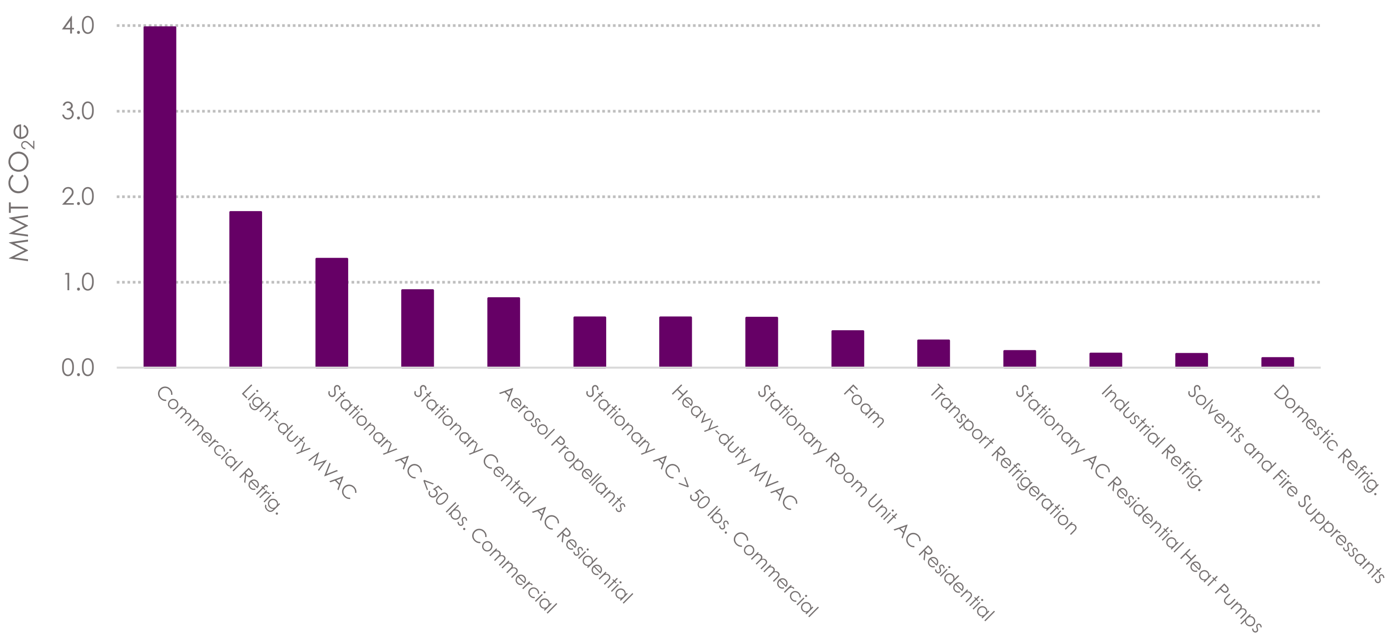


Figure 20. 2019 HFC emissions profile (GWP_{20})



4.2 NATURAL GAS TRANSMISSION AND DISTRIBUTION

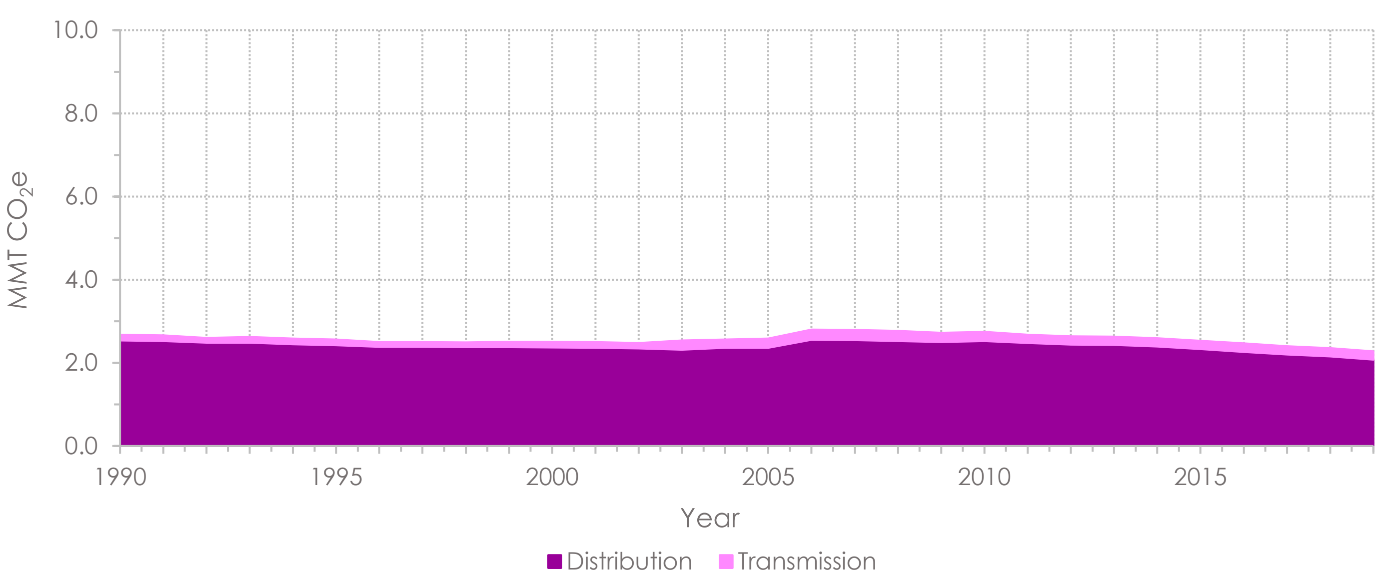
Natural gas, which consists primarily of methane, is used throughout New Jersey for space heating, hot water heating, cooking and industrial applications. In 2019, over 1,568 miles of long-distance transmission pipelines crossed the state, and nearly 35,600 miles of distribution mains delivered gas to users through more than 2.3 million service connections. At each step of the delivery process, methane can potentially be released to the atmosphere. However, because of methane's explosive risk, extensive precautions were already in place to minimize releases even before the risk of climate change was recognized. Further, New Jersey does not have any natural gas production wells or pre-transmission processing facilities, eliminating the risk of emissions from these operations.

Between 2006 and 2019, emissions from New Jersey's natural gas transmission and distribution system dropped from 2.8 to 2.3 MMT CO_2e (GWP_{100})/8.1 to 6.6 MMT CO_2e (GWP_{20}) (Figures 21 and 22, Table A-15). Emissions are primarily attributed to the distribution system, and specifically from older service connections. Efforts to replace older service lines with lower-emitting infrastructure are the primary cause of the observed decrease. An apparent increase in 2006 was the result of a reclassification of a large number of service connections in the PSEG distribution network from a lower-emitting category to a higher-emitting category. There was no significant change in the distribution system itself. As a result, emissions estimates for the years preceding 2006 are likely underestimated by a small amount (approximately 0.2 MMT CO_2e (GWP_{100})/ 0.6 MMT CO_2e (GWP_{20}). However, DEP has used the published data for the years in question and has not attempted to adjust the emissions estimates for those years.

State Action: Natural Gas Transmission and Distribution

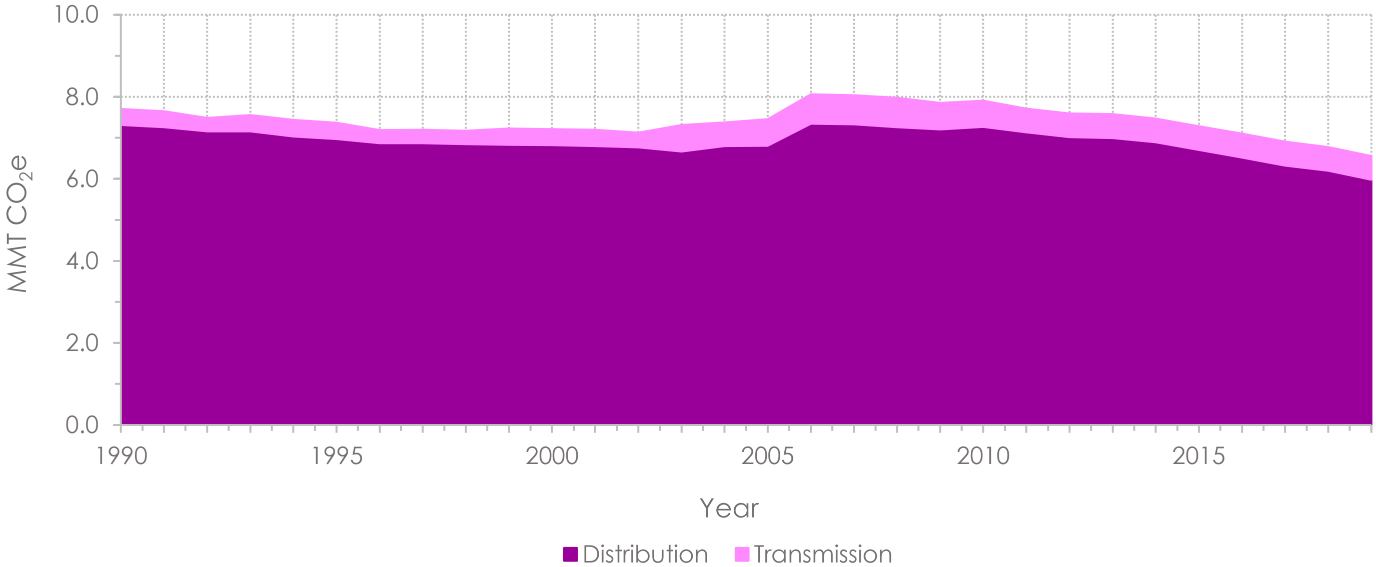
Through NJ PACT the DEP has proposed a new Greenhouse Gas Monitoring and Reporting Rule (N.J.A.C 7:27E)[51], which will in part, collect data on natural gas distribution system emissions. The proposed rule requires each gas public utility to document annually its leak abatement efforts by submitting a Pipeline Modernization Report to the DEP that details the utility's efforts to monitor leaks, replace leaking pipes, and quantify the number of blowdown events each year. Through this report the DEP will enhance its reporting of methane emissions from natural gas distribution.

Figure 21. Natural gas transmission and distribution (GWP_{100})



[51] New Jersey Department of Environmental Protection, NJ PACT: Protecting Against Climate Threats, Rule Proposals, Greenhouse Gas Monitoring and Reporting, https://www.nj.gov/dep/njpact/cpr.html#cpr-rule-proposals. Accessed February 4, 2022.

Figure 22. Natural gas transmission and distribution (GWP_{20})



4.3 LANDFILLS

Disposal of solid waste by landfill results in anaerobic decomposition that releases landfill gas, which is approximately equal amounts of methane and carbon dioxide by weight; however, only methane emissions from landfills are reported in this report. Carbon dioxide emissions are excluded based on international convention and USEPA policy since these emissions arise from biologically produced materials such as wood and paper which are already accounted for through assessment of land-use changes captured elsewhere in this report.

Modern landfills include systems to collect landfill gas and either directly vent it to the atmosphere, burn the gases by flaring, or when sufficient quantities are available, combust the gases onsite for electricity generation. Methane emissions reported here are those directly vented to the atmosphere. Emissions from waste disposed of out-of-state are also estimated based on the assumption that methane is released at the same rate per ton as waste disposed of at in-state landfills.

Resulting methane emissions from landfill disposal decreased from 8.6 MMT CO_2e (GWP_{100})/ 24.6 MMT CO_2e (GWP_{20}) in 1990 to 3.1 MMT CO_2e (GWP_{100})/ 9.0 MMT CO_2e (GWP_{20}) in 2007.[52] By 2019, emissions increased to 5.5 MMT CO_2e (GWP_{100})/15.8 MMT CO_2e (GWP_{20}) (Figures 23 and 24, Table A-16). Emissions have been divided fairly evenly between in-state and out-of-state sources. In 2019, out-of-state sources accounted for 55% of emissions, in-state sources 39%, and industrial landfills 6%.

State Action: Waste Management

New Jersey has passed a series of laws to reduce the amount of food waste generated in the state and entering the municipal waste stream. The Food Waste Reduction Act (P.L. 2017, c.136) establishes a goal of a 50% reduction in food waste generated by 2030 and requires the Department of Environmental Protection to develop and implement a plan to meet this goal. A draft plan was released in 2019.[53] Following on the heels of this law, in 2020, the Food Waste Recycling and Waste-to-Energy Production Act (P.L. 2020, c.24) was passed, requiring large food waste generators (who produce 52 tons or more of food waste per year) located within 25

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[52] Totals listed in the text may not agree exactly with sums of the numbers shown in the tables in Appendix A due to rounding of estimates in the tables.

[53] https://www.nj.gov/dep/dshw/food-waste/food_waste_reduction_plan.html

road miles of an approved recycling facility to source separate and recycle their food waste. The Department of Environmental Protection is actively developing a rule proposal to implement this law.

Figure 23. Emissions from solid waste landfills (GWP_{100})

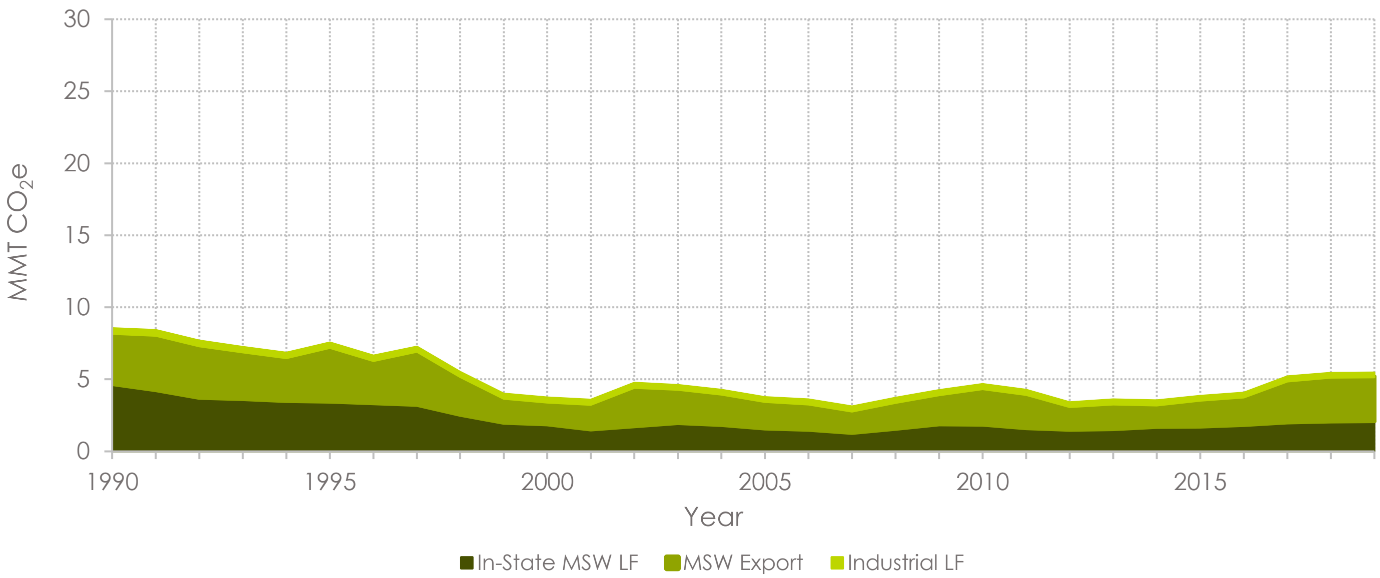
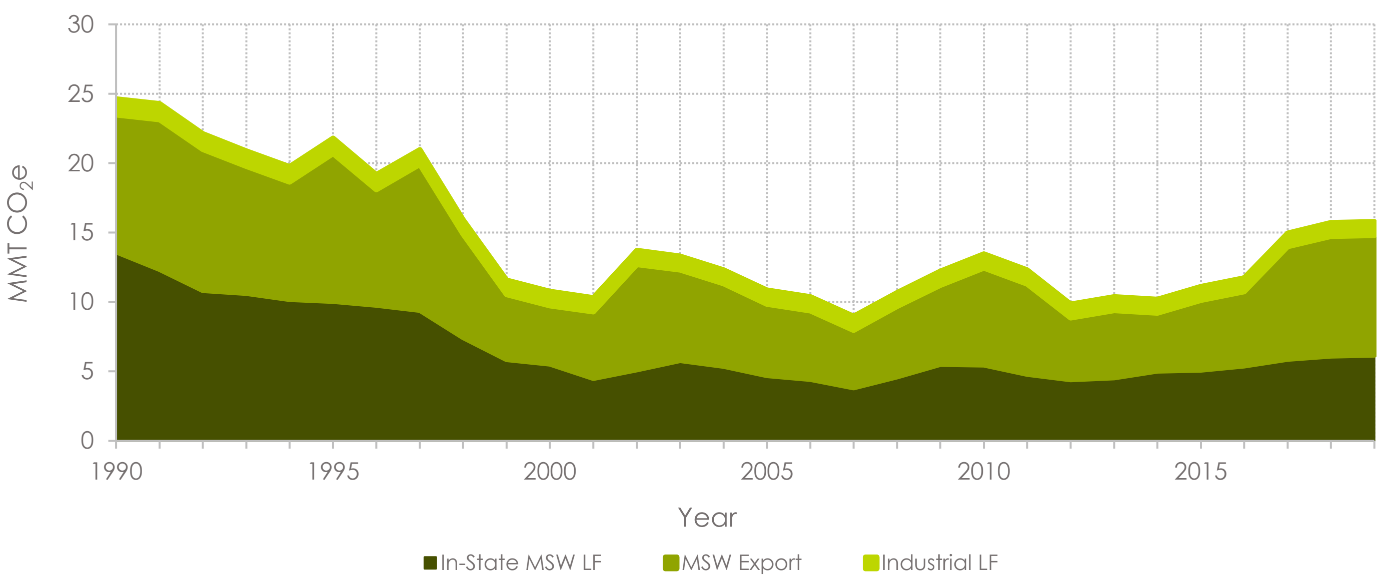


Figure 24. Emissions from solid waste landfills (GWP_{20})



4.4 WASTEWATER TREATMENT

Treatment of municipal wastewater can result in production of methane when anaerobic digestion is used as part of the solids management process. Nitrous oxide can also be produced in the treatment process and in residential septic systems. Carbon dioxide is also produced, but, as with landfills, it is excluded from consideration based on that fact that it comes from decomposition of biological materials and therefore does not represent a net increase in atmospheric CO_2.

Wastewater treatment emissions have remained nearly constant throughout the period, rising from 0.8 MMT CO_2e/2.4 MMT CO_2e (GWP20) in 1990 to 1.0 MMT CO_2e (GWP_{100})/2.8 MMT CO_2e (GWP_{20}) in 2019 (Figures 25 and 26; Table A-18). The estimates are based on nationally-determined assumptions regarding organic waste production and state population size, and may therefore not reflect individual state-specific circumstances. The estimates are, however, considered sufficiently accurate to allow wastewater treatment emissions to be compared with other emissions sources for policy development.

Figure 25. Wastewater treatment emissions (GWP_{100})

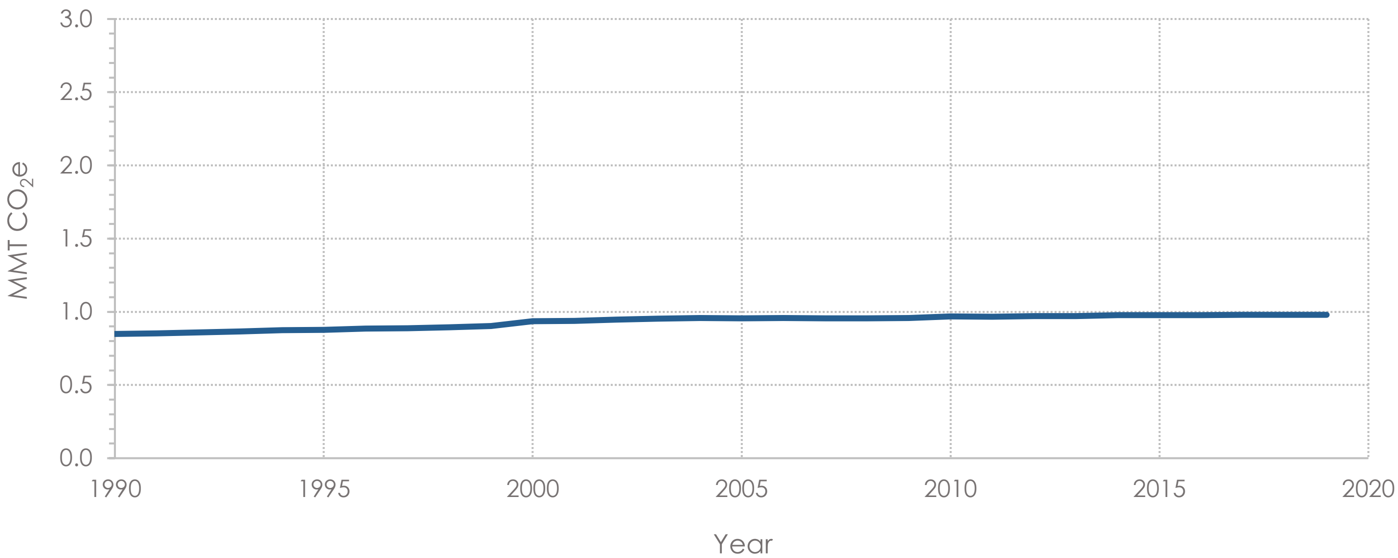
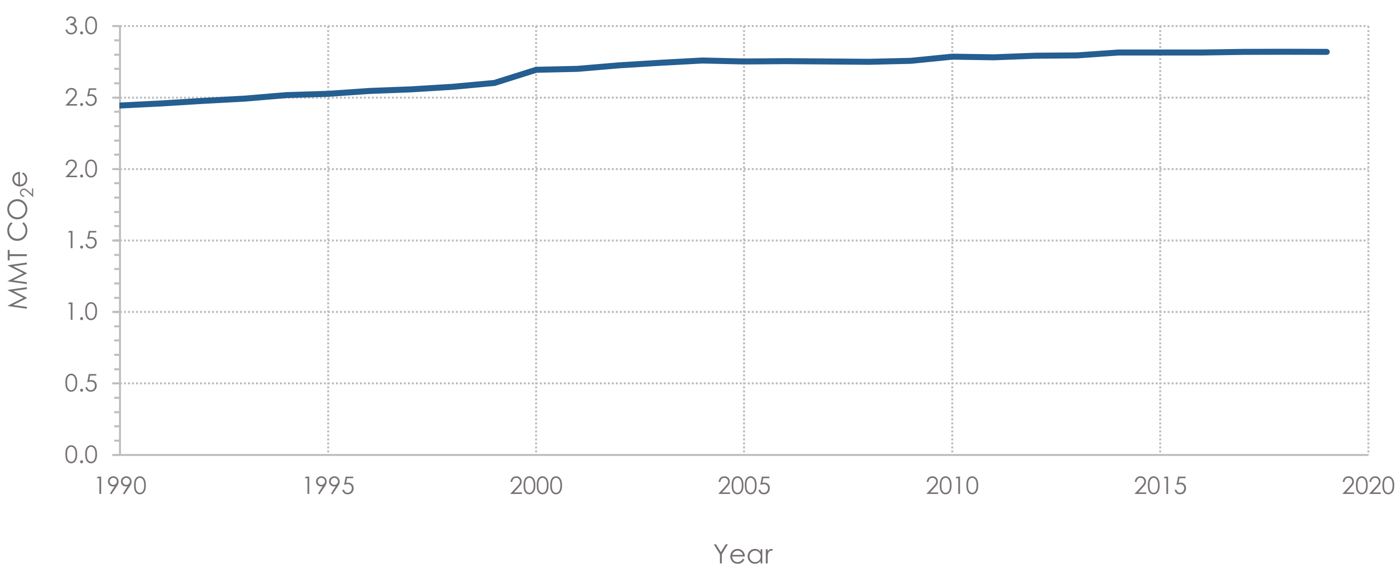


Figure 26. Wastewater treatment emissions (GWP_{20})



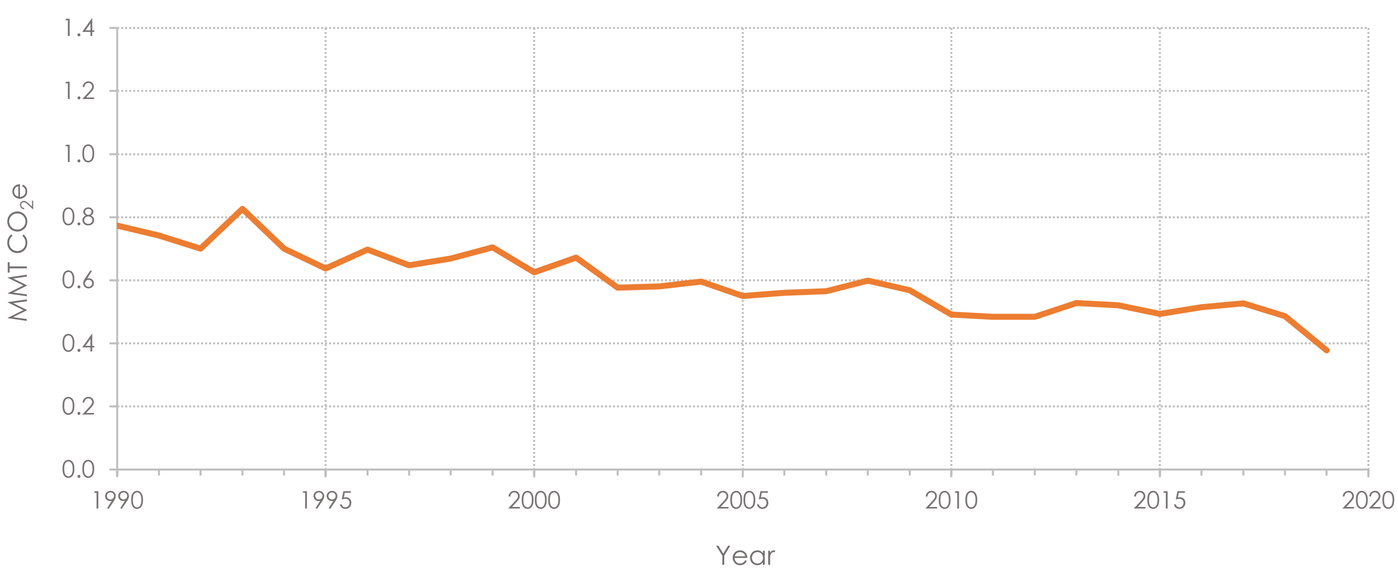
4.5 AGRICULTURE (NON-FUEL)

New Jersey is a national leader in the production of fruits and vegetables[54], a consequence of the state's favorable climate and close proximity to major population centers. Examples of non-fuel emissions include releases of nitrous oxide from the soil, carbon dioxide released by agricultural lime and similar minerals as they neutralize soil acids, and from livestock operations. Despite the robust size of New Jersey's agricultural sector, these activities tend to produce modest non-fuel greenhouse gas emissions. Between 1990 and 2019, they ranged annually from 0.4 to 0.8 MMT CO_2e (GWP_{100}) (Figure 27, Table A-19). Using a 20-year GWP, emissions ranged from 0.5 to 1.1 MMT CO_2e (GWP_{20}) across the same period (Figure 28, Table A-20). These estimates do not include emissions from fuel consumed at farms, for example in powered farm equipment. Fuel emissions in the agricultural sector are included as part of the fuel-based industrial emissions described above, pursuant to the classification methods of the US Energy Information Agency (US EIA).

State Action: Agriculture

The New Jersey Department of Environmental Protection and the New Jersey Department of Agriculture are working together to develop a Natural Working Lands Strategy for the state.[55] As part of this effort, strategies and policy recommendations to reduce emissions and enhance carbon sequestration on agricultural lands will be prioritized for state action. A draft scoping document was released in December of 2021 and targeted stakeholder meetings will be held throughout 2022.

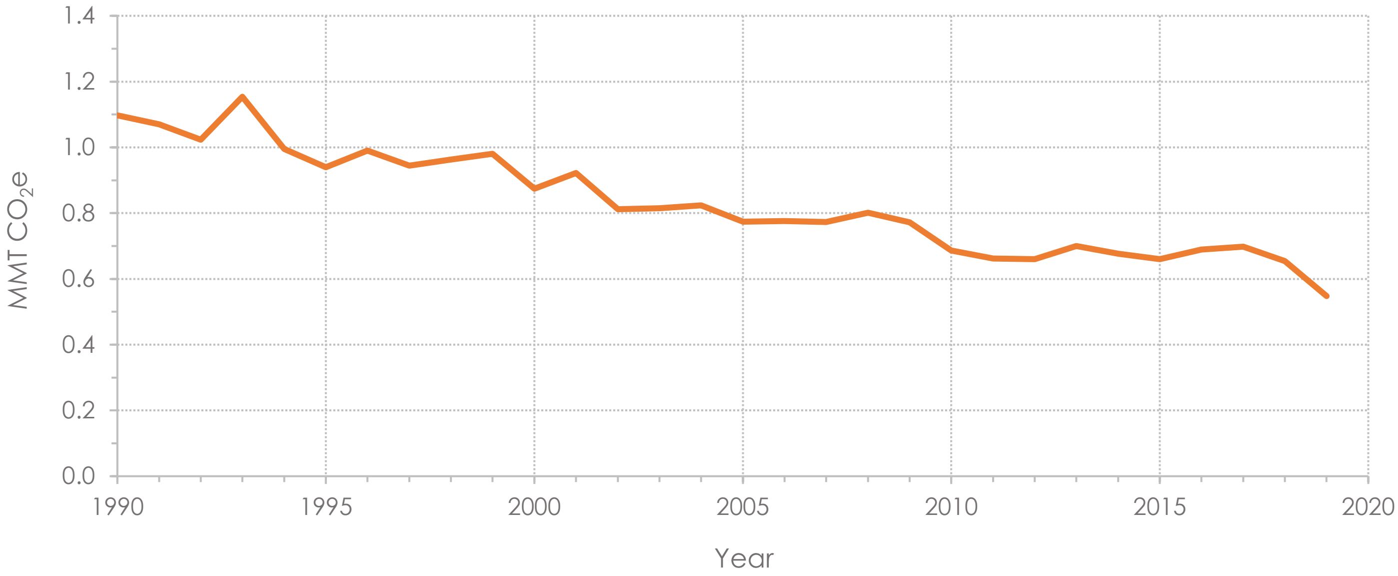
Figure 27. Agriculture (Non-fuel) emissions (GWP_{100})



[54] New Jersey is a top producer of eggplant (#1 nationally); spinach (#2); tomatoes (#3); cranberries (#4); asparagus (#4); bell peppers (#4); peaches (#5); blueberries (#5); cucumbers (#6); squash (#7); and corn (#10). Source: 2020 Annual Report and Agricultural Statistics, NJ Department of Agriculture, 2020. https://www.nj.gov/agriculture/pdf/2020AnnualReportFinal.pdf

[55] https://www.nj.gov/dep/climatechange/mitigation-nwls.html

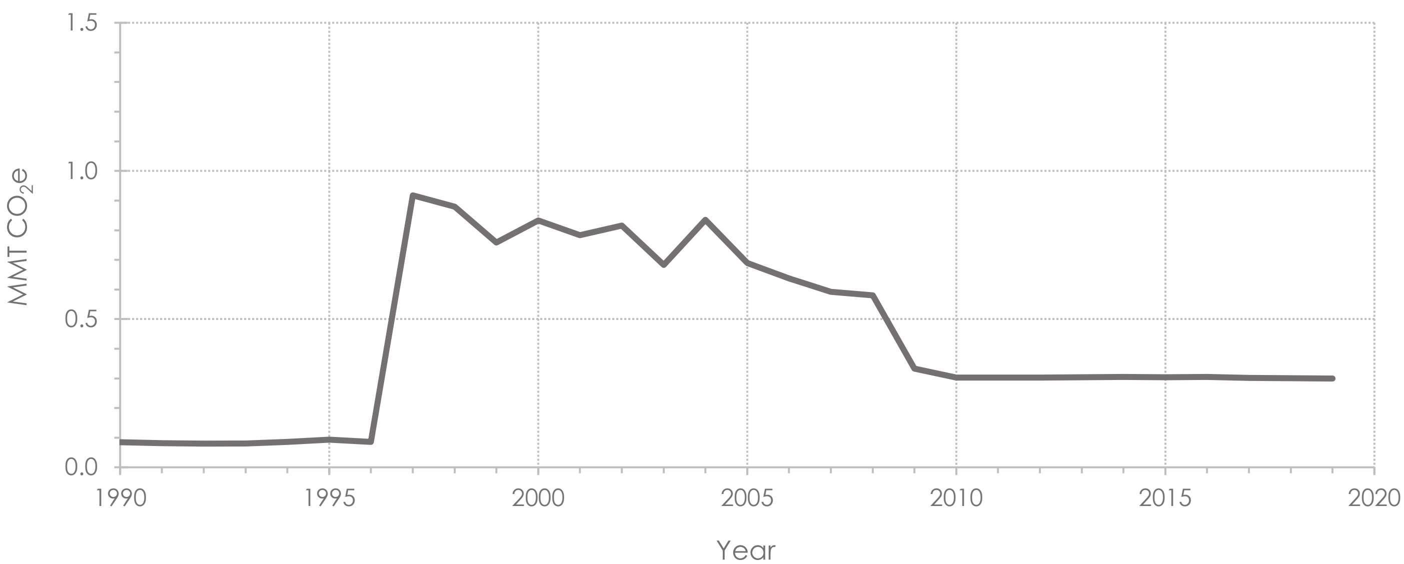
Figure 28. Agriculture (Non-fuel) emissions (GWP_{20})



4.6 NON-FUEL INDUSTRIAL

Certain industrial processes occurring in the state produce carbon dioxide in sufficient quantities to warrant inclusion in the greenhouse gas inventory, including activities related to limestone and dolomite, soda ash, iron and steel production, and urea consumption. Emissions have consistently been below 1.0 MMT CO_2 throughout the period, with iron and steel production being the largest contributors during the peak years between 1997 and 2008. Emissions in 2019 were approximately 0.3 MMT CO_2e (Figure 29; Table A-20). Because the emissions are carbon dioxide, the values are independent of GWP.

Figure 29. Non-fuel Industrial Emissions



4.7 EMISSIONS DUE TO LAND CLEARING

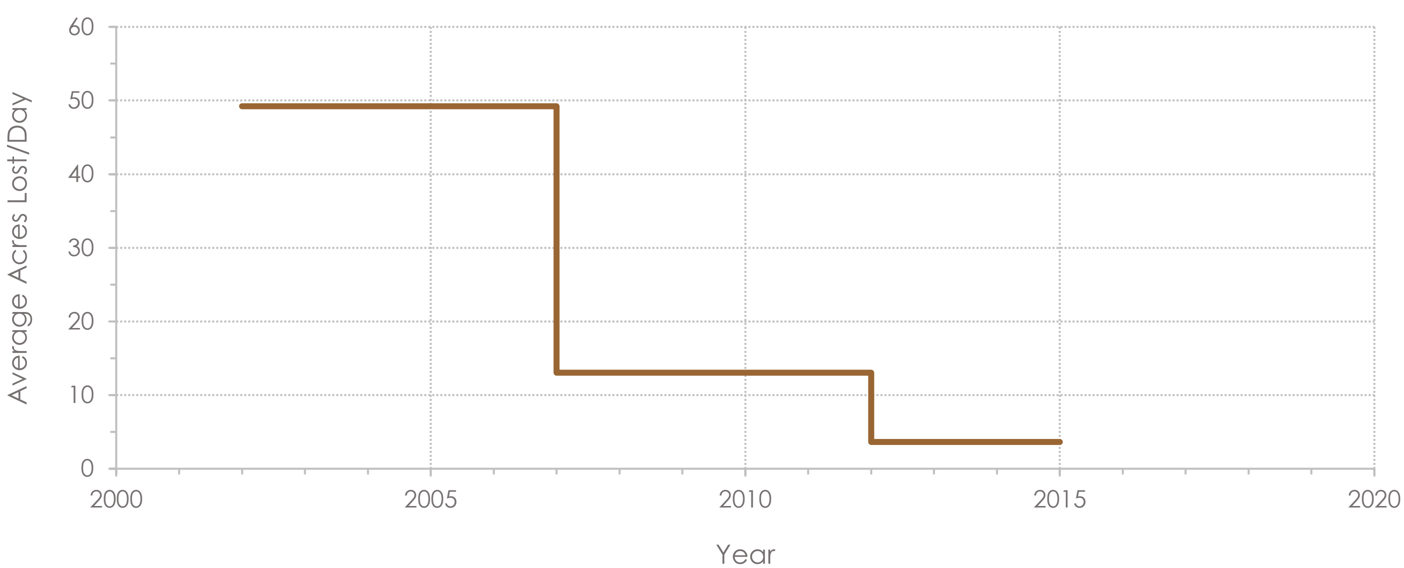
Large stores of carbon exist in the state's forests, wetlands and other biological reserves. When these lands are disturbed through development and urbanization, much of their stored carbon is released to the atmosphere as carbon dioxide, thereby accelerating climate change. The rate at which land is developed is directly influenced by economic, social, and governmental factors.

New Jersey has seen significant reductions in the rate of loss of natural lands (Figure 30), dropping from an average of 49 acres per day between 2002 and 2007 to 4 acres per day between 2012 and 2015. A combination of factors, including the economic recession of 2008, land conservation policies, and shifting demographic patterns, are linked to the slowing rate of loss.

The impact of land use changes on greenhouse gas emissions depends on the types of land affected as well as the overall amount of land converted. For example, salt marshes and tidal wetlands can capture and store as much as ten times as much carbon in a year than forests, on an acre-for-acre basis.[56]

Based on a land use analysis, it is estimated that loss of natural lands in New Jersey results in emissions of 1.0 MMT CO_2e annually, or approximate 1% of the state's gross emissions.

Figure 30. Decreasing rate of loss of forests, wetlands, farmlands and other undeveloped areas.[57]



4.8 SULFUR HEXAFLUORIDE

Sulfur hexafluoride (SF_6) is a long-lived climate pollutant with an exceptionally high global warming potential of 22,800, based on a 100-year time period. Because it can persist in the atmosphere for thousands of years, even small releases of SF_6 can create lasting impacts. In the past, SF_6 was widely used in high voltage electrical equipment because of its insulating and arc-inhibiting properties, and also in lesser amounts in a variety of industrial and scientific applications.

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[56] Pidgeon, E. 2009. Carbon sequestration by coastal marine habitats: Important missing sinks. Pages 47–51 *in* D. I. Laffoley and G. Grimsditch, editors. The management of natural coastal carbon sinks. IUCN, Gland, Switzerland. https://oceanfdn.org/sites/default/files/Laffoley%20The%20Management%20of%20Natural%20Coastal%20Carbon%20Sinks-.pdf

[57] Based on land use data from NJDEP Bureau of Geographic Information Systems

Due to its climate impact, use of SF_6 has decreased significantly since 1990 as older equipment is phased out and applications are revised to minimize its use. In New Jersey, emissions dropped from 0.5 MMT CO_2e (GWP_{100}) in 1990 to 0.08 MMT CO_2e (GWP_{100}) in 2019 (Figure 31; Table A-21). Due to its long lifetime in the atmosphere, the 20-year GWP of SF_6 is lower than its 100-year GWP, meaning that estimates made using the 20-year GWP are less than those found using the 100-year GWP. Based on a 20-year GWP, SF_6 emissions dropped from 0.4 MMT CO_2e (GWP_{20}) in 1990 to 0.06 MMT CO_2e (GWP_{20}) in 2019 (Figure 32; Table A-21).

Figure 31. Sulfur hexafluoride emissions (GWP_{100})

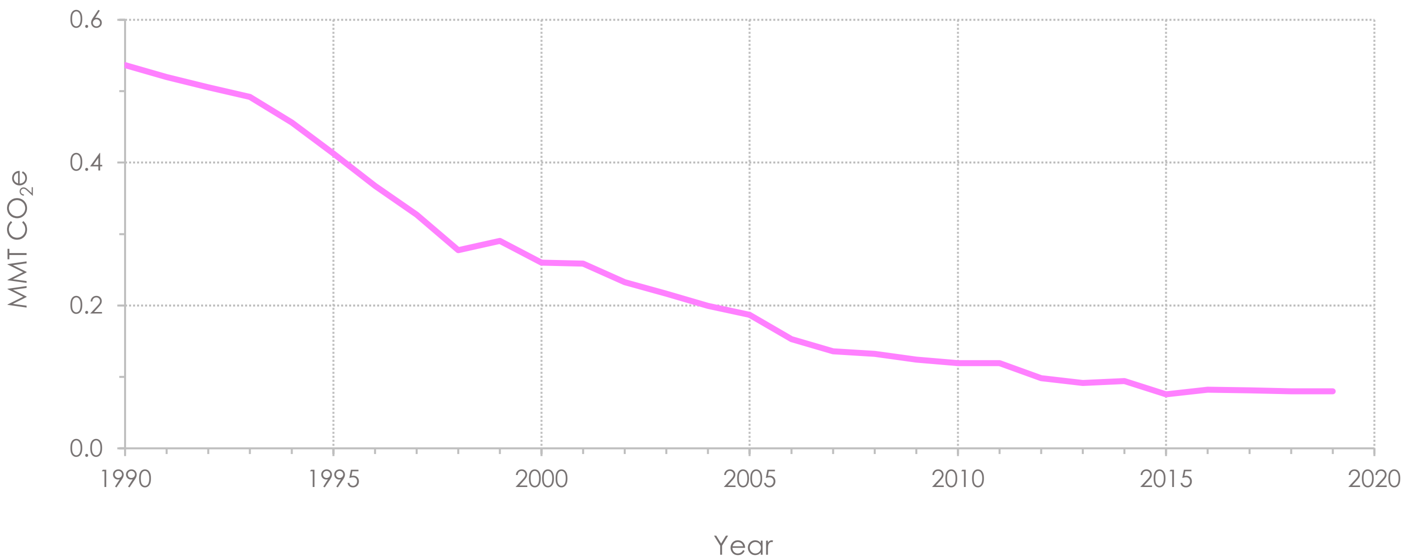
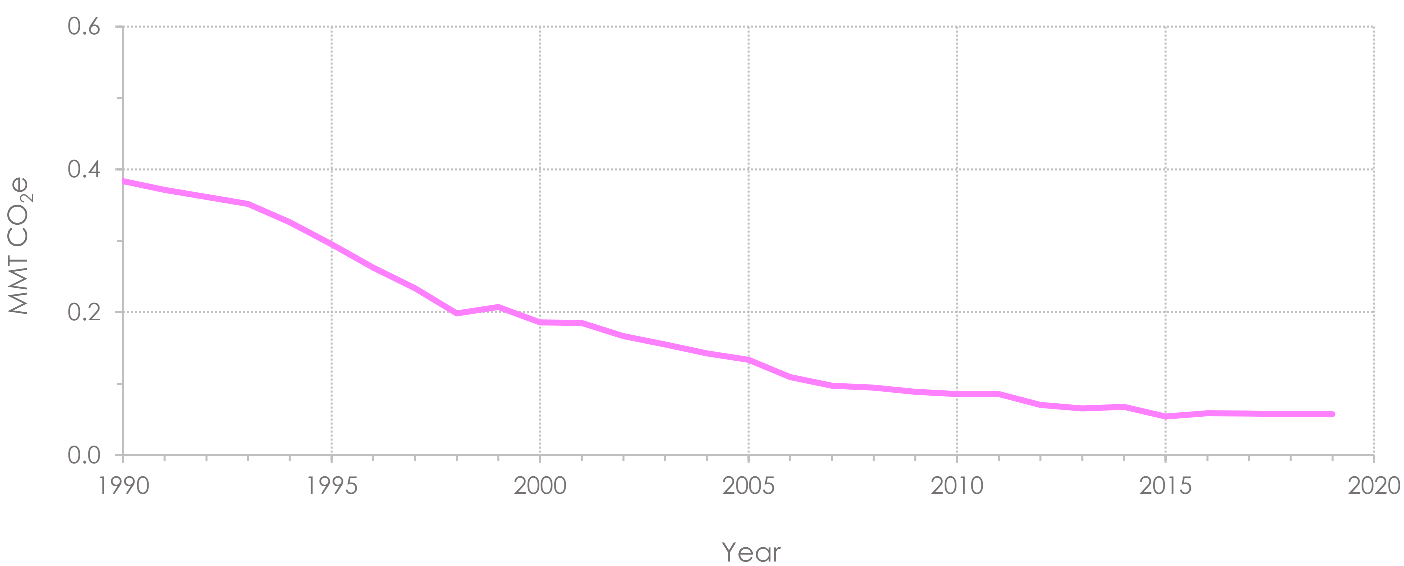


Figure 32. Sulfur hexafluoride emissions (GWP_{20})



5.0 CARBON SEQUESTRATION

5.1 CARBON SEQUESTRATION

Atmospheric carbon dioxide is naturally taken up by plants, the carbon being incorporated into biomass and ultimately into the soil. Over long periods, large amounts of carbon dioxide can be removed and incorporated into minerals. In fact, fossil fuels were created from atmospheric carbon dioxide through this process of photosynthetic sequestration and subsequent transformation. Terrestrial and aquatic photosynthesis can therefore reverse the accumulation of free atmospheric carbon dioxide.

New Jersey's natural lands remove a measurable amount of carbon dioxide each year. As determined by land use analysis and through measurement of the rates at which each type of land absorbs and sequesters carbon dioxide from the atmosphere, DEP estimates that approximately 8.1 MMT CO_2e are currently removed annually. This represents over 7% of 2019 gross emissions. Actively working to expand natural lands and enhance their performance as sequestration resources will even further accelerate achievement of the state's emissions goals.

State Action: Carbon Sequestration

As discussed above, in the Agricultural section of this report, the New Jersey Department of Environmental Protection and the New Jersey Department of Agriculture are working together to develop a Natural Working Lands Strategy (NWLS) for the state.[58] This strategy will identify and prioritize detailed strategies to mitigate the impacts of climate change through carbon storage and sequestration on New Jersey's natural and working lands. The recommendations in the NWLS are expected to be broadly applicable to land managers, including state and local government agencies, non-profits, universities, private landowners, and associated policymakers. A draft scoping document was released in December of 2021 and targeted stakeholder meetings will be held throughout 2022.

[58] https://www.nj.gov/dep/climatechange/mitigation-nwls.html

6.0 BLACK CARBON

6.1 BLACK CARBON

Black carbon, also known as elemental carbon and soot, is a type of fine particulate matter. The most common sources of black carbon in the atmosphere are associated with the incomplete combustion of hydrocarbons, for example from the burning of diesel fuel or wood, although other processes such as tire wear also contribute. Black carbon typically contains a wide variety of hydrocarbons and metals, and can adsorb other pollutants onto its surface such as acids and vapors.

Several variants of black carbon are known carcinogens; additionally, black carbon is a significant climate pollutant. Its dark color and the fact it is composed of small, lightweight particles allow it to act in the atmosphere through direct absorption of sunlight, alteration of clouds, and, once deposited on the ground, accelerated melting of snow and ice. Since it is not a gas, it behaves differently in the environment than other climate pollutants. It is quickly removed from the air by settling, generally in a few days to weeks.[59] It also does not remain suspended long enough to mix completely with the atmosphere. As a result, its effects are greatest close to the source.

Beginning with the public release of the 2014 National Emissions Inventory (NEI)[60], the USEPA has published detailed estimates of black carbon emissions for individual states in over 400 different source categories. However, EPA did not include black carbon quantities in earlier releases of the NEI. Also, the NEI is only released every three years, and, once published, estimates are not updated to reflect improved assessment methodologies. Thus, this report summarizes the first comprehensive black carbon inventory for New Jersey, covering years 2005 through 2017. The methods used to calculate the inventory are comparable to those applied in the 2017 NEI. Sector-specific estimates for 2018 and 2019 are provided where data is available. A detailed discussion of the methods can be found in Appendix B.

Black carbon is a component of the broader class of fine particulate matter having diameter of 2.5 µm or less ($PM_{2.5}$). When fine particulate matter is created, the amount of black carbon that is produced depends on the materials consumed and the process by which the particulates are created. For example, when diesel fuel is burned in an internal combustion engine, the fraction of the particulate matter that is black carbon has been found to be approximately 77%, but when natural gas is consumed in a turbine, black carbon only makes up closer to 7%.[61] Further, the fraction of $PM_{2.5}$ that is black carbon is distinct from the total amount of $PM_{2.5}$ produced by the process. Again, using natural gas as an example, it produces less $PM_{2.5}$ to begin with compared to diesel, and then a smaller fraction of that $PM_{2.5}$ is black carbon.

Substantial reductions in black carbon occurred between 2005 and 2017, led by decreases in the two largest sources, transportation and non-road equipment (Figures 33 and 34; Table A-22). The industrial, residential and electric generation sectors also experienced declines, and the commercial sector (excluding non-road equipment such as forklifts) experienced a very small increase. Results for these sectors will be discussed individually below. Overall, total black carbon emissions dropped from a 2005 high of 5.7 MMT CO_2e (GWP_{100})/ 20.0 MMT CO_2e (GWP_{20}) to a low in 2017 of 2.3 MMT/ 8.1 MMT CO_2e (GWP_{20}).[62]

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[59] Bond, T. C.; Doherty, S. J.; Fahey, D. W.; Forster, P. M.; Berntsen, T.; DeAngelo, B. J.; Flanner, M. G.; Ghan, S.; Kärcher, B.; Koch, D.; Kinne, S.; Kondo, Y.; Quinn, P. K.; Sarofim, M. C.; Schultz, M. G.; Schulz, M.; Venkataraman, C.; Zhang, H.; Zhang, S.; Bellouin, N.; Guttikunda, S. K. ; Hopke, P. K.; Jacobson, M. Z.; Kaiser, J. W.; Klimont, Z.; Lohmann, U.; Schwarz, J. P.; Shindell, D.; Storelvmo, T.; Warren, S. G.; Zender, C. S., Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical research: Atmospheres, v. 118, pp. 5380-5552, 2013

[60] https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

[61] USEPA SPECIATE 5.1 database. https://www.epa.gov/air-emissions-modeling/speciate-4

[62] The black carbon estimates presented here represent updates from those presented in the GWRA 80x50 report and previous NJ GHG Inventory publications. Significant changes include use of revised models for transportation, wildfires and prescribed burns; and

Although there is insufficient data to develop sector-specific estimates for 2018 and 2019, extrapolation of the 2014 to 2017 trend would lead to a continuing decrease, with a 2019 projected total of 1.8 MMT CO_2e (GWP_{100}) if the historic pattern continued. Given the continuing rollover of diesel truck and light-duty engines with cleaner technologies, a continued downward trend in black carbon emissions is anticipated.

Figure 33. Black Carbon Emissions 2005-2017 (GWP_{100})

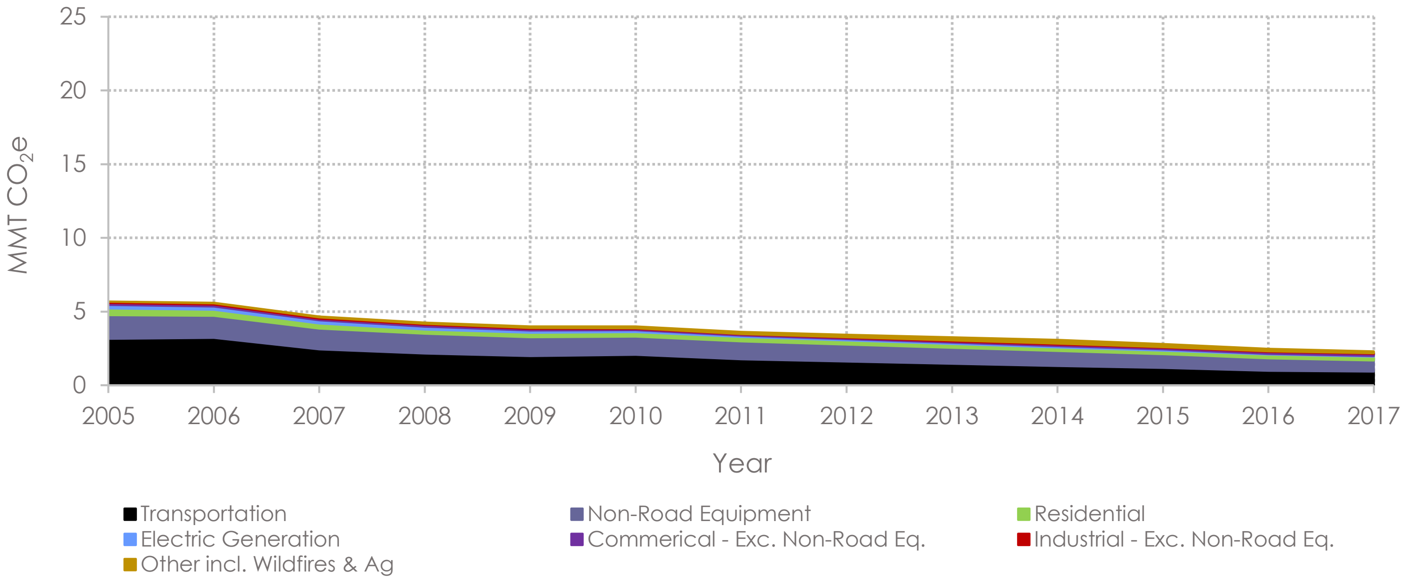
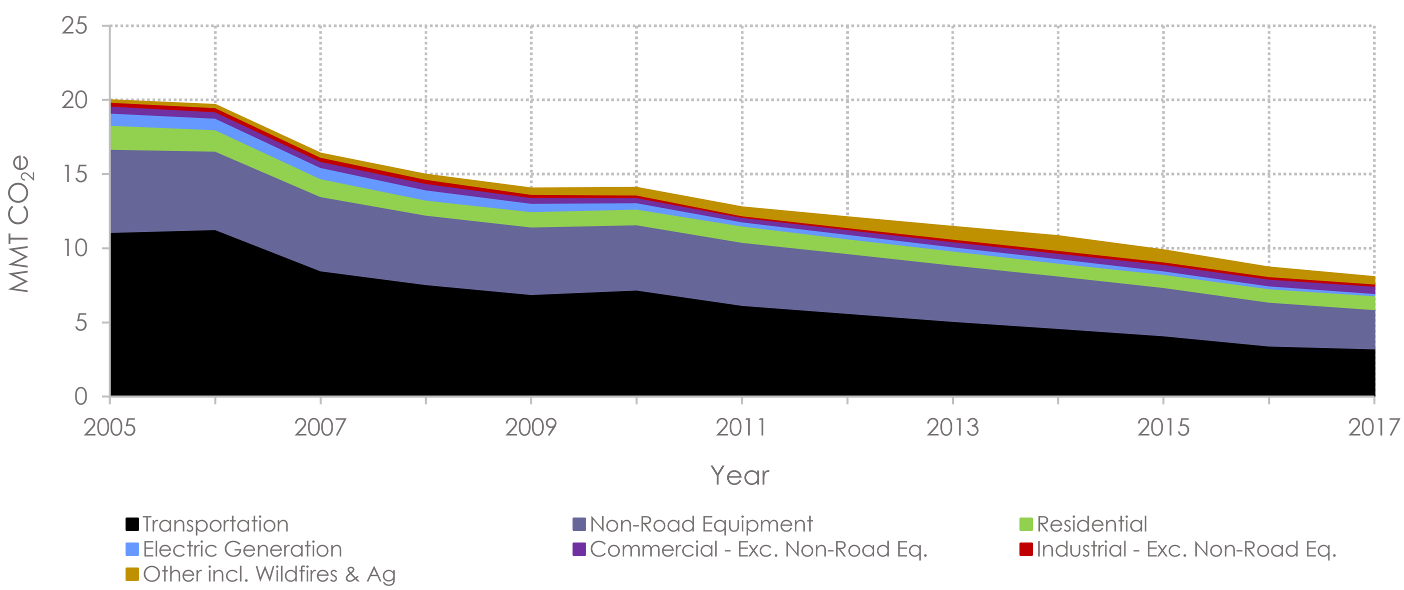


Figure 34. Black Carbon Emissions 2005-2017 (GWP_{20})



the use of speciation factors from the 2017 USEPA National Emissions Inventory. Additional information on how methods used in the National Emissions Inventory have changed over time can be found at https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei.

Transportation Sector

The transportation sector includes emissions from both on-road and non-road transportation. On-road transportation includes passenger vehicles, such as cars and trucks as well as medium- and heavy-duty vehicles. Non-road transportation includes modes of transportation such as trains, boats, and airplanes. Historically, transportation has been the largest contributor to black carbon in the state. In 2005, it accounted for 56% of black carbon emissions, totaling 3.2 MMT CO_2e (GWP_{100})/ 11.1 MMT CO_2e (GWP_{20}). However, due to aggressive policies requiring cleaner burning engines, emissions from this sector have dropped dramatically. In 2017, black carbon emissions decreased 71% to 0.9 MMT CO_2e (GWP_{100})/ 3.3 MMT CO_2e (GWP_{20}) with transportation accounting for 40% of total 2017 black carbon emissions (Figures 35 and 36)

Figure 35 Transportation Sector Black Carbon Emissions (GWP100)

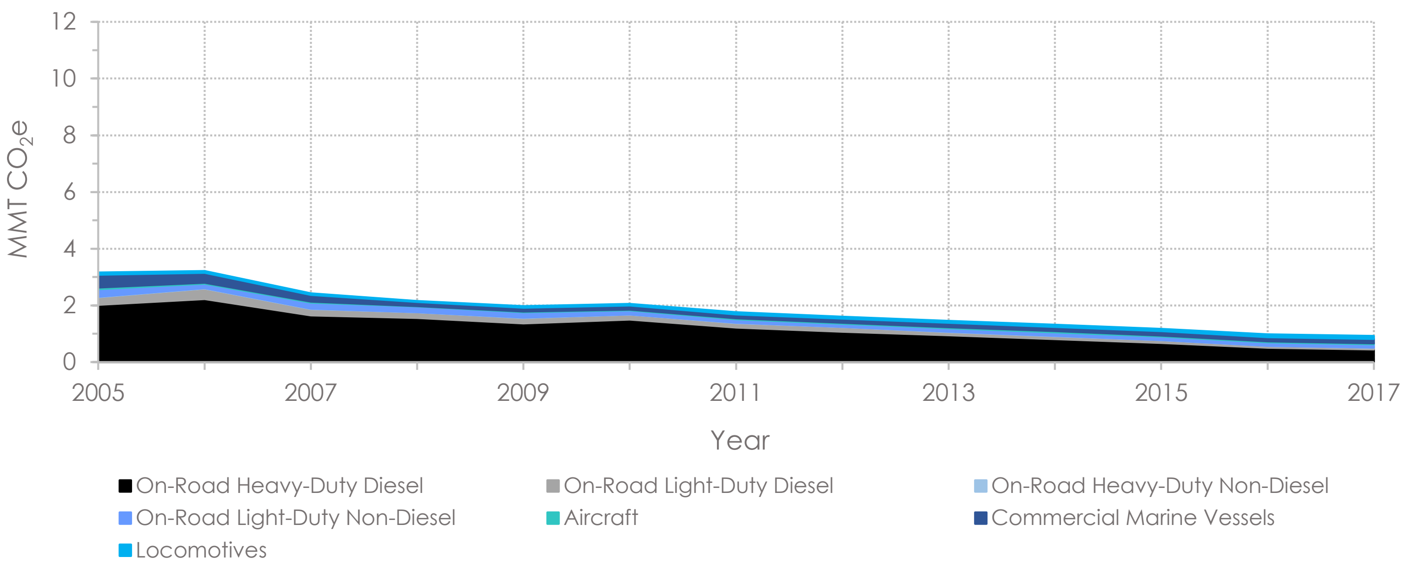
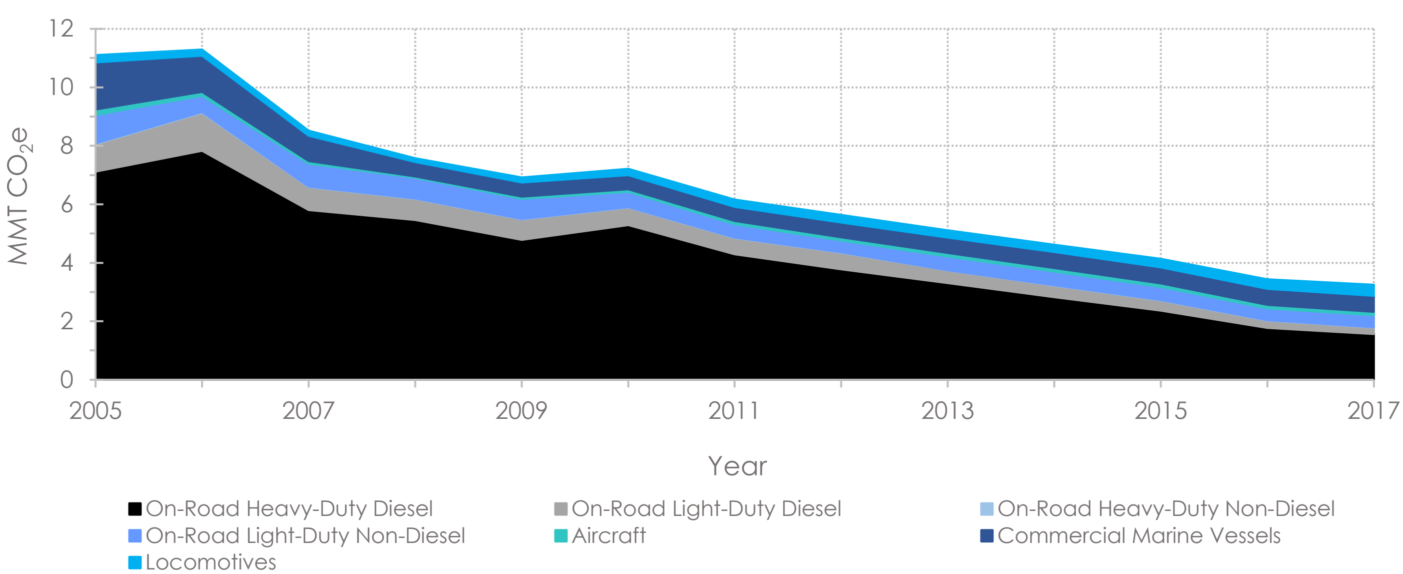


Figure 36 Transportation Sector Black Carbon Emissions (GWP20)



On-Road Transportation

From a high of 2.8 MMT CO_2e (GWP_{100})/9.7 MMT CO_2e (GWP_{20}) in 2006, on-road black carbon emissions fell 77% to 0.63 MMT CO_2e (GWP_{100})/2.2 MMT CO_2e (GWP_{20}) in 2019 (Figures 37 and 38; Table A-23). The majority of on-road black carbon emissions come from diesel-powered vehicles, which also account for the majority of reductions over the period (Figures 39 and 40; Table A-24). The chief force behind these improvements are federal mandates calling for cleaner engines, coupled with targeted programs facilitating replacement of older equipment. Gasoline-powered (non-diesel) vehicles have also seen steady reductions, with light-duty passenger cars and trucks dropping from 0.3 MMT CO_2e (GWP_{100})/ 1.0 MMT CO_2e (GWP_{20}) in 2005 to 0.1 (GWP_{100})/0.4 MMT CO_2e (GWP_{20}) in 2019.

Figure 37 On-Road Black Carbon Emissions by Fuel Type (GWP_{100})

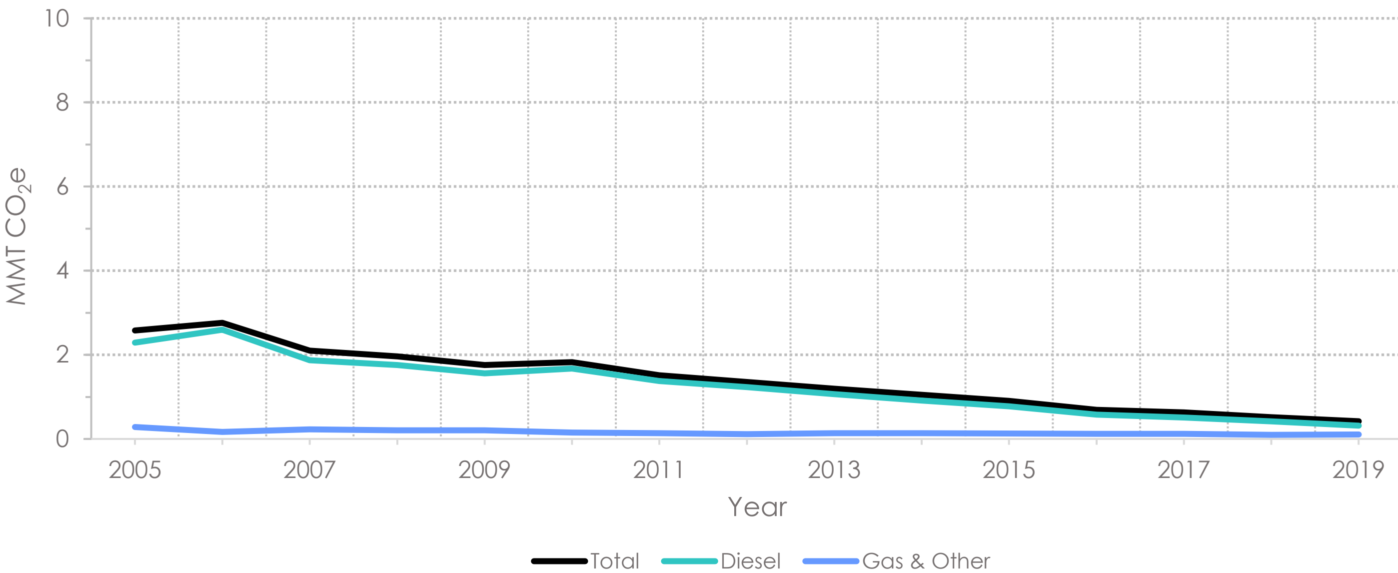


Figure 38 On-Road Black Carbon Emissions by Fuel Type (GWP_{20})

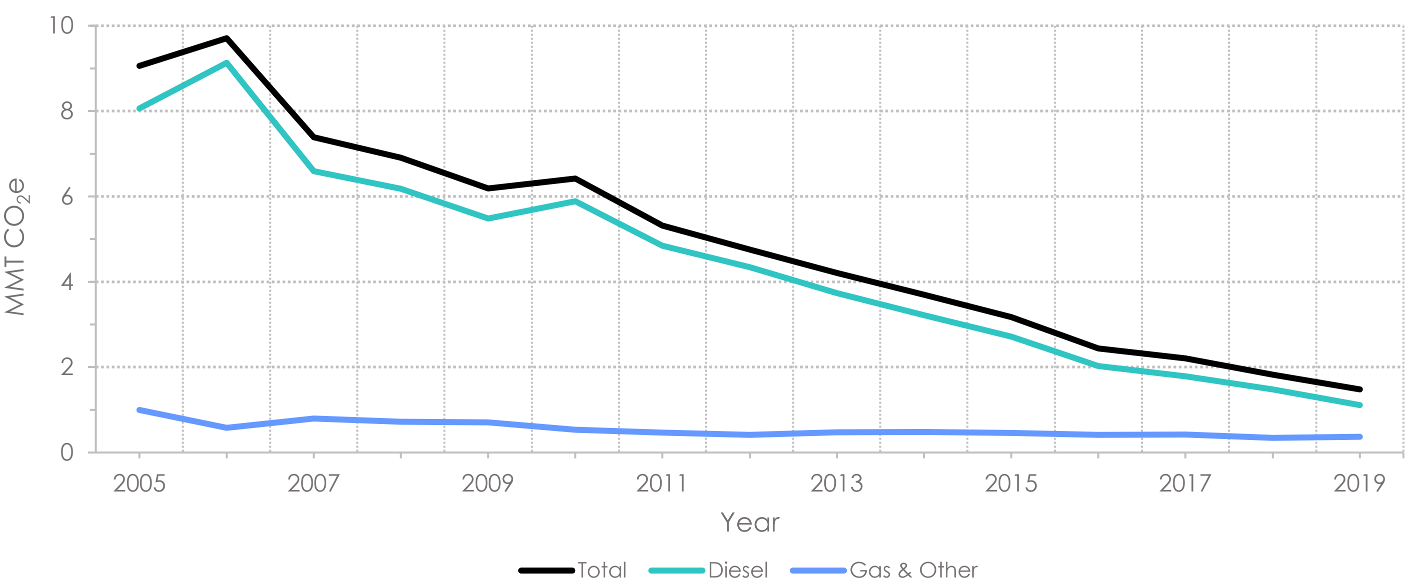


Figure 39. Black Carbon Emissions from Diesel Vehicles (GWP_{100})

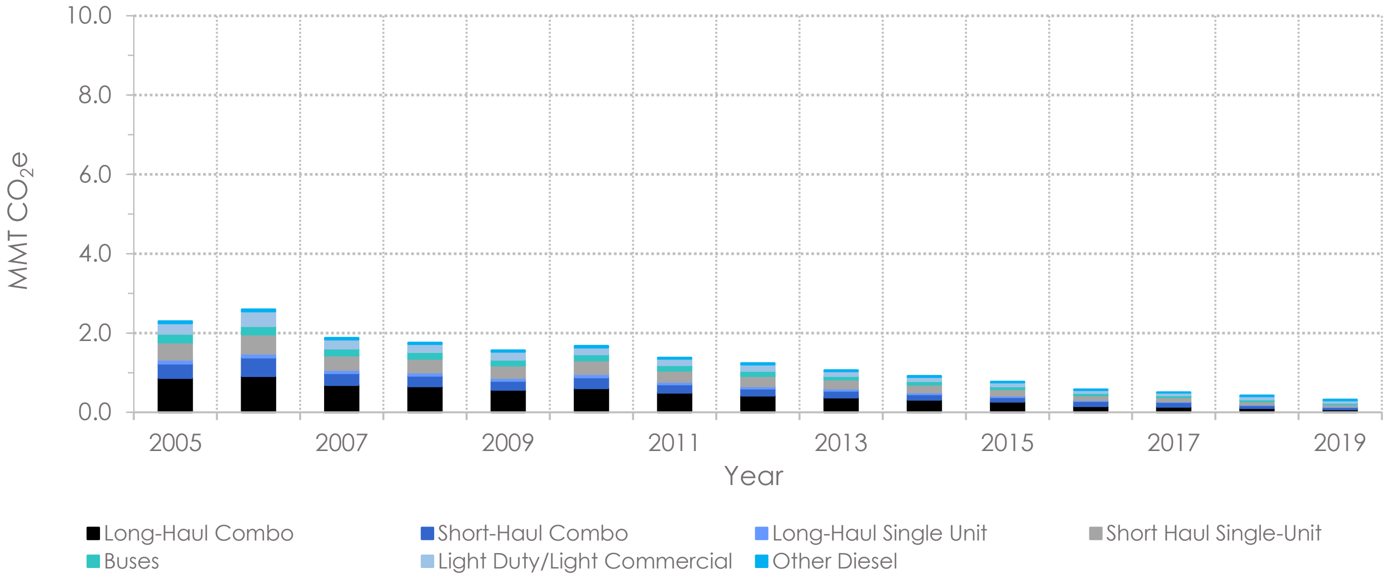
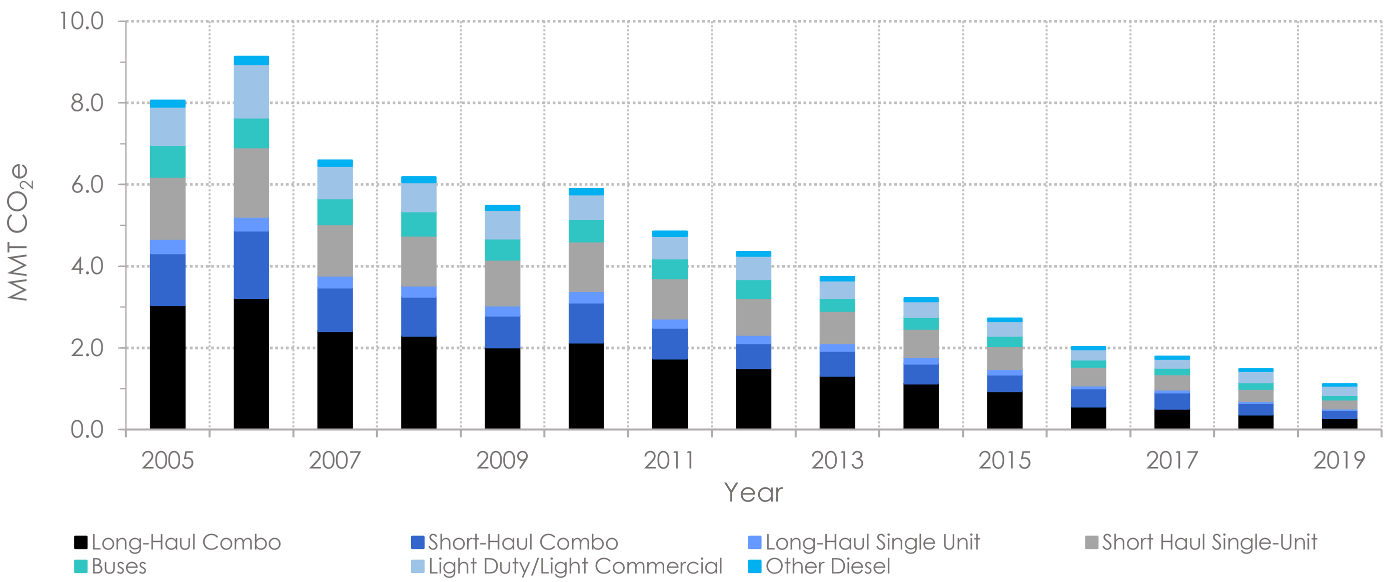


Figure 40. Black Carbon Emissions from Diesel Vehicles (GWP_{20})



Non-Road Transportation

Emissions from non-road transportation are associated with marine, aviation and rail transport. Commercial marine activity accounted for the bulk of black carbon emissions from the non-road transportation sector, with substantial decreases observed through the recession year of 2008 (Figures 41 and 42; Table A-25). In 2017, marine emissions accounted for 53% of the non-road transportation total.

In-state aviation emissions rose gradually following 2008, reaching 0.03 MMT CO_2e (GWP_{100})/ 0.12 MMT CO_2e (GWP_{20}) by 2017, or 11% of the sector total. However, this was still substantially below the 2005 peak of 0.05 MMT CO_2e (GWP_{100})/ 0.18 MMT CO_2e (GWP_{20}). It should be noted that the underlying USEPA NEI particulate data used to estimate aviation black carbon emissions was based on emissions from landings and take offs, and therefore represents actual flight activity within the state's boundaries.

Emissions associated with fossil-powered rail service (locomotives) were 0.07 MMT CO_2e (GWP_{100})/ 0.25 MMT CO_2e (GWP_{20}) in 2005, then reached a low of 0.04 MMT CO_2e (GWP_{100})/ 0.13 MMT CO_2e (GWP_{20}) in the recession year 2008, and gradually climbed to 0.11 MMT CO_2e (GWP_{100})/ 0.38 MMT CO_2e (GWP_{20}) in 2017.

Figure 41. Black Carbon from Non-Road Transportation (GWP_{100})

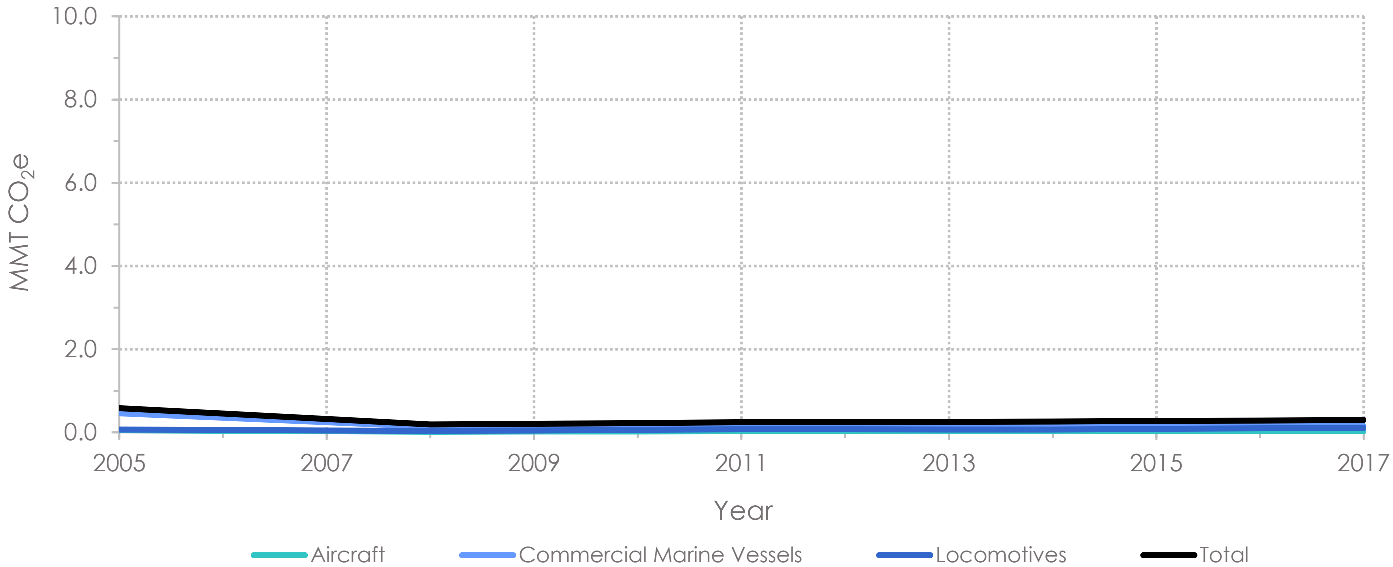
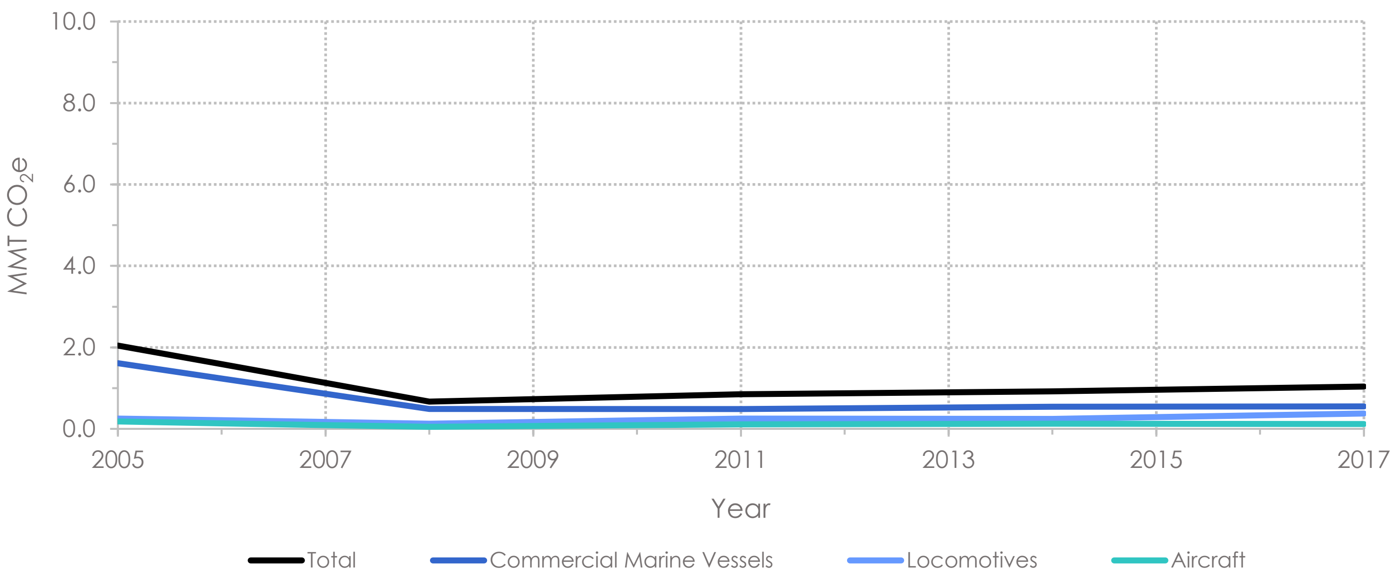


Figure 42. Black Carbon from Non-Road Transportation (GWP_{20})



Non-Road Equipment Sector

Non-road equipment includes bulldozers, excavators, cranes, and other non-road vehicles moving goods and personnel onsite. Emissions from non-road equipment were the second largest source of black carbon after on-road transportation. However, emissions in this category dropped by more than half over the period, from 1.6 MMT CO_2e (GWP_{100})/ 5.6 MMT CO_2e (GWP_{20}) in 2005 to 0.8 MMT CO_2e (GWP_{100})/ 2.7 MMT CO_2e (GWP_{20}) in 2017 (Figures 43 and 44; Table A-26). Further, 85% of these black carbon emissions were associated with diesel powered equipment, similar to observations in the on-road sector.

Figure 43. Black Carbon from Non-Road Equipment (GWP_{100})

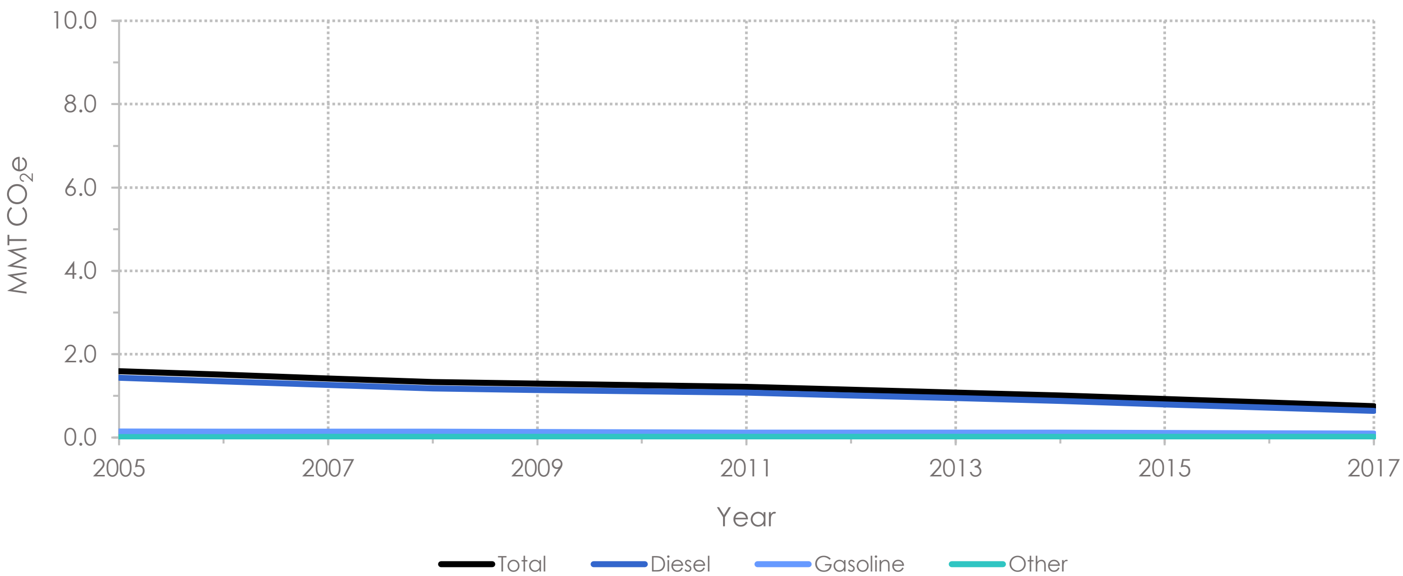
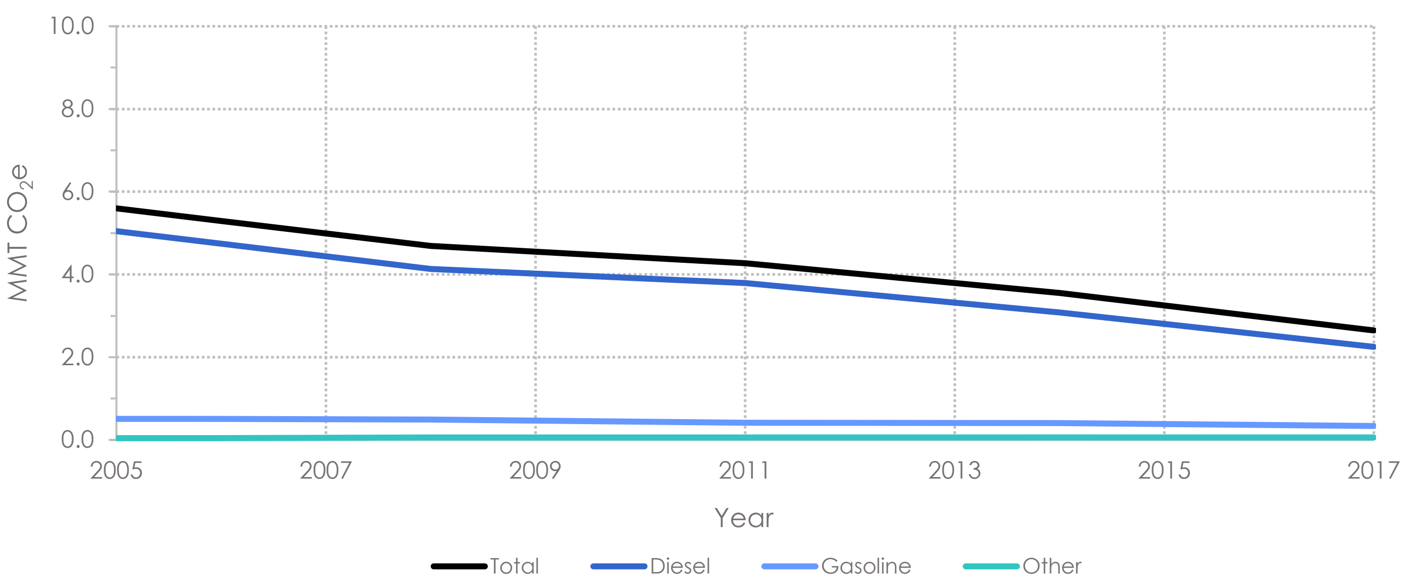


Figure 44. Black Carbon from Non-Road Equipment (GWP_{20})



Electric Generation Sector

In 2017, black carbon from the electric generation sector accounted for 1.9% of total black carbon emissions. Emissions from power plants and related equipment dropped dramatically from 2005 to 2011, and experienced a more gradual decline through 2017 (Figures 45 and 46; Table A-27). Overall, black carbon emissions for the sector fell 81%, from an initial emissions rate of 0.2 MMT CO_2e (GWP_{100})/ 0.8 MMT CO_2e (GWP_{20}) in 2005 to 0.04 MMT CO_2e (GWP_{100})/ 0.15 MMT CO_2e (GWP_{20}) in 2017. Black carbon reductions through 2008 can be attributed to the dramatic decline in coal-fueled electric generation, while subsequent declines were associated with reduced use of liquid petroleum fuels in electric generation. Black carbon emissions from natural gas fueled electric generation decreased slightly from 0.04 MMT CO_2e (GWP_{100})/ 0.12 MMT CO_2e (GWP_{20}) in 2005 to 0.03 MMT CO_2e (GWP_{100})/ 0.10 MMT CO_2e (GWP_{20}) in 2017; this is due in part to increased efficiency of generating sources. Other fuel sources such as landfill gas accounted for less than 0.005 MMT CO_2e (GWP_{100})/ 0.016 MMT CO_2e (GWP_{20}) across the period.

Figure 45. Electric Generation Sector Black Carbon Emissions (GWP_{100})

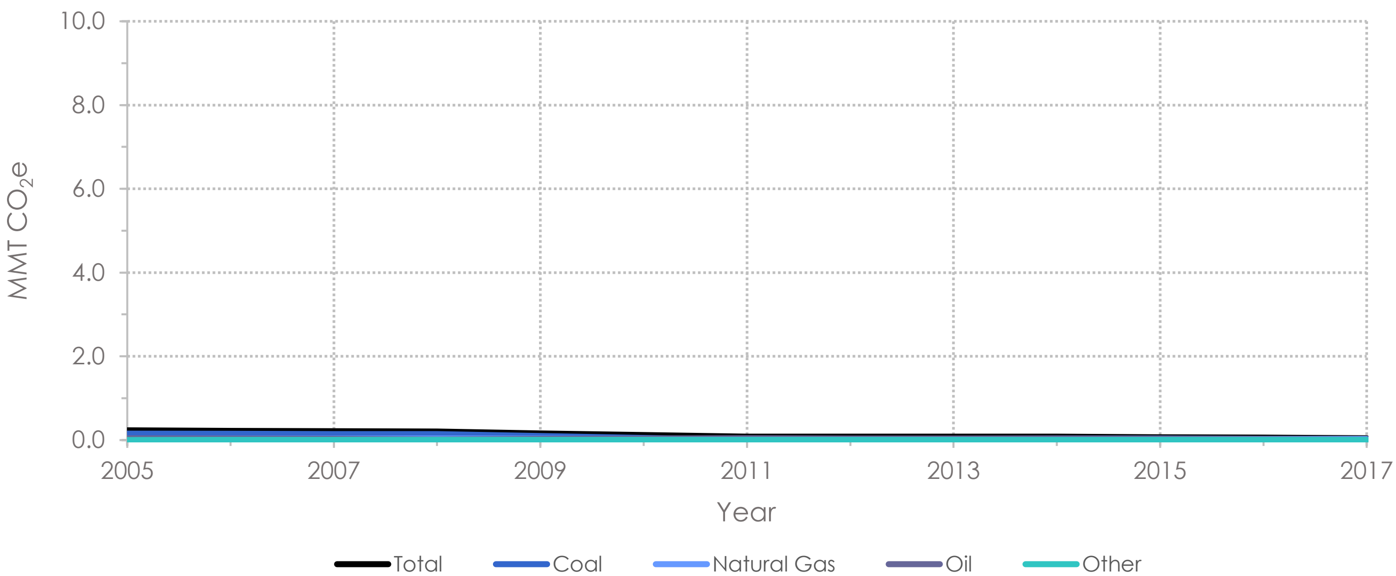
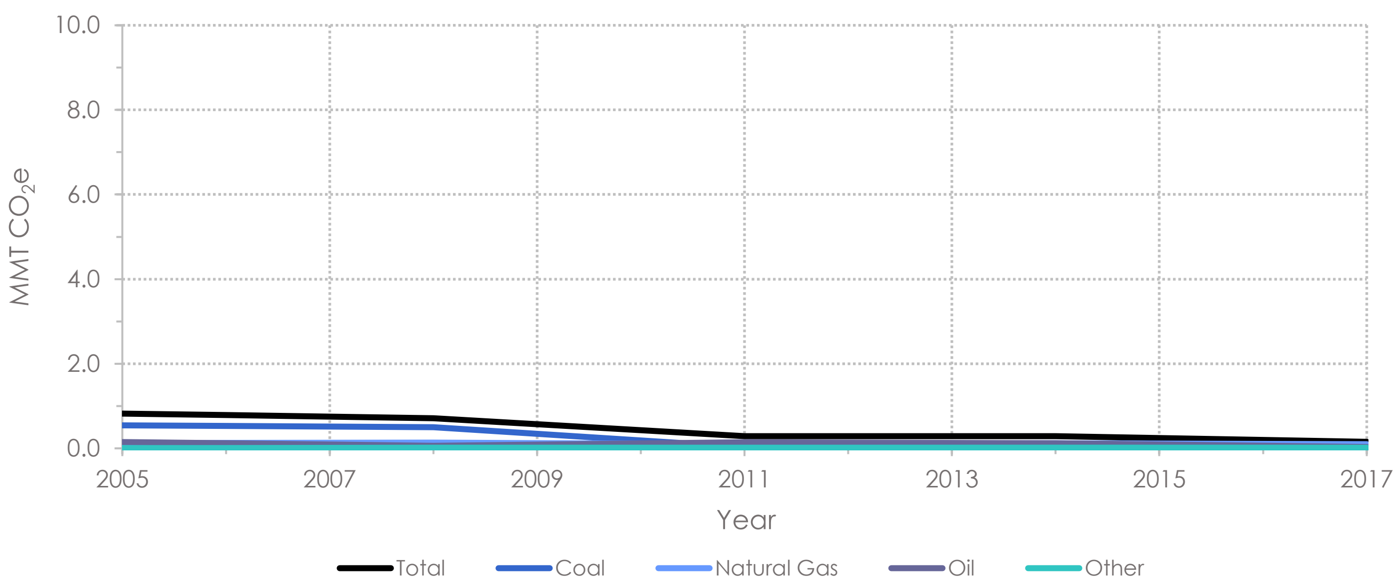


Figure 46. Electric Generation Sector Black Carbon Emissions (GWP_{20})



Residential Sector

In 2017 black carbon emissions from the residential sector made up 12% of total emissions. Residential sector black carbon emissions decreased by over 40%, from an initial total of 0.5 MMT CO_2e (GWP_{100})/ 1.6 MMT CO_2e (GWP_{20}) in 2005 to 0.3 MMT CO_2e (GWP_{100})/ 0.9 MMT CO_2e (GWP_{20}) in 2017 (Figures 47 and 48; Table A-28). The bulk of these emissions (over 90%) came from burning wood in wood stoves, fireplaces, and similar settings. Black carbon emissions from residential oil and natural gas combustion were significantly less. It should be noted that the methods used by USEPA to estimate particulate emissions from fire sources, and subsequently black carbon, have changed considerably over time. Some of the observed variability in the black carbon estimates may therefore be methodological rather than a reflection of year-to-year emissions shifts.

Figure 47. Residential Black Carbon Emissions (GWP_{100})

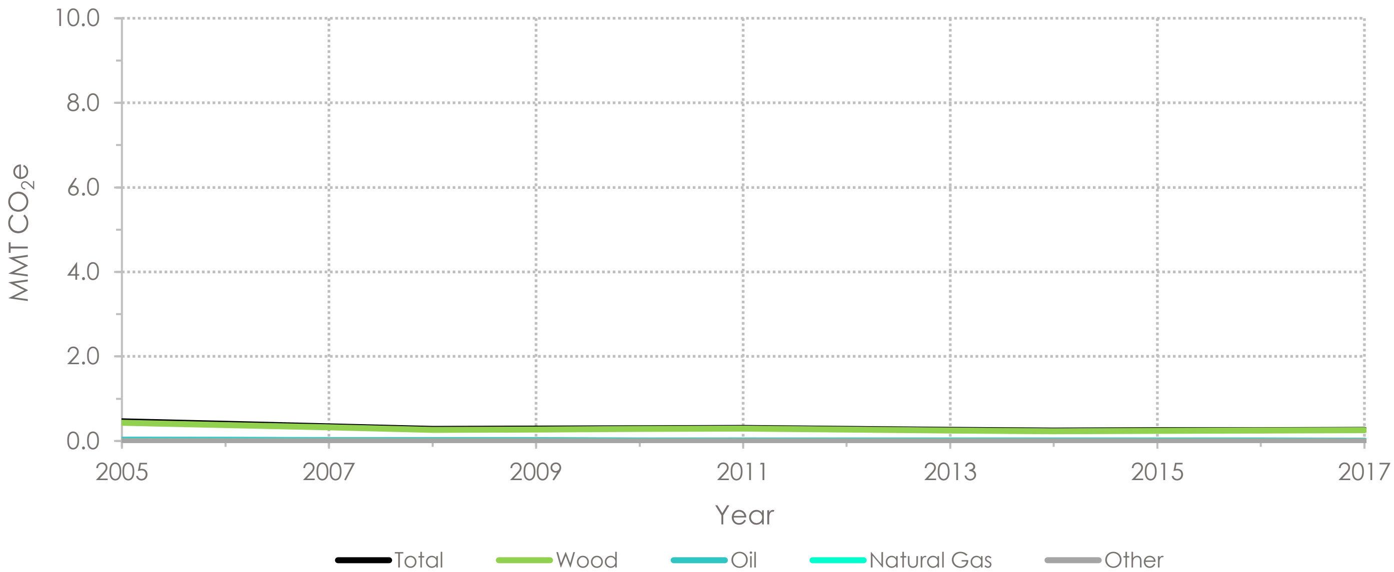
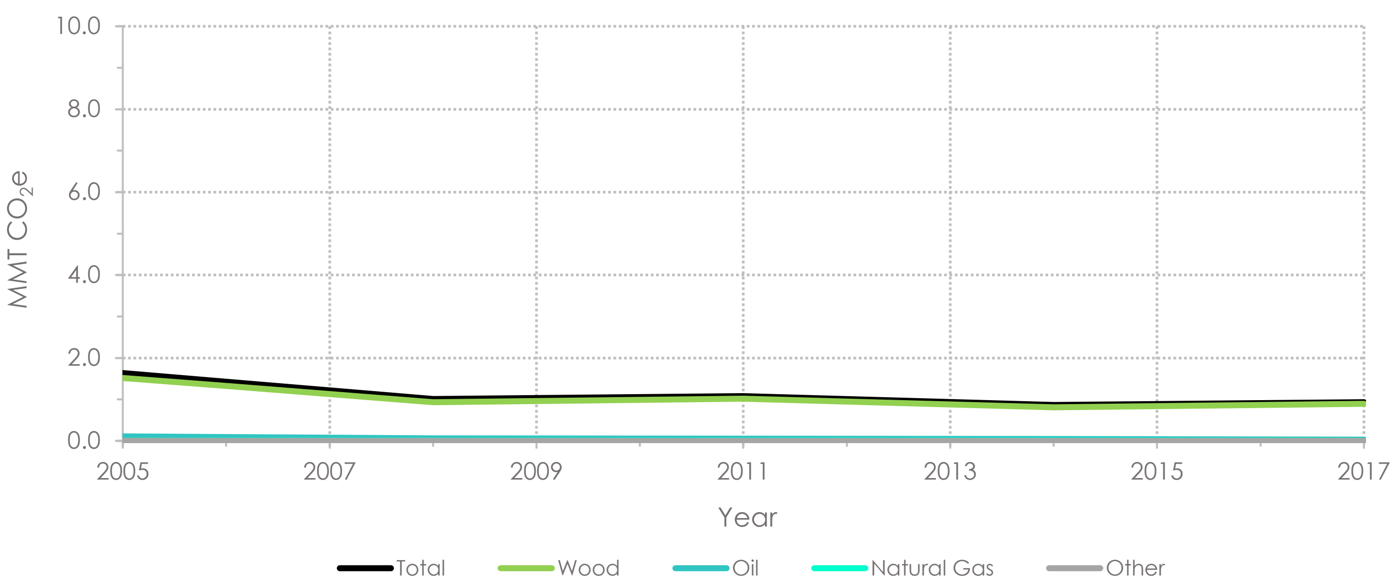


Figure 48. Residential Black Carbon Emissions (GWP_{20})



Commercial Sector, Except Non-Road Equipment

Emissions from the commercial sector have increased slightly, rising from 0.1 MMT CO_2e (GWP_{100})/ 0.5 MMT CO_2e (GWP_{20}) in 2005 to 0.1 MMT CO_2e (GWP_{100})/ 0.5 MMT CO_2e (GWP_{20}) in 2017, but have varied over the period and fell to a low of 0.1 MMT CO_2e (GWP_{100})/ 0.3 MMT CO_2e (GWP_{20}) in 2011 (Figures 49 and 50; Table A-29). The dominant contributor to the sector's emissions is commercial cooking, which accounted for between 50% and 75% of the total. Emissions from the second largest contributor, oil, dropped from 0.05 MMT CO_2e (GWP_{100})/ 0.18 MMT CO_2e (GWP_{20}) in 2005 to 0.02 MMT CO_2e (GWP_{100})/ 0.07 MMT CO_2e (GWP_{20}) in 2017, a decrease of over 60%.

Figure 49. Commercial Sector Black Carbon, Excluding Non-Road Equipment (GWP_{100})

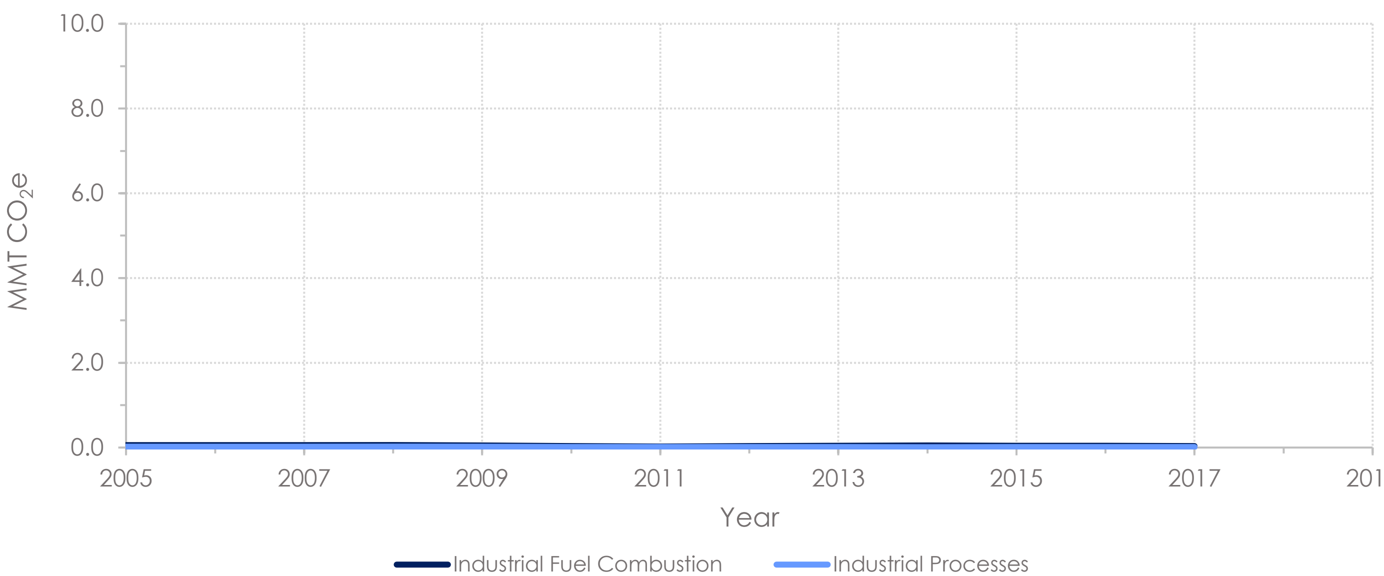
Figure 50. Commercial Sector Black Carbon, Excluding Non-Road Equipment (GWP_{20})

Industrial Sector, Except Non-Road Equipment

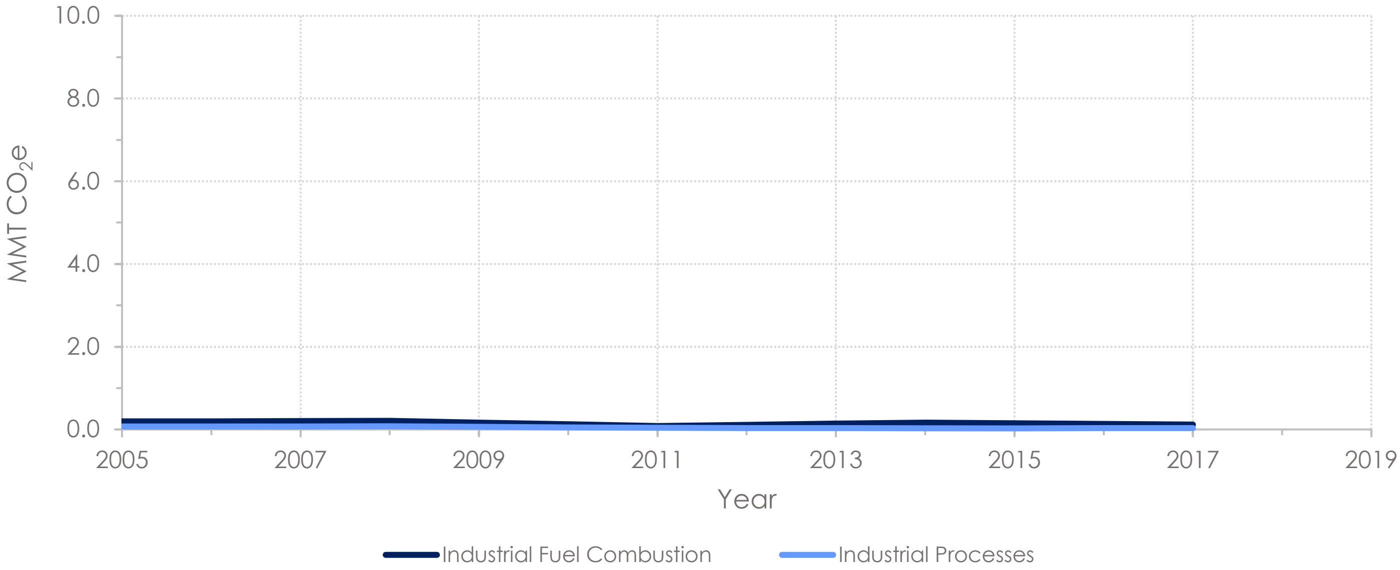
Combined emissions of black carbon from fuel combustion and process operations in the industrial sector were negligible at 0.04 MMT CO_2e (GWP_{100})/ 0.15 MMT CO_2e (GWP_{20}) in 2019, 42% below 2005 emissions of 0.07 MMT CO_2e (GWP_{100})/ 0.26 MMT CO_2e (GWP_{20}) (Figures 51 and 52, Tables A-2 and A-4). Black carbon emissions from the use of fossil fuels in boilers and internal combustion engines decreased overall, from 0.06 MMT CO_2e (GWP_{100})/ 0.19 MMT CO_2e (GWP_{20}) in 2005 to 0.03 MMT CO_2e (GWP_{100})/ 0.12 MMT CO_2e (GWP_{20}) in 2017, although emissions fluctuated during this time (Figures 53 and 54; Table A-30). The bulk of emissions were attributed to use of oil, which accounted for between 55% and 93% of black carbon from this category. Coal was only a very minor contributor in 2005 at 0.0002 MMT CO_2e (GWP_{100})/ 0.0006 MMT CO_2e (GWP_{20}), and was entirely absent by 2008.

Black carbon emissions from industrial processes, distinct from fuel combustion, were even less and experienced a decline from 0.02 MMT CO_2e (GWP_{100})/ 0.07 MMT CO_2e (GWP_{20}) in 2005 to 0.01 MMT CO_2e (GWP_{100})/ 0.03 MMT CO_2e (GWP_{20}) in 2017, a drop of 55% (Figures 55 and 56; Table A-31). Because of the large number of different processes in use, most are categorized into a large grouping identified as “Other,” but notable named sources include petroleum refineries, pulp and paper manufacturing, chemical production, and emissions associated with storage and transfer of materials.

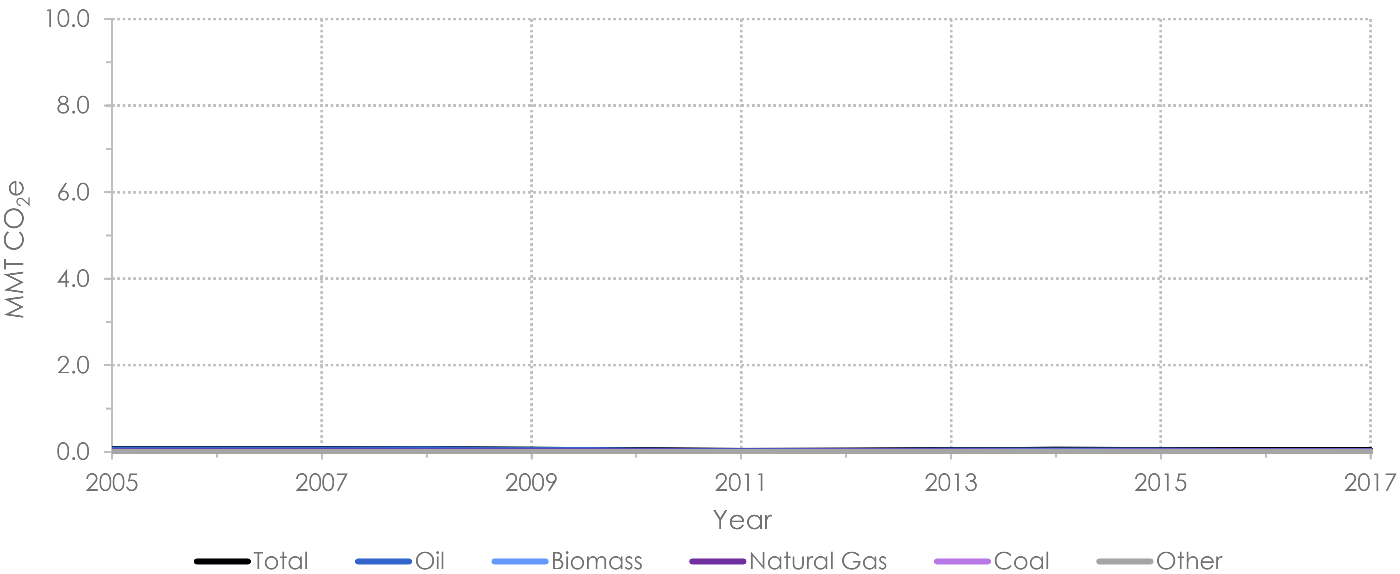
Figure 51. Total Industrial-Sector Black Carbon Emissions, including Fuel Combustion and Process Operations (GWP_{100})



Figures 52. Total Industrial-Sector Black Carbon Emissions, including Fuel Combustion and Process Operations (GWP_{20})



Figures 53. Black Carbon from Industrial Fuel Combustion in Boilers and Internal Combustion Engines (GWP_{100})



Figures 54. Black Carbon from Industrial Fuel Combustion in Boilers and Internal Combustion Engines (GWP_{20})

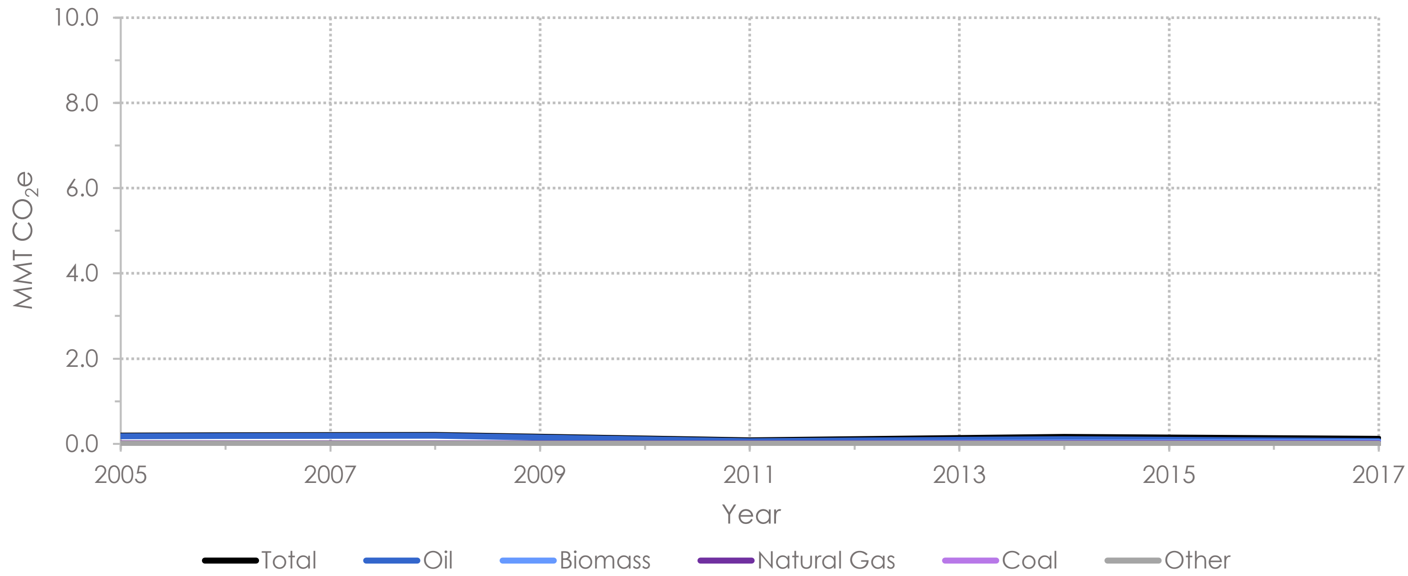
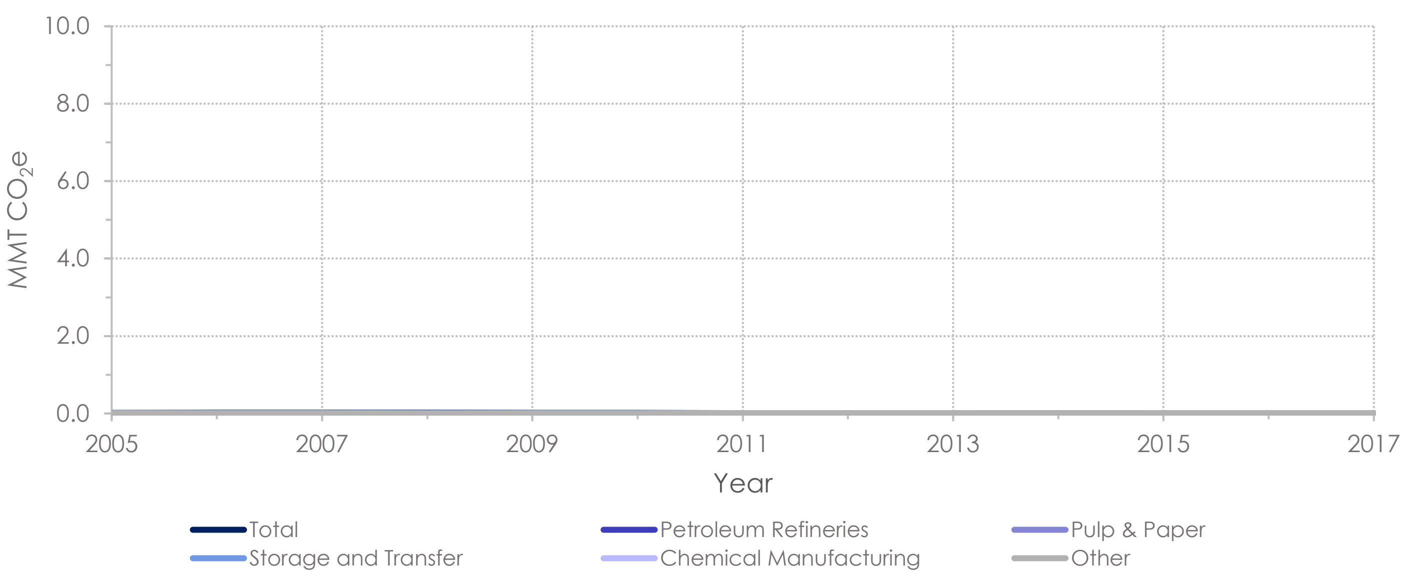
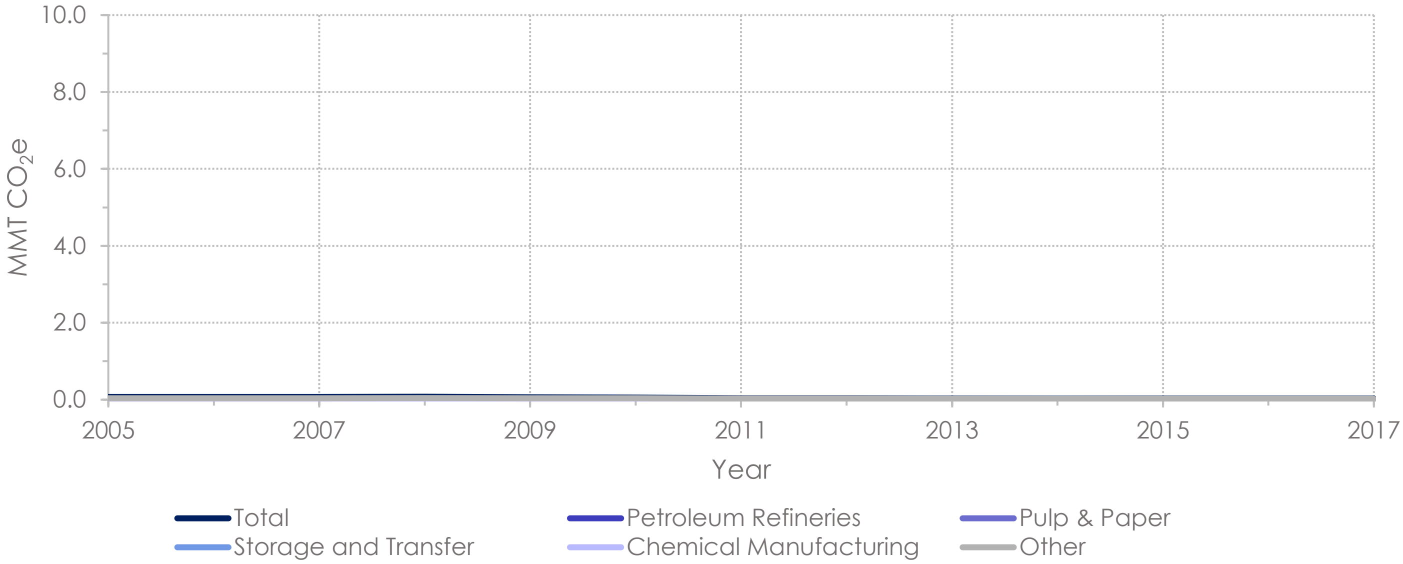


Figure 55. Black Carbon from Industrial Processes (GWP_{100})[63]



[63] "Other" industrial process category includes ferrous and non-ferrous metals manufacturing, industrial surface coating and solvent use, mining, and additional sources.

Figure 56. Black Carbon from Industrial Processes (GWP_{20}) [64]



Other Sector: Wildfires, Prescribed Burns, and Related Sources

Open combustion of wood and agricultural residue produces substantial amounts of smoke and accompanying black carbon. While the quantities generated in New Jersey are smaller than those from on-road diesel vehicles and non-road diesel equipment, fire emissions are an important consideration globally. They are also difficult to accurately assess because of their unpredictable behavior and random occurrence. As a result, methods for characterizing open burning have evolved considerably across the period of study and year-to-year comparisons are therefore subject to interpretation. For example, prior to 2008 emissions from wildfires and prescribed burns were combined into a catchall category of miscellaneous sources but broken into separate categories in later years. Nonetheless, the results for 2008 onward provide a general indicator of the magnitude of black carbon emissions from these activities. Wildfire emissions averaged 0.04 MMT CO_2e (GWP_{100})/ 0.14 MMT CO_2e (GWP_{20}) annually between 2008 and 2017, but with a wide degree of variability from year to year (Figures 57 and 58; Table A-32). Prescribed burns averaged 0.05 MMT CO_2e (GWP_{100})/ 0.17 MMT CO_2e (GWP_{20}), again with substantial variability. Agricultural burning averaged 0.02 MMT CO_2e (GWP_{100})/ 0.06 MMT CO_2e (GWP_{20}), with a smaller degree of variability. Emissions from agricultural burning arose primarily from combustion associated with forest residues and orchard crops.

[64] "Other" industrial process category includes ferrous and non-ferrous metals manufacturing, industrial surface coating and solvent use, mining, and additional sources.

Figure 57. Wildfires, Prescribed Burns, and Related Sources (GWP_{100})

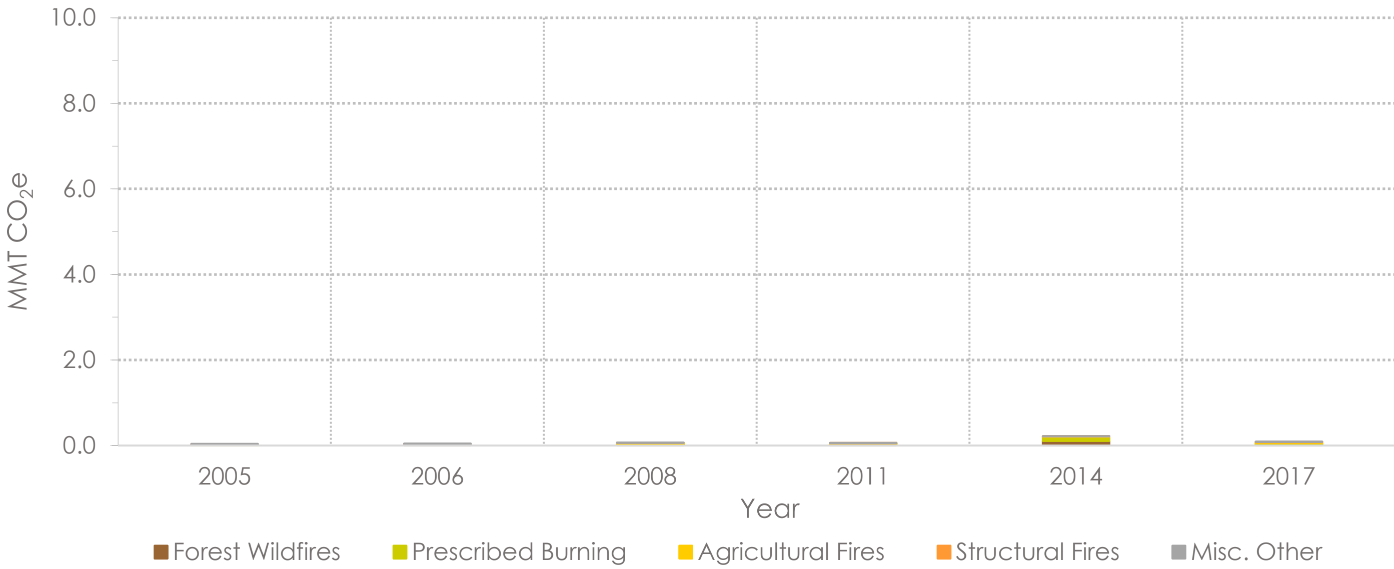
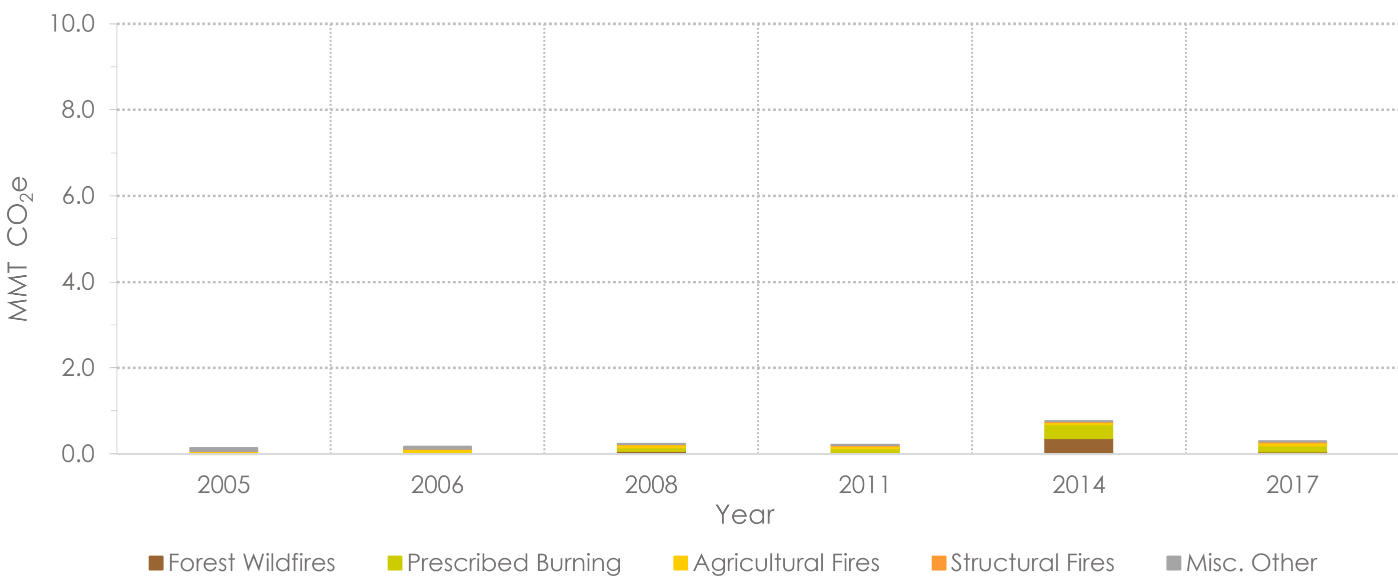


Figure 58. Wildfires, Prescribed Burns, and Related Sources (GWP_{20})



State Action: Black Carbon

Because of its significant impact on health, $PM_{2.5}$ and its subset, black carbon, have been a longstanding focus of regulatory concern at both the state and federal level. New Jersey air quality regulations prioritize reductions of $PM_{2.5}$, and consequently reductions of black carbon. In addition to the fundamental requirement to adopt state-of-the-art (SOTA) technology for all new, reconstructed or significantly-modified stationary air pollution sources, the state has sought targeted solutions to reduce emissions from coal-fired powerplants and refineries. These targeted actions have led to significant reductions of $PM_{2.5}$ and black carbon. Consent Decrees were negotiated with New Jersey's two major refineries to achieve emission reductions from five major refinery processes, leading to $PM_{2.5}$ reductions. And in 2009, the DEP adopted performance standards[65] to reduce allowable NOx, SO_2 and particulate emissions from all ten coal-fired boilers in New Jersey.

New Jersey has also adopted rules for mobile sources that complement federal initiatives. Since 2005, New Jersey's Low Emission Vehicle (LEV) program has reduced on-road emissions through stringent emissions standards for all new vehicles offered for sale in the State.[66] The three-minute idling rule has also contributed to these gains.[67] Targeted programs for reducing emissions from diesel-powered vehicles include tightened restrictions on allowable smoke opacity,[68] and mandatory inspection of on-board diagnostic systems for heavy-duty vehicles.[69] These efforts contributed to the emission reduction trends delineated in Figure 38 above. The recently-adopted Advanced Clean Trucks Program,[70] coupled with other funding commitments to support adoption of electric vehicles,[71] will further reduce black carbon emissions.

The state has also instituted regulations and programs for non-road equipment that complement federal requirements. For example, the New Jersey's Clean Construction Program offers up to $100,000 to support replacement of outdated equipment, with specific attention to improving air quality in urban and sensitive areas.[72] The DEP has also recently made funding available to the South Jersey Port Corporation, which operates and maintains two of the port terminals in Camden County, to upgrade old diesel forklifts. The funding will replace nine of their oldest (31 to 55 years old), highest-use forklifts with new Tier 4 engine forklifts which will significantly reduce $PM_{2.5}$ and black carbon emissions from those sources.

[65] N.J.A.C. 7:27-4.2 and 7:27-10.2
6638 N.J.R. 497(b) (January 17, 2006).
[67] https://www.nj.gov/dep/stopthesoot/sts-idle.htm
[68] https://www.state.nj.us/mvc/pdf/inspections/diesel-opacitycutpoints.pdf
[69] http://www.nj.gov/dep/rules/adoptions/adopt_20161003a.pdf
[70] https://www.nj.gov/dep/rules/adoptions/adopt_20211220a.pdf
[71] https://nj.gov/rggi/docs/rggi-strategic-funding-plan.pdf
[72] https://www.state.nj.us/dep/stopthesoot/eoi.htm

7.0 CONCLUSIONS

7.1 CONCLUSIONS

Since enactment of the Global Warming Response Act in 2007, the State has achieved its GWRA 2020 emissions goal to reduce emissions below the 1990 level. Specifically, the 2019 net emissions of 98.5 MMT CO_2e (GWP_{100}) were 12% below the 1990 level of 111.4 MMT CO_2e.[73] Emissions for 2019 were also 19% below the 2006 level of 121.1 MMT CO_2e. Technological advances and shifts to cleaner fuels led to a substantial 37% reduction in emissions from electricity generation since 2006, most notably due to reduced reliance on coal and an accelerating expansion of renewable energy. Transportation emissions have also dropped by 20%, while black carbon emissions have dropped by 60%. Overall, the State has successfully arrested growth in greenhouse gas emissions and achieved tangible reductions, a major departure from the high-emission outcome envisioned in the 2008 Greenhouse Gas Inventory Report under a no-action scenario. Nonetheless, these rates of improvement fall short of the statutory objectives of the GWRA to reduce emissions by 80% before 2050, let alone meet the 50% reduction target mandated by Governor Murphy's Executive Order 274. To reach these goals, the State must increase the rate of reduction.

Fortunately, under Governor Murphy's leadership, the State has rapidly progressed through planning into implementation, establishing detailed pathways forward in the 2019 Energy Master Plan and the 2020 GWRA 80x50 Report. New Jersey's drive towards offshore wind, clean transportation, and solar PV, coupled with investigation of new heating technologies, support for alternative fuels and policies that maintain the viability of our nuclear fleet, represent a clear direction forward.

Looking back at one of the earliest international forums focused on climate change, held by the United Nations World Environment Programme in 1985,[74] the executive director of the Programme at the time, Mostafa K. Tolba, summed it up simply: there must be "a mechanism to get this ball rolling." New Jersey is finally at the cusp of an energy and environmental transformation that demonstrates its leadership and focus as a center for positive change. Once underway, the state will find that the path becomes clearer with every step forward.

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[73] 2019 emissions based on GWP_{20} were 9% below the 1990 level and 12% below the 2006 level.

[74] World Meteorological Organization (1986). Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts, Villach, Austria, 9-15 October 1985. *WMO No. 661.* World Meteorological Organization. Retrieved from https://library.wmo.int/doc_num.php?explnum_id=8512

APPENDIX A. GHG TABLES

Table A-1. NJ GHG Emissions, MMT CO_2e, based on GWP_{100}[75]

	YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ENERGY	**Transportation**	**33.2**	**47.4**	**47.6**	**49.6**	**47.6**	**42.6**	**42.8**	**43.4**	**41.3**	**41.4**	**41.5**	**40.8**	**42.8**	**40.4**	**40.6**	**38.0**
	On-Road Gasoline	26.2	34.4	34.5	35.1	34.2	33.3	32.9	32.3	31.6	31.8	32.1	31.7	32.5	31.1	30.4	29.7
	On-Road Distillate	4.0	8.4	8.4	8.9	7.7	6.2	6.8	7.8	6.7	6.8	7.2	6.8	7.7	6.9	7.2	6.3
	On-Road CNG and Other	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.1
	Aviation	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Marine	1.6	3.2	3.2	4.2	4.3	1.8	1.7	1.7	1.6	1.5	0.7	0.8	1.1	1.1	1.7	0.6
	Rail (Distillate)	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.3
	Buildings	**26.5**	**28.2**	**23.7**	**27.1**	**26.6**	**26.7**	**25.6**	**25.7**	**23.0**	**25.3**	**28.5**	**26.3**	**23.6**	**23.6**	**26.5**	**25.4**
	Residential	15.5	16.9	14.2	16.1	15.9	15.6	14.6	14.0	12.5	14.7	16.2	15.6	13.6	13.9	15.8	15.3
	Commercial	11.0	11.3	9.6	11.0	10.7	11.1	10.9	11.7	10.5	10.6	12.3	10.8	10.1	9.7	10.7	10.2
	Fuel-Based Industrial	14.8	13.4	12.0	11.9	10.5	9.1	9.6	10.9	10.8	10.1	8.2	8.0	8.4	7.5	8.0	8.0
	Electricity	**26.9**	**34.1**	**30.9**	**32.3**	**29.9**	**23.5**	**26.1**	**23.3**	**20.7**	**20.3**	**20.8**	**19.5**	**20.8**	**18.0**	**19.1**	**19.4**
	In-State Electric	12.3	19.7	18.5	19.6	19.0	14.9	17.7	15.6	14.7	14.1	16.8	18.4	20.0	17.2	17.9	17.3
	Imported Electric	14.5	13.5	11.6	11.7	10.1	7.8	7.7	6.8	5.2	5.4	3.1	0.4	0.0	0.0	0.4	1.2
	MSW Incineration	0.1	0.9	0.8	1.0	0.8	0.8	0.7	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.9
NON-ENERGY	Halogenated Gases (excl. SF6)	0.0	2.2	2.3	2.5	2.7	2.9	3.1	3.4	3.6	3.9	4.1	4.4	4.6	4.8	5.0	5.2
	SF6	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Non-Fuel Agriculture	0.8	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4
	Natural Gas Trans. & Distr.	2.7	2.6	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.4	2.4	2.3
	Landfills	**8.6**	**3.8**	**3.6**	**3.1**	**3.7**	**4.2**	**4.7**	**4.3**	**3.4**	**3.6**	**3.5**	**3.9**	**4.1**	**5.2**	**5.5**	**5.5**
	In-State	4.7	1.6	1.5	1.3	1.6	1.9	1.9	1.7	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.1
	Out-of-State	3.4	1.8	1.7	1.4	1.8	2.0	2.4	2.3	1.5	1.7	1.4	1.8	1.9	2.8	3.0	3.0
	Industrial	0.4	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Wastewater Treatment	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Non-Fuel Industrial	0.1	0.7	0.6	0.6	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Released through Land Clearing	0.6	1.8	1.8	0.3	0.3	0.3	0.3	0.3	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TOTAL GROSS EMISSIONS		115.4	135.9	127.1	131.9	126.3	114.1	116.8	115.7	107.6	110.1	112.1	108.2	109.7	104.7	109.9	106.6
SEQUESTERED		-4.0	-6.0	-6.0	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6	-8.1	-8.1	-8.1	-8.1	-8.1	-8.1	-8.1
TOTAL NET EMISSIONS		**111.4**	**129.9**	**121.1**	**124.3**	**118.7**	**106.5**	**109.2**	**108.1**	**100.0**	**102.0**	**104.0**	**100.1**	**101.6**	**96.6**	**101.8**	**98.5**

[75] All numbers rounded to the nearest tenth. Subtotals may not agree exactly with sums of the numbers shown due to rounding. More detailed data is presented later in this Appendix and in Appendix D.

Table A-2 NJ Black Carbon Emissions, MMT CO_2e, based on GWP_{100}[76]

	YEAR	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BLACK CARBON	**Total Black Carbon**	**5.68**	**5.59**	**4.66**	**4.25**	**3.99**	**4.00**	**3.63**	**3.44**	**3.25**	**3.08**	**2.81**	**2.48**	**2.29**
	Transportation	**3.16**	**3.21**	**2.42**	**2.15**	**1.97**	**2.05**	**1.75**	**1.60**	**1.45**	**1.31**	**1.18**	**0.98**	**0.92**
	On-Road Transportation	2.58	2.76	2.10	1.96	1.76	1.83	1.51	1.35	1.20	1.05	0.90	0.69	0.63
	Non-Road Transportation	0.58	0.45	0.32	0.19	0.21	0.22	0.24	0.25	0.26	0.26	0.27	0.28	0.30
	Non-Road Mobile Equipment	1.59	1.51	1.42	1.33	1.29	1.25	1.21	1.15	1.08	1.01	0.92	0.84	0.75
	Residential	0.46	0.41	0.35	0.29	0.29	0.30	0.31	0.29	0.27	0.25	0.25	0.26	0.27
	Electric Generation	0.23	0.22	0.21	0.20	0.16	0.12	0.08	0.08	0.08	0.08	0.07	0.06	0.04
	Commercial - Exc. Non-Road Equipment	0.13	0.13	0.12	0.12	0.11	0.10	0.08	0.09	0.10	0.11	0.12	0.13	0.14
	Industrial - Exc. Non-Road Eq.	**0.07**	**0.08**	**0.08**	**0.08**	**0.07**	**0.05**	**0.03**	**0.04**	**0.05**	**0.06**	**0.05**	**0.05**	**0.04**
	Industrial Fuel Combustion	0.06	0.06	0.06	0.06	0.05	0.04	0.02	0.03	0.04	0.05	0.04	0.04	0.03
	Industrial Process Emissions	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Other, including Wildfires & Agriculture	0.03	0.05	0.06	0.08	0.10	0.13	0.15	0.19	0.22	0.26	0.21	0.17	0.12

Note: Black carbon emissions were calculated for years in which $PM_{2.5}$ data was available from the USEPA National Emission Inventory (2005, 2008, 2011, 2014 and 2017). Estimates for intervening years were found through interpolation.

[76] All numbers rounded to the nearest hundredth. Subtotals may not agree exactly with sums of the numbers shown due to rounding. More detailed data is presented later in this Appendix and in Appendix D.

Table A-3. NJ GHG Emissions, MMT CO_2e, based on GWP_{20}[77]

	YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ENERGY	**Transportation**	**33.2**	**47.5**	**47.9**	**49.7**	**47.7**	**42.7**	**42.9**	**43.5**	**41.4**	**41.5**	**41.6**	**40.9**	**43.0**	**40.5**	**40.8**	**38.1**
	On-Road Gasoline	26.3	34.5	34.8	35.2	34.3	33.4	32.9	32.4	31.7	31.9	32.2	31.8	32.6	31.1	30.5	29.7
	On-Road Distillate	4.0	8.4	8.4	8.9	7.7	6.2	6.8	7.8	6.7	6.8	7.2	6.8	7.7	6.9	7.2	6.3
	On-Road CNG and Other	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.2	0.2
	Aviation	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Marine	1.6	3.2	3.3	4.2	4.3	1.8	1.7	1.7	1.6	1.5	0.7	0.8	1.2	1.1	1.7	0.6
	Rail (Distillate)	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.3
	Buildings	**26.5**	**28.2**	**23.8**	**27.2**	**26.6**	**26.7**	**25.6**	**25.7**	**23.0**	**25.3**	**28.5**	**26.3**	**23.7**	**23.7**	**26.6**	**25.5**
	Residential	15.5	16.9	14.2	16.1	15.9	15.6	14.7	14.0	12.5	14.8	16.2	15.6	13.6	13.9	15.8	15.3
	Commercial	11.0	11.3	9.6	11.0	10.7	11.2	10.9	11.7	10.5	10.6	12.3	10.8	10.1	9.7	10.7	10.2
	Fuel-Based Industrial	14.8	13.5	12.1	11.9	10.6	9.2	9.7	11.0	10.9	10.2	8.2	8.0	8.4	7.5	8.0	8.0
	Electricity	**27.0**	**34.2**	**31.0**	**32.4**	**30.0**	**23.6**	**26.2**	**23.3**	**20.7**	**20.3**	**20.8**	**19.6**	**20.8**	**18.0**	**19.2**	**19.4**
	In-State Electric	12.3	19.8	18.5	19.7	19.1	15.0	17.8	15.7	14.8	14.2	16.9	18.4	20.1	17.2	17.9	17.4
	Imported Electric	14.5	13.5	11.6	11.7	10.1	7.8	7.7	6.8	5.2	5.4	3.1	0.4	0.0	0.0	0.4	1.2
	MSW Incineration	0.1	0.9	0.8	1.0	0.8	0.8	0.7	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.9
NON-ENERGY	Halogenated Gases (excl. SF6)	0.0	5.2	5.6	6.0	6.3	6.6	7.2	7.7	8.2	8.7	9.3	9.8	10.4	10.9	11.3	11.9
	SF6	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Non-Fuel Agriculture	1.1	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.5
	Natural Gas Trans. & Distr.	7.7	7.5	8.1	8.0	8.0	7.8	7.9	7.7	7.6	7.6	7.5	7.3	7.1	6.9	6.8	6.6
	Landfills	**24.6**	**10.9**	**10.4**	**9.0**	**10.7**	**12.2**	**13.5**	**12.3**	**9.8**	**10.4**	**10.2**	**11.1**	**11.7**	**15.0**	**15.7**	**15.8**
	In-State	13.6	4.7	4.4	3.8	4.6	5.5	5.5	4.8	4.4	4.6	5.0	5.1	5.4	5.9	6.1	6.2
	Out-of-State	9.9	5.1	4.9	4.1	5.1	5.7	7.0	6.5	4.4	4.8	4.2	5.0	5.3	8.1	8.6	8.6
	Industrial	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Wastewater Treatment	2.4	2.8	2.8	2.8	2.7	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8
	Non-Fuel Industrial	0.1	0.7	0.6	0.6	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	Released through Land Clearing	0.6	1.8	1.8	0.3	0.3	0.3	0.3	0.3	0.3	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TOTAL GROSS EMISSIONS		138.5	153.1	144.9	148.6	144.4	133.2	137.0	135.4	125.7	128.9	131.0	127.8	130.0	127.3	133.1	130.1
SEQUESTERED		-4.0	-6.0	-6.0	-7.6	-7.6	-7.6	-7.6	-7.6	-7.6	-8.1	-8.1	-8.1	-8.1	-8.1	-8.1	-8.1
TOTAL NET EMISSIONS		**134.5**	**147.1**	**138.9**	**141.0**	**136.8**	**125.6**	**129.4**	**127.8**	**118.1**	**120.8**	**122.9**	**119.7**	**121.9**	**119.2**	**125.0**	**122.0**

[77] All numbers rounded to the nearest tenth. Subtotals may not agree exactly with sums of the numbers shown due to rounding. More detailed data is presented later in this Appendix and in Appendix D.

Table A-4 NJ Black Carbon Emissions, MMT CO_2e, based on GWP_{20}[78]

	YEAR	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BLACK CARBON	**Total Black Carbon**	**19.98**	**19.67**	**16.39**	**14.95**	**14.03**	**14.06**	**12.76**	**12.09**	**11.44**	**10.81**	**9.87**	**8.71**	**8.05**
	Transportation	**11.10**	**11.29**	**8.52**	**7.57**	**6.92**	**7.21**	**6.17**	**5.63**	**5.11**	**4.62**	**4.14**	**3.44**	**3.25**
	On-Road Transportation	9.06	9.71	7.39	6.90	6.19	6.42	5.32	4.76	4.21	3.70	3.18	2.44	2.21
	Non-Road Transportation	2.04	1.59	1.13	0.67	0.73	0.79	0.85	0.87	0.90	0.92	0.96	1.00	1.04
	Non-Road Mobile Equipment	5.60	5.29	4.99	4.69	4.55	4.41	4.27	4.03	3.79	3.55	3.25	2.95	2.65
	Residential	1.63	1.43	1.22	1.01	1.03	1.06	1.08	1.01	0.94	0.87	0.89	0.91	0.93
	Electric Generation	0.82	0.78	0.75	0.71	0.57	0.43	0.29	0.29	0.29	0.29	0.24	0.20	0.15
	Commercial - Exc. Non-Road Equipment	0.46	0.44	0.43	0.41	0.37	0.33	0.30	0.32	0.35	0.38	0.42	0.45	0.49
	Industrial - Exc. Non-Road Eq.	**0.26**	**0.27**	**0.28**	**0.29**	**0.23**	**0.18**	**0.12**	**0.15**	**0.17**	**0.19**	**0.18**	**0.17**	**0.15**
	Industrial Fuel Combustion	0.19	0.20	0.20	0.21	0.17	0.12	0.08	0.11	0.14	0.17	0.15	0.14	0.12
	Industrial Process Emissions	0.07	0.07	0.07	0.08	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03
	Other, including Wildfires & Agriculture	0.11	0.16	0.22	0.28	0.36	0.45	0.53	0.66	0.79	0.92	0.76	0.59	0.43

Note: Black carbon emissions were calculated for years in which $PM_{2.5}$ data was available from the USEPA National Emission Inventory (2005, 2008, 2011, 2014 and 2017). Estimates for intervening years were found through interpolation.

[78] All numbers rounded to the nearest hundredth. Subtotals may not agree exactly with sums of the numbers shown due to rounding. More detailed data is presented later in this Appendix and in Appendix D.

Table A-5. On-Road greenhouse gas emissions by vehicle category for 2006, 2018 and 2019 (MMT CO_2e)

GWP_{100}

VEHICLE CATEGORY	YEAR		
	2006	2018	2019
Gas Passenger Vehicles	31.5	27.8	27.1
Diesel Freight & Commercial	6.7	5.5	4.8
Gas Freight & Commercial	2.9	2.5	2.5
Diesel Passenger Vehicles	1.0	0.8	0.8
Diesel Buses	0.7	0.9	0.7
Gas Buses	0.0	0.1	0.1
CNG Trucks & Buses	0.0	0.1	0.1
Motor Homes	0.1	0.1	0.0

GWP_{20}

VEHICLE CATEGORY	YEAR		
	2006	2018	2019
Gas Passenger Vehicles	31.8	27.9	27.2
Diesel Freight & Commercial	6.7	5.5	4.8
Gas Freight & Commercial	2.9	2.5	2.5
Diesel Passenger Vehicles	1.0	0.8	0.8
Diesel Buses	0.7	0.9	0.7
Gas Buses	0.0	0.1	0.1
CNG Trucks & Buses	0.0	0.2	0.2
Motor Homes	0.1	0.1	0.0

Table A-6. On-Road greenhouse gas emissions by vehicle type for 2006, 2018 and 2019 (MMT CO_2e) GWP_{100}

FUEL AND VEHICLE TYPE	YEAR		
	2006	2018	2019
Gasoline Motorcycle	0.1479	0.1590	0.1576
Gasoline Passenger Car	13.4950	11.9015	11.6792
Gasoline Passenger Truck	17.8863	15.6811	15.2421
Gasoline Light Commercial Truck	2.3479	1.9967	1.9497
Gasoline Other Buses	0.0087	0.0188	0.0142
Gasoline Transit Bus	0.0094	0.0488	0.0372
Gasoline School Bus	0.0123	0.0070	0.0050
Gasoline Refuse Truck	0.0062	0.0009	0.0007
Gasoline Single Unit Short-haul Truck	0.4493	0.4113	0.3859
Gasoline Single Unit Long-haul Truck	0.0811	0.1173	0.1097
Gasoline Motor Home	0.0397	0.0293	0.0276
Gasoline Combination Short-haul Truck	0.0026	0.0001	0.0000
Diesel Passenger Car	0.0546	0.0962	0.0925
Diesel Passenger Truck	0.9471	0.7048	0.7163
Diesel Light Commercial Truck	0.3049	0.1603	0.1524
Diesel Other Buses	0.1612	0.1281	0.0942
Diesel Transit Bus	0.2312	0.3449	0.2554
Diesel School Bus	0.2945	0.4286	0.3149
Diesel Refuse Truck	0.1320	0.1106	0.1025
Diesel Single Unit Short-haul Truck	1.4924	1.5271	1.4090
Diesel Single Unit Long-haul Truck	0.3329	0.4253	0.3898
Diesel Motor Home	0.0147	0.0214	0.0205
Diesel Combination Short-haul Truck	1.4403	1.0616	0.9208
Diesel Combination Long-haul Truck	2.9951	2.2150	1.8463
CNG Other Buses	0.0175	0.0137	0.0101
CNG Transit Bus	0.0165	0.0384	0.0283
CNG School Bus	0.0009	0.0056	0.0044
CNG Refuse Truck	0.0001	0.0132	0.0154
CNG Single Unit Short-haul Truck	0.0017	0.0249	0.0259
CNG Single Unit Long-haul Truck	0.0003	0.0079	0.0079
CNG Motor Home	0.0000	0.0000	0.0000
CNG Combination Short-haul Truck	0.0000	0.0217	0.0224
E-85 Passenger Car	0.0000	0.0080	0.0080
E-85 Passenger Truck	0.0000	0.0420	0.0408
E-85 Light Commercial Truck	0.0000	0.0061	0.0058

GWP_{20}

FUEL AND VEHICLE TYPE	YEAR		
	2006	2018	2019
Gasoline Motorcycle	0.1531	0.1618	0.1601
Gasoline Passenger Car	13.6184	11.9280	11.7019
Gasoline Passenger Truck	18.0548	15.7141	15.2705
Gasoline Light Commercial Truck	2.3719	2.0026	1.9545
Gasoline Other Buses	0.0087	0.0189	0.0142
Gasoline Transit Bus	0.0094	0.0489	0.0373
Gasoline School Bus	0.0125	0.0071	0.0050
Gasoline Refuse Truck	0.0063	0.0009	0.0007
Gasoline Single Unit Short-haul Truck	0.4549	0.4127	0.3871
Gasoline Single Unit Long-haul Truck	0.0818	0.1175	0.1099
Gasoline Motor Home	0.0403	0.0295	0.0277
Gasoline Combination Short-haul Truck	0.0027	0.0001	0.0000
Diesel Passenger Car	0.0546	0.0963	0.0925
Diesel Passenger Truck	0.9471	0.7059	0.7174
Diesel Light Commercial Truck	0.3049	0.1606	0.1527
Diesel Other Buses	0.1612	0.1282	0.0942
Diesel Transit Bus	0.2312	0.3451	0.2556
Diesel School Bus	0.2945	0.4292	0.3153
Diesel Refuse Truck	0.1320	0.1107	0.1026
Diesel Single Unit Short-haul Truck	1.4924	1.5310	1.4128
Diesel Single Unit Long-haul Truck	0.3329	0.4258	0.3902
Diesel Motor Home	0.0147	0.0215	0.0205
Diesel Combination Short-haul Truck	1.4403	1.0627	0.9217
Diesel Combination Long-haul Truck	2.9951	2.2167	1.8477
CNG Other Buses	0.0231	0.0187	0.0140
CNG Transit Bus	0.0222	0.0526	0.0391
CNG School Bus	0.0010	0.0078	0.0061
CNG Refuse Truck	0.0001	0.0173	0.0203
CNG Single Unit Short-haul Truck	0.0020	0.0331	0.0347
CNG Single Unit Long-haul Truck	0.0003	0.0106	0.0107
CNG Motor Home	0.0000	0.0000	0.0000
CNG Combination Short-haul Truck	0.0000	0.0278	0.0288
E-85 Passenger Car	0.0000	0.0081	0.0080
E-85 Passenger Truck	0.0000	0.0422	0.0410
E-85 Light Commercial Truck	0.0000	0.0061	0.0059

Table A-7. Marine emissions (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoline Recreational Boats	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Diesel Recreational Boats	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Diesel Ships & Non-Recreational Boats	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.1	0.3	0.2	0.2	0.2	0.1
Residual Fuel	1.0	2.5	2.6	3.4	3.6	1.2	1.1	1.0	1.0	0.9	0.2	0.2	0.5	0.5	1.1	0.1
Total	**1.6**	**3.2**	**3.2**	**4.2**	**4.3**	**1.8**	**1.7**	**1.7**	**1.6**	**1.5**	**0.7**	**0.8**	**1.1**	**1.1**	**1.7**	**0.6**

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Gasoline Recreational Boats	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
Diesel Recreational Boats	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1
Diesel Ships & Non-Recreational Boats	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.1	0.3	0.2	0.2	0.2	0.1
Residual Fuel	1.0	2.5	2.6	3.5	3.6	1.2	1.1	1.0	1.0	0.9	0.2	0.2	0.5	0.5	1.1	0.1
Total	**1.6**	**3.2**	**3.3**	**4.2**	**4.3**	**1.8**	**1.7**	**1.7**	**1.6**	**1.5**	**0.7**	**0.8**	**1.2**	**1.1**	**1.7**	**0.6**

Table A-8. Rail emissions from distillate (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Rail Emissions	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.3

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Rail Emissions	0.3	0.4	0.4	0.4	0.3	0.3	0.3	0.4	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.3

Table A-9. Emissions from electricity generation (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
In-State Generation	12.3	19.7	18.5	19.6	19.0	14.9	17.7	15.6	14.7	14.1	16.8	18.4	20.0	17.2	17.9	17.3
MSW Incineration	0.1	0.9	0.8	1.0	0.8	0.8	0.7	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.9
Imported Electricity	14.5	13.5	11.6	11.7	10.1	7.8	7.7	6.8	5.2	5.4	3.1	0.4	0.0	0.0	0.4	1.2
Total	**26.9**	**34.1**	**30.9**	**32.3**	**29.9**	**23.5**	**26.1**	**23.3**	**20.7**	**20.3**	**20.8**	**19.5**	**20.8**	**18.0**	**19.1**	**19.4**

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
In-State Generation	12.3	19.8	18.5	19.7	19.1	15.0	17.8	15.7	14.8	14.2	16.9	18.4	20.1	17.2	17.9	17.4
MSW Incineration	0.1	0.9	0.8	1.0	0.8	0.8	0.7	0.8	0.7	0.8	0.8	0.7	0.8	0.8	0.8	0.9
Imported Electricity	14.5	13.5	11.6	11.7	10.1	7.8	7.7	6.8	5.2	5.4	3.1	0.4	0.0	0.0	0.4	1.2
Total	**27.0**	**34.2**	**31.0**	**32.4**	**30.0**	**23.6**	**26.2**	**23.3**	**20.7**	**20.3**	**20.8**	**19.6**	**20.8**	**18.0**	**19.2**	**19.4**

Table A-10. Residential greenhouse gas emissions (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distillate Fuel Oil	5.8	3.8	3.0	3.2	3.4	2.8	2.3	1.9	1.8	1.9	2.1	2.1	1.4	1.4	1.8	1.8
Propane	0.2	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Kerosene	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	9.3	12.8	10.9	12.5	12.1	12.4	11.9	11.6	10.4	12.6	13.8	13.2	12.0	12.3	13.7	13.2
Total	**15.5**	**16.9**	**14.2**	**16.1**	**15.9**	**15.6**	**14.6**	**14.0**	**12.5**	**14.7**	**16.2**	**15.6**	**13.6**	**13.9**	**15.8**	**15.3**

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distillate Fuel Oil	5.86	3.8	3.0	3.2	3.4	2.8	2.3	2.0	1.8	1.9	2.1	2.1	1.4	1.4	1.8	1.8
Propane	0.20	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Kerosene	0.12	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Natural Gas	9.35	12.8	10.9	12.6	12.1	12.4	12.0	11.7	10.5	12.6	13.8	13.2	12.0	12.3	13.7	13.2
Total	**15.5**	**16.9**	**14.2**	**16.1**	**15.9**	**15.6**	**14.7**	**14.0**	**12.5**	**14.8**	**16.2**	**15.6**	**13.6**	**13.9**	**15.8**	**15.3**

Table A-11. Commercial greenhouse gas emissions (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distillate Fuel Oil	3.5	1.5	0.9	1.4	1.0	0.9	0.8	1.0	0.8	0.9	0.9	0.8	0.7	0.6	0.6	0.7
Propane	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Kerosene	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.8	0.8	0.8	0.8
Natural Gas	6.3	9.4	8.4	9.3	9.3	9.9	9.9	10.5	9.5	9.6	11.2	9.1	8.5	8.2	9.2	8.6
Residual Fuel Oil	0.7	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**11.0**	**11.3**	**9.6**	**11.0**	**10.7**	**11.1**	**10.9**	**11.7**	**10.5**	**10.6**	**12.3**	**10.8**	**10.1**	**9.7**	**10.7**	**10.2**

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distillate Fuel Oil	3.5	1.5	0.9	1.4	1.0	0.9	0.8	1.0	0.8	0.9	0.9	0.8	0.7	0.6	0.6	0.7
Propane	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Kerosene	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.8	0.8	0.8	0.8	0.8
Natural Gas	6.3	9.4	8.4	9.3	9.3	9.9	9.9	10.5	9.5	9.6	11.2	9.1	8.5	8.2	9.2	8.6
Residual Fuel Oil	0.7	0.1	0.1	0.1	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**11.0**	**11.3**	**9.6**	**11.0**	**10.7**	**11.2**	**10.9**	**11.7**	**10.5**	**10.6**	**12.3**	**10.8**	**10.1**	**9.7**	**10.7**	**10.2**

Table A-12. Industrial greenhouse gas emissions from fuel consumption (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distillate Fuel Oil	1.5	0.8	1.0	0.8	0.8	0.8	0.7	0.9	0.8	0.7	0.9	0.9	0.9	0.7	0.7	0.7
Kerosene	0.1	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline	0.2	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.4	0.5	0.5	0.5	0.5
Natural Gas	4.9	4.1	3.6	3.5	3.0	2.6	2.7	2.7	3.0	3.4	3.4	3.1	3.4	3.0	3.5	3.6
Petroleum Coke	3.0	3.6	3.1	3.3	3.4	3.1	2.3	3.3	2.8	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Residual Oil	1.7	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Still Gas	2.0	3.5	3.4	3.3	2.7	2.0	2.0	2.1	2.5	2.4	2.4	2.3	2.4	2.1	2.1	2.0
Hydrocarbon Gas Liquids	0.7	0.1	0.1	0.2	0.1	0.1	1.4	1.4	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Total	**14.8**	**13.4**	**12.0**	**11.9**	**10.5**	**9.1**	**9.6**	**10.9**	**10.8**	**10.1**	**8.2**	**8.0**	**8.4**	**7.5**	**8.0**	**8.0**

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Distillate Fuel Oil	1.5	0.8	1.0	0.8	0.8	0.8	0.7	0.9	0.8	0.7	0.9	0.9	0.9	0.7	0.7	0.7
Kerosene	0.1	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasoline	0.2	0.4	0.4	0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.5	0.5	0.5	0.5	0.5
Natural Gas	4.9	4.1	3.6	3.5	3.0	2.7	2.7	2.7	3.0	3.4	3.4	3.1	3.4	3.0	3.5	3.6
Petroleum Coke	3.1	3.7	3.2	3.4	3.5	3.1	2.4	3.4	2.9	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Residual Oil	1.7	0.2	0.2	0.2	0.1	0.1	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Still Gas	2.0	3.5	3.4	3.3	2.7	2.0	2.1	2.1	2.5	2.4	2.4	2.3	2.5	2.1	2.1	2.0
Hydrocarbon Gas Liquids	0.7	0.1	0.1	0.2	0.1	0.1	1.4	1.4	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Total	**14.8**	**13.5**	**12.1**	**11.9**	**10.6**	**9.2**	**9.7**	**11.0**	**10.9**	**10.2**	**8.2**	**8.0**	**8.4**	**7.5**	**8.0**	**8.0**

Table A-13. HFC emissions by source type and category (GWP_{100})

SOURCE	CATEGORY	YEAR														
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Commercial Refrigeration	Refrigeration	0.37	0.43	0.50	0.57	0.64	0.77	0.90	1.02	1.14	1.25	1.36	1.47	1.57	1.66	1.75
Industrial Refrigeration	Refrigeration	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.06	0.07	0.07
Domestic Refrigeration	Refrigeration	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05
Stationary AC > 50 lbs. Commercial	Air Conditioning	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.16	0.17	0.18	0.20	0.22	0.23	0.24	0.26
Stationary AC <50 lbs. Commercial	Air Conditioning	0.00	0.00	0.00	0.00	0.00	0.05	0.10	0.16	0.22	0.28	0.34	0.39	0.45	0.51	0.56
Stationary AC Residential Heat Pumps	Air Conditioning	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.03	0.05	0.06	0.06	0.07	0.09
Stationary Central AC Residential	Air Conditioning	0.02	0.02	0.03	0.03	0.04	0.07	0.09	0.12	0.16	0.19	0.23	0.27	0.32	0.36	0.40
Stationary Room Unit AC Residential	Air Conditioning	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.08	0.09	0.11	0.13	0.14	0.16	0.17	0.26
Light-duty MVAC	Mobile R/AC	1.05	1.13	1.19	1.21	1.23	1.20	1.21	1.18	1.17	1.14	1.08	1.02	0.96	0.88	0.80
Heavy-duty MVAC	Mobile R/AC	0.19	0.19	0.19	0.19	0.20	0.21	0.21	0.21	0.22	0.22	0.23	0.24	0.24	0.25	0.26
Transport Refrigeration	Mobile R/AC	0.07	0.08	0.10	0.11	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.14	0.14
Foam	Foams	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.09	0.13	0.16	0.16	0.19
Aerosol Propellants	Aerosols	0.29	0.29	0.29	0.32	0.33	0.34	0.35	0.35	0.36	0.35	0.35	0.35	0.36	0.36	0.36
Solvents and Fire Suppressant	Other	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Total		**2.16**	**2.35**	**2.52**	**2.70**	**2.86**	**3.11**	**3.37**	**3.61**	**3.88**	**4.12**	**4.35**	**4.60**	**4.81**	**4.99**	**5.24**
BY CATEGORY																
Refrigeration		0.41	0.47	0.55	0.62	0.70	0.84	0.97	1.10	1.22	1.35	1.46	1.57	1.68	1.78	1.87
Air Conditioning - Stationary		0.09	0.11	0.13	0.17	0.19	0.30	0.41	0.53	0.66	0.80	0.94	1.08	1.22	1.35	1.56
Air Conditioning - Mobile		1.31	1.40	1.47	1.51	1.54	1.54	1.54	1.52	1.51	1.49	1.44	1.39	1.34	1.27	1.20
Foams		0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.09	0.13	0.16	0.16	0.19
Aerosol Propellants		0.29	0.29	0.29	0.32	0.33	0.34	0.35	0.35	0.36	0.35	0.35	0.35	0.36	0.36	0.36
Solvents and Fire Suppressants		0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07

Table A-14. HFC emissions by source type and category (GWP_{20})

SOURCE	CATEGORY	YEAR														
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Commercial Refrigeration	Refrigeration	0.90	1.03	1.18	1.34	1.50	1.78	2.04	2.30	2.54	2.81	3.06	3.31	3.54	3.77	3.98
Industrial Refrigeration	Refrigeration	0.05	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.16
Domestic Refrigeration	Refrigeration	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11
Stationary AC > 50 lbs. Commercial	Air Conditioning	0.16	0.18	0.21	0.24	0.26	0.29	0.32	0.35	0.38	0.41	0.45	0.49	0.52	0.56	0.59
Stationary AC <50 lbs. Commercial	Air Conditioning	0.00	0.00	0.00	0.00	0.00	0.12	0.24	0.36	0.49	0.62	0.75	0.89	1.02	1.15	1.27
Stationary AC Residential Heat Pumps	Air Conditioning	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.04	0.06	0.08	0.10	0.13	0.13	0.16	0.19
Stationary Central AC Residential	Air Conditioning	0.04	0.05	0.06	0.08	0.09	0.15	0.21	0.28	0.35	0.43	0.52	0.62	0.71	0.81	0.91
Stationary Room Unit AC Residential	Air Conditioning	0.02	0.03	0.04	0.06	0.09	0.11	0.14	0.18	0.21	0.25	0.28	0.32	0.36	0.39	0.58
Light-duty MVAC	Mobile R/AC	2.54	2.69	2.82	2.84	2.85	2.77	2.76	2.66	2.62	2.55	2.43	2.30	2.17	2.00	1.82
Heavy-duty MVAC	Mobile R/AC	0.46	0.45	0.44	0.45	0.46	0.48	0.47	0.48	0.48	0.50	0.52	0.54	0.55	0.57	0.59
Transport Refrigeration	Mobile R/AC	0.16	0.20	0.23	0.26	0.28	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.32
Foam	Foams	0.01	0.01	0.01	0.02	0.02	0.04	0.06	0.09	0.11	0.14	0.20	0.29	0.36	0.36	0.42
Aerosol Propellants	Aerosols	0.70	0.69	0.69	0.75	0.77	0.79	0.79	0.80	0.80	0.79	0.80	0.80	0.80	0.81	0.81
Solvents and Fire Suppressant	Other	0.15	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Total		5.22	5.62	5.97	6.33	6.65	7.17	7.70	8.17	8.69	9.26	9.80	10.38	10.89	11.31	11.91
BY CATEGORY																
Refrigeration		0.99	1.14	1.30	1.46	1.64	1.94	2.22	2.49	2.74	3.02	3.28	3.55	3.80	4.03	4.26
Air Conditioning - Stationary		0.21	0.26	0.32	0.39	0.45	0.69	0.94	1.21	1.49	1.79	2.11	2.45	2.75	3.07	3.54
Air Conditioning - Mobile		3.16	3.34	3.49	3.55	3.59	3.54	3.52	3.43	3.39	3.35	3.24	3.14	3.03	2.88	2.72
Foams		0.01	0.01	0.01	0.02	0.02	0.04	0.06	0.09	0.11	0.14	0.20	0.29	0.36	0.36	0.42
Aerosol Propellants		0.70	0.69	0.69	0.75	0.77	0.79	0.79	0.80	0.80	0.79	0.80	0.80	0.80	0.81	0.81
Solvents and Fire Suppressants		0.15	0.17	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16

Table A-15. Natural Gas Transmission and Distribution (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Transmission	0.14	0.22	0.25	0.25	0.25	0.22	0.22	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Distribution	2.54	2.36	2.55	2.54	2.52	2.50	2.52	2.48	2.44	2.43	2.39	2.33	2.26	2.20	2.15	2.08
Total	**2.68**	**2.59**	**2.80**	**2.79**	**2.77**	**2.73**	**2.75**	**2.68**	**2.64**	**2.63**	**2.59**	**2.53**	**2.47**	**2.40**	**2.35**	**2.28**

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Transmission	0.40	0.64	0.72	0.72	0.72	0.65	0.65	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
Distribution	7.31	6.81	7.35	7.33	7.26	7.20	7.26	7.13	7.01	7.00	6.89	6.70	6.52	6.32	6.20	5.98
Total	**7.71**	**7.45**	**8.06**	**8.04**	**7.97**	**7.85**	**7.91**	**7.71**	**7.59**	**7.58**	**7.47**	**7.28**	**7.10**	**6.90**	**6.78**	**6.56**

Table A-16. Landfill Emissions (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
In-State MSW LF	4.73	1.64	1.54	1.33	1.60	1.91	1.90	1.67	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.1
Industrial LF	0.40	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
MSW Export	3.42	1.79	1.71	1.43	1.76	1.98	2.42	2.26	1.5	1.7	1.4	1.8	1.9	2.8	3.0	3.0
Total	**8.55**	**3.77**	**3.60**	**3.11**	**3.71**	**4.24**	**4.68**	**4.27**	**3.4**	**3.6**	**3.5**	**3.9**	**4.1**	**5.2**	**5.5**	**5.5**

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
In-State MSW LF	13.62	4.71	4.44	3.83	4.61	5.51	5.48	4.80	4.42	4.55	5.02	5.09	5.41	5.90	6.12	6.18
Industrial LF	1.15	1.01	1.01	1.01	1.01	1.01	1.01	1.00	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98
MSW Export	9.86	5.14	4.93	4.13	5.07	5.70	6.98	6.51	4.43	4.84	4.17	5.04	5.34	8.09	8.62	8.62
Total	**24.63**	**10.86**	**10.37**	**8.97**	**10.69**	**12.22**	**13.47**	**12.31**	**9.85**	**10.39**	**10.19**	**11.12**	**11.74**	**14.97**	**15.72**	**15.78**

Table A-18. Wastewater treatment emissions (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wastewater Treatment	0.85	0.96	0.96	0.96	0.95	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Wastewater Treatment	2.44	2.75	2.75	2.75	2.75	2.76	2.79	2.78	2.79	2.80	2.81	2.82	2.82	2.82	2.82	2.82

Table A-19. Non-fuel agricultural emissions (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Non-Fuel Agriculture	0.77	0.55	0.56	0.57	0.60	0.57	0.49	0.48	0.48	0.53	0.52	0.49	0.51	0.53	0.49	0.38

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Non-Fuel Agriculture	1.10	0.77	0.78	0.77	0.80	0.77	0.69	0.66	0.66	0.70	0.68	0.66	0.69	0.70	0.65	0.55

Table A-20. Non-fuel industrial emissions of carbon dioxide (MMT CO_2)

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Non-Fuel Industrial CO_2	0.08	0.69	0.64	0.59	0.58	0.33	0.30	0.30	0.30	0.30	0.31	0.30	0.30	0.30	0.30	0.30

Table A-21. Sulfur hexafluoride emissions (MMT CO_2e)

GWP_{100}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sulfur Hexafluoride	0.54	0.19	0.15	0.14	0.13	0.12	0.12	0.12	0.10	0.09	0.10	0.08	0.08	0.08	0.08	0.08

GWP_{20}

YEAR	1990	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Sulfur Hexafluoride	0.38	0.13	0.11	0.10	0.09	0.09	0.09	0.09	0.07	0.07	0.07	0.05	0.06	0.06	0.05	0.06

Table A-22. Black carbon emissions by sector (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Transportation	3.16	3.21	2.15	1.75	1.31	0.92
Non-Road Equipment	1.59	1.51	1.33	1.21	1.01	0.75
Residential	0.46	0.41	0.29	0.31	0.25	0.27
Electric Generation	0.23	0.22	0.20	0.08	0.08	0.04
Commercial [1]	0.13	0.13	0.12	0.08	0.11	0.14
Industrial [1]	0.07	0.08	0.08	0.03	0.06	0.04
Other [2]	0.03	0.05	0.08	0.15	0.26	0.12
Total	**5.68**	**5.59**	**4.25**	**3.63**	**3.08**	**2.29**

[1] Except non-road equipment
[2] Includes wildfires and agriculture

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Transportation	11.10	11.29	7.57	6.17	4.62	3.25
Non-Road Equipment	5.60	5.29	4.69	4.27	3.55	2.65
Residential	1.63	1.43	1.01	1.08	0.87	0.93
Electric Generation	0.82	0.78	0.71	0.29	0.29	0.15
Commercial [1]	0.46	0.44	0.41	0.30	0.38	0.49
Industrial [1]	0.26	0.27	0.29	0.12	0.19	0.15
Other [2]	0.11	0.16	0.28	0.53	0.92	0.43
Total	**19.98**	**19.67**	**14.95**	**12.76**	**10.81**	**8.05**

[1] Except non-road equipment
[2] Includes wildfires and agriculture

Table A-23. On-road black carbon emissions (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017	2018	2019
Diesel Heavy Duty	2.02	2.23	1.55	1.22	0.80	0.44	0.34	0.25
Diesel Light Duty	0.27	0.37	0.20	0.16	0.11	0.06	0.08	0.06
Non-Diesel Heavy Duty	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Non-Diesel Light Duty	0.28	0.16	0.20	0.13	0.13	0.12	0.09	0.10
Total On-Road	2.58	2.76	1.96	1.51	1.05	0.63	0.52	0.42

GWP_{20}

Year	2005	2006	2008	2011	2014	2017	2018	2019
Diesel Heavy Duty	7.12	7.83	5.47	4.29	2.83	1.56	1.21	0.89
Diesel Light Duty	0.94	1.31	0.72	0.56	0.39	0.22	0.27	0.23
Non-Diesel Heavy Duty	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Non-Diesel Light Duty	0.97	0.56	0.71	0.46	0.47	0.41	0.33	0.36
Total On-Road	9.06	9.71	6.90	5.32	3.70	2.21	1.82	1.48

Table A-24. Largest Sources of Black Carbon from On-Road Diesel Vehicles (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017	2018	2019
Long-Haul Combo	0.87	0.92	0.65	0.50	0.32	0.14	0.11	0.08
Short-Haul Combo	0.36	0.47	0.27	0.21	0.14	0.11	0.08	0.06
Long-Haul Single Unit	0.10	0.09	0.08	0.06	0.05	0.02	0.02	0.01
Short Haul Single-Unit	0.43	0.48	0.35	0.28	0.20	0.11	0.08	0.06
Buses	0.22	0.21	0.17	0.14	0.08	0.04	0.05	0.03
Light Duty/Light Commercial	0.27	0.37	0.20	0.16	0.11	0.06	0.08	0.06
Other Diesel	0.04	0.05	0.04	0.03	0.02	0.01	0.01	0.01
Total On-Road Diesel	**2.29**	**2.60**	**1.76**	**1.38**	**0.91**	**0.51**	**0.42**	**0.32**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017	2018	2019
Long-Haul Combo	3.05	3.22	2.30	1.74	1.13	0.51	0.37	0.28
Short-Haul Combo	1.27	1.66	0.95	0.75	0.49	0.40	0.27	0.20
Long-Haul Single Unit	0.36	0.33	0.28	0.23	0.16	0.06	0.05	0.04
Short Haul Single-Unit	1.52	1.70	1.22	0.99	0.69	0.38	0.29	0.22
Buses	0.77	0.73	0.59	0.48	0.29	0.15	0.17	0.12
Light Duty/Light Commercial	0.94	1.31	0.72	0.56	0.39	0.22	0.27	0.23
Other Diesel	0.15	0.18	0.12	0.10	0.07	0.05	0.05	0.04
Total On-Road Diesel	**8.06**	**9.13**	**6.18**	**4.85**	**3.22**	**1.78**	**1.48**	**1.11**

Table A-25. Non-road Transportation Black Carbon Emissions (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Aircraft	0.052	0.039	0.014	0.031	0.036	0.033
Commercial Marine Vessels	0.458	0.352	0.140	0.138	0.156	0.156
Locomotives	0.071	0.060	0.036	0.073	0.070	0.107
Total Non-Road Transportation	**0.581**	**0.451**	**0.190**	**0.242**	**0.262**	**0.296**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Aircraft	0.182	0.138	0.050	0.108	0.128	0.115
Commercial Marine Vessels	1.612	1.239	0.492	0.486	0.547	0.548
Locomotives	0.250	0.209	0.127	0.256	0.246	0.377
Total Non-Road Transportation	**2.044**	**1.586**	**0.669**	**0.850**	**0.921**	**1.040**

Table A-26. Non-Road Equipment Black Carbon Emissions. (MMT CO2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Diesel	1.44	1.35	1.18	1.08	0.88	0.64
Gasoline	0.14	0.14	0.14	0.12	0.12	0.10
Other	0.01	0.01	0.02	0.02	0.02	0.02
Total Non-Road Equipment	**1.59**	**1.51**	**1.33**	**1.21**	**1.01**	**0.75**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Diesel	5.05	4.74	4.14	3.79	3.09	2.25
Gasoline	0.51	0.50	0.50	0.42	0.41	0.34
Other	0.04	0.05	0.06	0.06	0.06	0.06
Total Non-Road Equipment	**5.60**	**5.29**	**4.69**	**4.27**	**3.55**	**2.65**

Table A-27. Electric Sector Black Carbon Emissions (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Biomass	0.000	0.000	0.000	0.000	0.000	0.000
Coal	0.155	0.150	0.142	0.008	0.008	0.002
Natural Gas	0.035	0.036	0.039	0.028	0.035	0.029
Oil	0.042	0.034	0.017	0.041	0.034	0.009
Other	0.002	0.003	0.004	0.004	0.005	0.003
Total Electric Generation	**0.234**	**0.223**	**0.202**	**0.081**	**0.082**	**0.044**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Biomass	0.000	0.000	0.000	0.000	0.000	0.000
Coal	0.544	0.528	0.498	0.029	0.029	0.009
Natural Gas	0.122	0.127	0.136	0.098	0.122	0.101
Oil	0.149	0.119	0.060	0.145	0.121	0.033
Other	0.007	0.009	0.015	0.014	0.016	0.012
Total Electric Generation	**0.821**	**0.784**	**0.709**	**0.286**	**0.289**	**0.154**

Table A-28. Residential Black Carbon Emissions (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Natural Gas	0.003	0.003	0.003	0.003	0.003	0.003
Oil	0.031	0.027	0.018	0.015	0.013	0.008
Other	0.000	0.000	0.000	0.000	0.000	0.000
Wood	0.431	0.376	0.265	0.290	0.230	0.254
Total Residential	**0.465**	**0.405**	**0.286**	**0.308**	**0.246**	**0.265**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Natural Gas	0.009	0.009	0.009	0.009	0.010	0.009
Oil	0.108	0.094	0.064	0.053	0.046	0.029
Other	0.001	0.001	0.000	0.000	0.000	0.000
Wood	1.516	1.322	0.933	1.020	0.809	0.895
Total Residential	**1.635**	**1.426**	**1.007**	**1.082**	**0.865**	**0.934**

Table A-29. Black carbon emissions from the Commercial Sector, except non-road equipment. (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Commercial Cooking	0.075	0.069	0.058	0.061	0.060	0.105
Biomass	0.000	0.000	0.000	0.002	0.010	0.011
Coal	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas	0.004	0.004	0.004	0.003	0.005	0.004
Oil	0.050	0.052	0.055	0.018	0.032	0.019
Other	0.001	0.001	0.001	0.001	0.001	0.000
Total Commercial	**0.130**	**0.126**	**0.117**	**0.084**	**0.107**	**0.139**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Commercial Cooking	0.262	0.243	0.204	0.213	0.212	0.370
Biomass	0.000	0.000	0.000	0.006	0.036	0.040
Coal	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas	0.015	0.014	0.013	0.012	0.016	0.013
Oil	0.177	0.182	0.193	0.063	0.112	0.067
Other	0.002	0.002	0.002	0.002	0.002	0.001
Total Commercial	**0.457**	**0.442**	**0.412**	**0.296**	**0.378**	**0.490**

Table A-30. Black carbon from industrial fuel combustion (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Biomass	0.000	0.000	0.000	0.002	0.010	0.011
Coal	0.0002	0.0001	0.000	0.000	0.000	0.000
Natural Gas	0.004	0.004	0.004	0.003	0.005	0.004
Oil	0.050	0.052	0.055	0.018	0.032	0.019
Other	0.001	0.001	0.001	0.001	0.001	0.000
Total Industrial Fuel Combustion	**0.055**	**0.057**	**0.059**	**0.024**	**0.047**	**0.034**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Biomass	0.000	0.000	0.000	0.006	0.036	0.040
Coal	0.0006	0.0004	0.000	0.000	0.000	0.000
Natural Gas	0.015	0.014	0.013	0.012	0.016	0.013
Oil	0.177	0.182	0.193	0.063	0.112	0.067
Other	0.002	0.002	0.002	0.002	0.002	0.001
Total Industrial Fuel Combustion	**0.195**	**0.199**	**0.208**	**0.083**	**0.166**	**0.120**

Table A-31. Industrial Process Black Carbon (metric tonnes (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Cement Mfg.	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000
Chemical Mfg.	0.00092	0.00077	0.00048	0.00080	0.00031	0.00028
Ferrous Metals	0.00068	0.00059	0.00040	0.00013	0.00012	0.00010
Mining	0.00200	0.00221	0.00262	0.00211	0.00001	0.00001
Other	0.00870	0.00860	0.00840	0.00661	0.00542	0.00630
Non-ferrous Metals	0.00020	0.00017	0.00013	0.00009	0.00015	0.00012
Oil & Gas Production	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Petroleum Refineries	0.00493	0.00621	0.00876	0.00109	0.00121	0.00106
Pulp & Paper	0.00132	0.00098	0.00029	0.00009	0.00046	0.00056
Storage and Transfer	0.00050	0.00047	0.00040	0.00032	0.00015	0.00035
Industrial Surface Coating & Solvent Use	0.00029	0.00033	0.00042	0.00013	0.00013	0.00009
Total Industrial Processes	**0.01955**	**0.02033**	**0.02191**	**0.01137**	**0.00795**	**0.00887**

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Cement Mfg.	0.00005	0.00003	0.00000	0.00000	0.00000	0.00000
Chemical Mfg.	0.00324	0.00272	0.00169	0.00281	0.00109	0.00097
Ferrous Metals	0.00238	0.00206	0.00142	0.00044	0.00044	0.00035
Mining	0.00703	0.00776	0.00921	0.00741	0.00004	0.00005
Other	0.03061	0.03025	0.02954	0.02326	0.01904	0.02215
Non-ferrous Metals	0.00069	0.00061	0.00045	0.00032	0.00051	0.00041
Oil & Gas Production	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
Petroleum Refineries	0.01732	0.02182	0.03082	0.00384	0.00425	0.00373
Pulp & Paper	0.00464	0.00343	0.00101	0.00032	0.00160	0.00196
Storage and Transfer	0.00175	0.00164	0.00142	0.00112	0.00053	0.00124
Industrial Surface Coating & Solvent Use	0.00102	0.00117	0.00148	0.00046	0.00046	0.00032
Total Industrial Processes	**0.06874**	**0.07150**	**0.07704**	**0.04000**	**0.02797**	**0.03118**

Table A-32. Wildfires, Prescribed Burns, and Related Sources (MMT CO_2e)

GWP_{100}

Year	2005	2006	2008	2011	2014	2017
Forest Wildfires[1]	0.000	0.007	0.021	0.005	0.106	0.016
Prescribed Burning[1]	0.000	0.007	0.022	0.032	0.090	0.040
Agricultural Fires	0.018	0.018	0.019	0.017	0.016	0.020
Structural Fires	0.003	0.003	0.002	0.003	0.003	0.006
Misc. Other	0.017	0.012	0.003	0.002	0.002	0.002
Total	**0.021**	**0.036**	**0.064**	**0.058**	**0.214**	**0.082**

[1] Wildfires and prescribed burns included in "Misc. Other" category prior to 2008.

GWP_{20}

Year	2005	2006	2008	2011	2014	2017
Forest Wildfires[1]	0.000	0.025	0.075	0.019	0.372	0.057
Prescribed Burning[1]	0.000	0.026	0.077	0.114	0.315	0.139
Agricultural Fires	0.064	0.065	0.066	0.059	0.056	0.070
Structural Fires	0.011	0.010	0.008	0.012	0.011	0.022
Misc. Other	0.060	0.043	0.010	0.007	0.006	0.007
Total	**0.075**	**0.126**	**0.226**	**0.204**	**0.754**	**0.288**

[1] Wildfires and prescribed burns included in "Misc. Other" category prior to 2008.

APPENDIX B. METHODS

B.1. GLOBAL WARMING POTENTIALS

Global Warming Potentials (GWP) values used in this report (Table B-1) were taken from IPCC AR4, Climate Change 2007 - The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the IPCC, 2007, Table 2.14, pages 212-213. Use of GWP_{100} values from AR4 Table 2.14 is required when conducting national assessments pursuant to international reporting requirements. GWP values for black carbon were from Section 12.1 of T. C. Bond, et al., Bounding the role of black carbon in the climate system: a scientific assessment. J. Geophysical Research, Vol 118, pp. 5380-5552, 2013, and are cited by the IPCC.

Table B-1 Global Warming Potentials

Climate Pollutant	GWP_{100}	GWP_{20}	Reference
Carbon Dioxide (CO_2)	1	1	IPCC AR4 Table 2.14
Methane (CH_4)	25	72	IPCC AR4 Table 2.14
Nitrous Oxide (N_2O)	298	289	IPCC AR4 Table 2.14
Sulfur Hexafluoride (SF_6)	22,800	16300	IPCC AR4 Table 2.14
Hydrofluorocarbons	See Reference	See Reference	IPCC AR4 Table 2.14
Black Carbon	910	3200	Bond, et al., 2013

B.2. COMMERCIAL, FUEL-BASED INDUSTRIAL, AND RESIDENTIAL SECTOR EMISSIONS

Residential, commercial and fuel-based industrial sector emissions were estimated by multiplying the amounts of applicable fuels sold within the sector by appropriate emissions factors. The fuel sales data was provided by the US Energy Information Agency (USEIA) State Energy Data System[79] (Tables B-2, B-3 and B-4). Emissions factors were from the USEPA[80] or, if unavailable from the USEPA, from the USEIA.[81] Emissions factors were adjusted to include methane and nitrous oxide in addition to carbon dioxide.

In accordance with USEPA and IPCC practice, emissions of CO_2 from wood are not included because they are considered biogenic, meaning that they arise from natural sources rather than fossil fuels and do not represent a net increase in atmospheric carbon dioxide.[82] Emissions from loss of wooded land are addressed in the measurement of carbon fluxes associated with clearing of land, which is a separate category in the inventory.

Fuel ethanol is not included because the majority is produced from biogenic materials such as grain. It is also primarily used as a blending agent for motor gasoline, and is therefore included in emissions estimates for that fuel.

Within the industrial sector, petroleum coke is generated as a biproduct of hydrocarbon fracking at refineries. This material can be combusted as a fuel, thereby contributing to emissions, or it can be used as a feedstock in

[79] https://www.eia.gov/state/seds/

[80] https://www.epa.gov/climateleadership/ghg-emission-factors-hub

[81] https://www.eia.gov/environment/emissions/co2_vol_mass.php

[82] IPCC, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Section 8.2.1.

USEPA, 2021. Inventory of U.S. Greenhouse Gas Emissions and Sinks, EPA430-R-21-005, Section 3.11.

Extremely small amounts of methane and nitrous oxide can be produced during combustion of wood, but the quantities are not considered large enough to significantly affect the overall totals in this report and are not included. However, wood combustion is included in the black carbon analysis in this report.

the manufacture of devices such as electrodes. The USEIA documents the sale of petroleum coke in New Jersey, and the USEPA default method for emissions calculations assumes that this material is combusted within the state. Consistent with this protocol, for years prior to 2014 this report assumes that all petroleum coke sold in the state was combusted and contributed to emissions. However, the NJDEP has documented that petroleum coke has not been combusted in the state starting in 2014, the material being exported out of the state for use as a feedstock. Industrial emissions estimates for 2014 and subsequent years therefore exclude petroleum coke.

Hydrocarbon gas liquids (HGLs) are a category of fuel that includes propane, butane, and a number of related compounds. In 2010, USEIA made significant changes to its methods for estimating individual HGL components and also separated out certain materials.[83] This is reflected in the emissions record.

Table B-2. EIA Fuel Consumption Categories for the Commercial Sector[84]

Data Category Name	EIA Mnemonic Series Name (MSN)
Coal consumed by the commercial sector	CLCCB
Distillate fuel oil consumed by the commercial sector	DFCCB
Hydrocarbon gas liquids consumed by the commercial sector (propane)	HLCCB
Kerosene price in the commercial sector	KSCCB
Motor gasoline consumed by the commercial sector	MGCCB
Natural gas consumed by (delivered to) the commercial sector	NGCCB
Residual fuel oil consumed by the commercial sector	RFCCB

Table B-3. EIA Fuel Consumption Categories for the Industrial Sector[85]

Data Category Name	EIA Mnemonic Series Name (MSN)
Coal consumed by the industrial sector	CLICB
Distillate fuel oil consumed by the industrial sector	DFICB
Kerosene consumed by the industrial sector	KSICB
Motor gasoline consumed by the industrial sector	MGICB
Natural gas consumed by (delivered to) the industrial sector	NGICB
Petroleum coke consumed by the industrial sector, only included through 2013. Zero for subsequent years.	PCICB
Residual fuel oil consumed by the industrial sector	RFICB
Still gas consumed by the industrial sector	SGICB
Hydrocarbon gas liquids (HGL) consumed by the industrial sector	
For years through 2009, HGL is:	
Hydrocarbon gas liquids consumed by the industrial sector	HLICB
For years 2010 onward, HGL is the sum of:	
Butylene from refineries consumed by the industrial sector	BQICB
Butylene from refineries consumed by the industrial sector	BYICB
Ethane consumed by the industrial sector	EQICB
Ethylene from refineries consumed by the industrial sector	EYICB

[83] USEIA, Technical Notes on the State Energy Data System: Consumption, Section 4, Petroleum, Hydrocarbon Gas Liquids
[84] The MSN codes shown in this table identify the data fields in the USEIA data that were used to calculate emissions. See https://www.eia.gov/state/seds/ for additional information.
[85] The MSN codes shown in this table identify the data fields in the USEIA data that were used to calculate emissions. See https://www.eia.gov/state/seds/ for additional information.

Isobutane consumed by the industrial sector	IQICB
Isobutylene from refineries consumed by the industrial sector	IYICB
Natural gasoline (pentanes plus) consumed by the industrial sector	PPICB
Propane consumed by the industrial sector	PQICB
Propylene from refineries consumed by the industrial sector	PYICB

Table B-4. EIA Fuel Consumption Categories for the Residential Sector[86]

Data Category Name	EIA Mnemonic Series Name (MSN)
Coal consumed by the residential sector	CLRCB
Distillate fuel oil consumed by the residential sector	DFRCB
Hydrocarbon gas liquids consumed by the residential sector (propane)	HLRCB
Kerosene consumed by the residential sector	KSRCB
Natural gas consumed by (delivered to) the residential sector	NGRCB

B.3. TRANSPORTATION

On-Road Transportation

On-road emissions estimates for 2006, 2018 and 2019 were found using the third release of the USEPA MOtor Vehicle Emission Simulator (MOVES3) transportation emissions model for on-road estimates. MOVES3 produces detailed emissions profiles useing specific, county-by-county information on vehicle types and ages, miles traveled by each of numerous vehicle categories, and regional fuel characteristics.

Estimates for 1990, 2005, and 2007-2017, were based on USEIA fuel sales data for the entire transportation sector, apportioned to the on-road sector and then scaled to align with MOVES3 output. Specifically, the USEIA fuel sales estimates for each applicable fuel type in the transportation sector were apportioned to on-road transportation based on Table 3-13 of the 2021 USEPA Inventory of US Greenhouse Gas Emissions and Sinks.[87] As an example, in 2006, 98.8% of gasoline emissions in the transportation sector were attributed by USEPA to on-road vehicles, with the remainder arising from boats. This fraction (98.8%) was then assumed to equal the fraction of transportation-sector gasoline used in New Jersey for on-road use. An initial emissions estimate for each applicable fuel type was then found by multiplying NJ on-road fuel consumption by the respective emissions factor. Fuels considered included motor gasoline, distillate fuel oil (diesel), natural gas (CNG), and propane.

These initial fuel-based estimates were then compared with MOVE3 output for 2006 and 2018. On-road emissions based on fuel sales were 7.9% greater than the MOVES3 estimate for 2006 and 5.6% greater than the MOVES3 estimate for 2018.[88] To align estimates based on fuel sales with those from MOVES3, adjustment factors based on the ratio of MOVES3 to fuel estimates were interpolated for years between 2006 and 2018 and applied to the fuel-based estimates for the respective years. For 1990 and 2005, the adjustment factor for 2006 was applied.

[86] The MSN codes shown in this table identify the data fields in the USEIA data that were used to calculate emissions. See https://www.eia.gov/state/seds/ for additional information.

[87] USEPA, include citation Note that we used the .csv file. https://www.epa.gov/sites/default/files/2021-05/chapter.zip

[88] Fuel-based emissions may differ from those based on MOVES3 due to factors such as out-of-state vehicles refueling in New Jersey and returning to their home state, and imprecision in the emissions factors applied to fuel sales estimates.

Aviation

USEIA jet fuel sales data combines fuel used at both New Jersey and New York airports. USEIA acknowledges this limitation and has indicated that their data has not been corrected to account for this. [89] A second concern is that total fuel sales are a poor proxy for actual in-state emissions because substantial quantities of commercial jet fuel are consumed in flight outside the state. Both of the above factors lead to greatly overstated emissions estimates. A prior analysis by NJDEP[90] concluded that aviation emissions that occur within the state total approximately 1.0 MMT CO_2e annually, based on either GWP_{100} or GWP_{20}. This figure is generally consistent with the estimate of 0.813 MMT CO_2e found by USEPA in the 2017 National Emissions Inventory. [91] The NEI estimate is based on the Federal Aviation Administration's Aviation Environmental Design Tool (AEDT) model, which quantifies emissions based on landing and takeoff activity and aircraft performance data rather than records of bulk fuel sales. [92] The NEI estimate includes emissions from commercial, general, and military aviation sources within the state. Although the NEI estimate does not include methane or nitrous oxide, emissions of these components are expected to be small.

Marine Transportation

Marine emissions estimates were based on USEIA fuel sales data for residual oil, distillate fuel, and gasoline in the transportation sector. Fuel was apportioned to domestic marine activity based on fuel application data in Table 3-13 of the USEPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2019 (2021). [93] These fuel quantities were then multiplied by emissions factors for the fuel type that accounted for CO_2, methane, and nitrous oxide. Because fuel sales data is only applicable to transactions in the state of New Jersey, estimates do not account for fuel brought to New Jersey from elsewhere or purchased here and then carried away for use elsewhere. Fluctuations in apparent emissions may therefore represent changes in market conditions rather than underlying marine activity.

Rail Transportation

USEIA data on in-state sales of distillate fuel do not accurately reflect rail activity because much of rail transit is interstate. Fuel may therefore be easily purchased from vendors out-of-state and used in New Jersey as needed. Specifically, these records show that very little distillate fuel is sold inside in the state for rail use. [94] (Figure B-1) Similar effects can be seen in Delaware and Maryland sales records, while Pennsylvania and New York sales often increase when the other states decrease. However, the combined sales quantities across the region[95] have remained relatively constant for many years (Figure B-2).

In order to reduce the influence of interstate transfers, New Jersey rail distillate consumption was approximated by multiplying New Jersey's total distillate sales (for all sectors) by the fraction of distillate sold regionally for rail use. [96] This metric responds to overall changes in New Jersey distillate sales across all sectors, including rail,

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[89] USEIA, Technical Notes, State Energy Data 2019: Consumption. Section 4, pages 57-58, Jet Fuel, Note 3. https://www.eia.gov/state/seds/seds-technical-notes-complete.php?sid=US#Consumption

[90] New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990-2020, November 2008, Appendix C. https://dep.nj.gov/ghg/

[91] Sum of CO_2 emissions for SCC codes 2275050011, 2275050012, 227506001, 2275060012, 2275020000 and 2275001000. https://gaftp.epa.gov/air/nei/2017/data_summaries/2017v1/2017neiJan_facility_process_byregions.zip

[92] 2017 NEI Technical Support Document, Section 3.2, page 3-17 ff. https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-technical-support-document-tsd

[93] Data was taken from the comma-delimited format file of Table 3-13, downloaded from https://www.epa.gov/sites/default/files/2021-05/chapter.zip. Note that the annual total amounts for some years do not include international bunker quantities while others do.

[94] Based on USEIA Fuel Oil and Kerosene Sales (FOKS) data. https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=KD0VALSNJ1&f=A

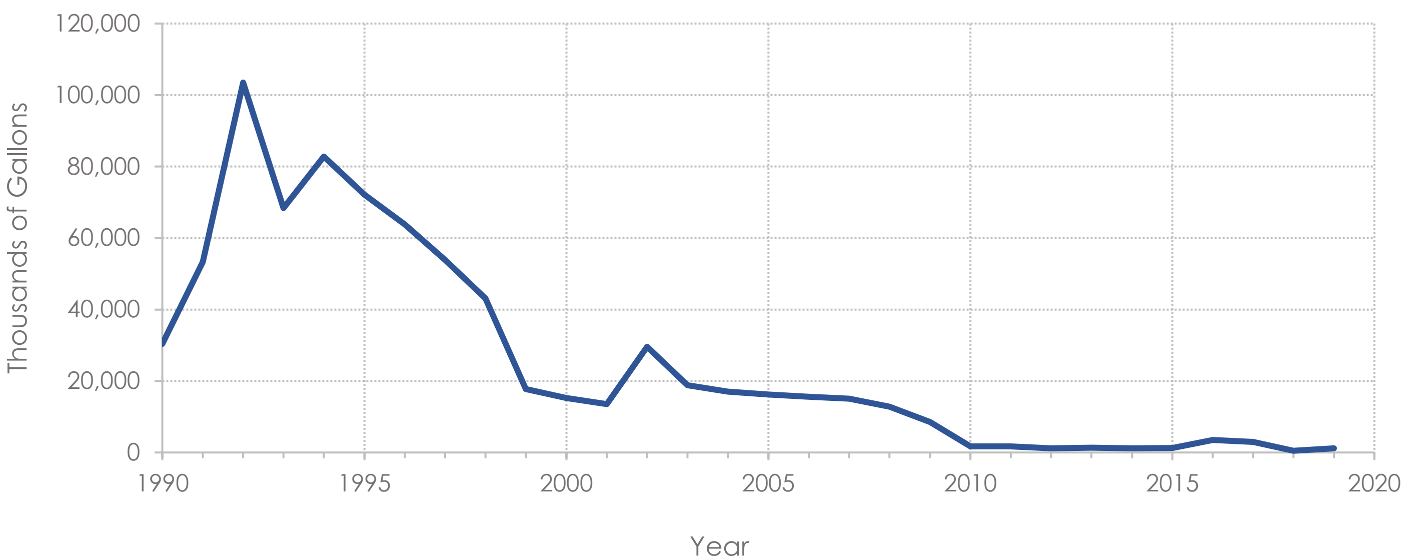
[95] USEIA defines the PADD 1B region as NJ, NY, PA, DE, MD and the District of Columbia.

[96] Calculated using USEIA Fuel Oil and Kerosene Sales (FOKS) data. The energy content per barrel of distillate for each given year was taken from the USEIA State Energy Data System, MSN Code DFTCK.

and to regional transitions in rail operations, but will not precisely reflect the benefits of rail electrification actions taken in New Jersey. It also does not account for interstate transfers of fuel into or out of the overall region. Evaluation of specific policies may therefore require individual assessments of effectiveness. Nonetheless, the approach used here does provide a general indication of rail fuel consumption in the state.

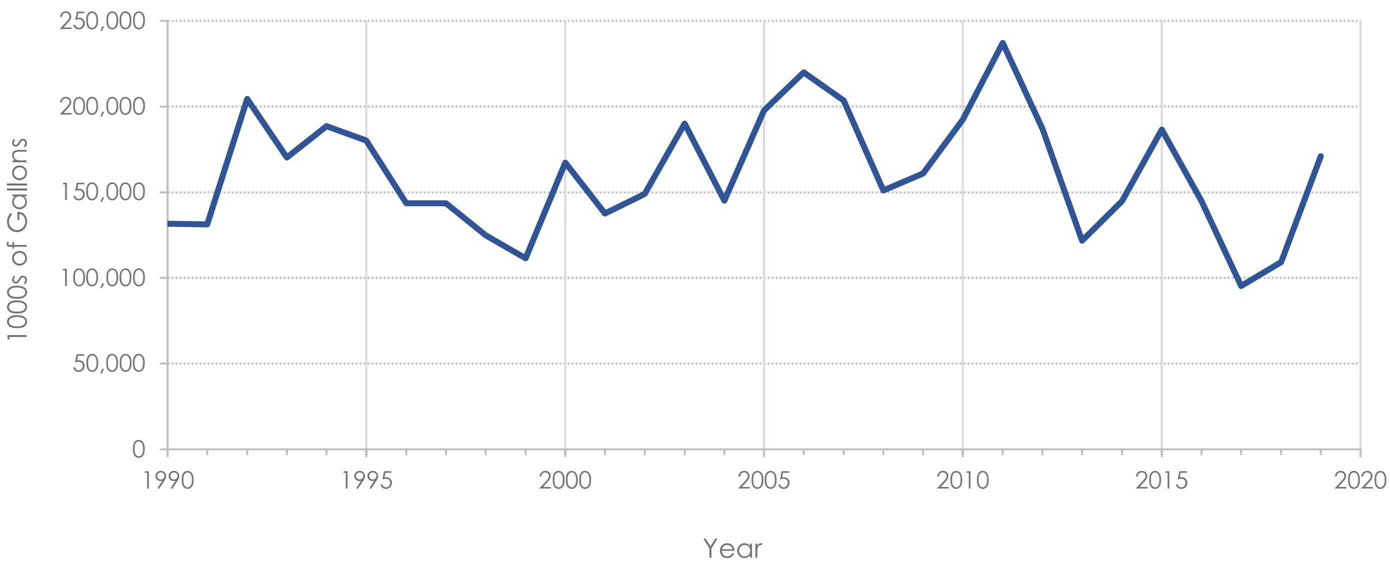
To evaluate the accuracy of this approach, estimated emissions for 2016 were compared to estimates based on in-state fuel consumption data provided previously to the Department by individual rail carriers. Estimates from the two methods agreed within 0.2%. Specifically, estimated emissions based the regional allocation approach were 0.2753 MMT CO_2e (GWP_{100}), and estimates based on rail-carrier submitted fuel use were 0.2758 MMT CO_2e.[97]

Figure B-1. Sales of distillate fuel to the rail sector recorded in New Jersey



[97] Estimated emissions using GWP_{20} were 0.2758 MMT CO_2e based on the regional allocation approach and 0.2763 MMT CO_2e based on the rail-carrier provided fuel consumption data, again with a difference of less than 0.2%. The underlying uncertainties in the data are likely greater than this close level of agreement suggests.

Figure B-2. Sales of distillate fuel to the rail sector recorded in the EIA PADD 1B region



B.4. ELECTRICITY

Emissions from In-State Generating Facilities

For 2005 onward, carbon dioxide and methane mass emissions for in-state electric generating facilities filing under NAICS codes 221112 and 22111 were taken from the NJDEP Emissions Statement Database. To find nitrous oxide emissions, the implied thermal input based on CO_2 emissions statement data was divided by the USEPA emissions factor for natural gas. [98] Although coal was used more extensively in earlier years, the assumption of all natural gas did not alter the overall emissions estimates due to the small quantities of N_2O involved. Estimated N_2O emissions were then found by multiplying the implied thermal input by USEPA emissions factors for N_2O. CO_2e was found by multiplying mass amounts of CO_2, CH_4 and N_2O by their corresponding GWP and summing.

Emissions from Imported electricity

Imported electricity was found by subtracting the amount of electricity generated in the state from the amount of retail electricity sold in New Jersey, based on USEIA data.[99] For each individual year from 2005 onward, CO_2e emissions rates were calculated based on grid emissions data from the PJM GATS system mix table. [100] Specifically, for each fuel type listed in PJM GATS, the amount of power produced (in MWh) and the mass of CO_2 generated (in pounds) is listed. For a given fuel, the amount of power input necessary to generate the quantity of CO_2 listed was calculated using IPCC CO_2 emissions factors.[101] Mass emissions of methane and nitrous oxide were then found by applying corresponding IPCC emissions factors based on the energy input amount as calculated above.[102] CO_2e quantities for methane and nitrous oxide were found using corresponding GWPs (both 100 year and 20 year). The total CO_2e of methane produced and the total CO_2e of nitrous oxide produced were found by summing the contributions of the given gas from all fuels. Emissions rates of CO_2,

[98] https://www.epa.gov/climateleadership/ghg-emission-factors-hub

[99] Retail sales data was from USEIA SEDS https://www.eia.gov/state/seds/seds-data-complete.php. Retail sales data is listed under Mnemonic Series Name (MSN) ESTCP. Annual generation data was from https://www.eia.gov/electricity/data/state/ "Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920, and EIA-923)"

[100] https://gats.pjm-eis.com/gats2/PublicReports/PJMSystemMix

[101] 2006 IPCC Guidelines for GHG Inventories Vol. 2, Energy, pages 1.23 and 1.24. https://www.ipcc-nggip.iges.or.jp/public/2006gl

[102] 2006 IPCC Guidelines for GHG Inventories Vol. 2, Energy, pages 2.16 and 2.17. https://www.ipcc-nggip.iges.or.jp/public/2006gl

methane and nitrous oxide per MWh generated were found by dividing the respective CO_2e values for each gas by the overall total power produced. The overall rate of CO_2e generation was taken as the sum of the CO_2e production rates for each of the three gases. Emission rates were further increased by 7% to account for transmission losses.

Emissions from imported electricity for a given year were found by multiplying the amount of imported electricity for that year by the adjusted PJM emissions factor for that year as calculated above. Estimates for years prior to 2005 used the 2005 PJM emissions factor. The emissions factors were based on the annual emissions from the entirety of the PJM grid area.

Emissions from Solid Waste Incineration

Waste-to-energy emissions for 2005 onward were based on carbon dioxide and methane mass emissions for in-state waste-to-energy generating facilities filing under NAICS code 562213 were taken from the NJDEP Emissions Statement Database. Thermal input was estimated from CO_2 emissions using the USEPA CO_2 emissions factor for municipal solid waste, and N_2O was then estimated by multiplying the thermal input by the MSW emissions factor for N_2O. Mass amounts for CO_2, CH_4 and N_2O were multiplied by their respective GWP and the amounts summed to find the total emissions on a CO_2e basis. Carbon dioxide from biological sources (biogenic waste) is excluded based on IPCC guidelines. To find non-biogenic emissions, the fraction of biogenic to total emissions was assumed equal to the ratio of biogenic to total fuel input, in MMBTUs, as reported on EIA Form 923. Specifically, the sum of biogenic fuel energy inputs under fuel code MSB was divided by the sum of all fuel energy inputs used at the solid waste incinerators to find the biogenic ratio. Quantities of fossil fuels used at the facilities, including distillate, natural gas, and other gases, were less than 0.4% of total energy input with the remainder being solid waste. The non-biogenic fraction was taken as the balance (1 - biogenic fraction). Total emissions from the solid waste incinerators (in CO_2e) were multiplied by the non-biogenic fraction to find the applicable greenhouse gas emissions identified in the report.

Solar Photovoltaic Capacity and Output

Installed solar capacity was taken from NJBPU Solar Activity Reports.[103] Solar PV power output was estimated using the NJBPU ten-year average Specific Energy Production (SEP) factor of 1,154 MWh power/MW capacity.[104] Power production other than solar PV was from USEIA generation data.[105]

B.5. NON-ENERGY EMISSIONS

Halogenated Gases (excluding sulfur hexafluoride)

HFCs emissions were based on the US Climate Alliance (USCA) GHG Inventory Tool for HFCs, Methane and Black Carbon (July 24, 2019). The tool was prepared by the California Air Resources Board (CARB) using their F-Gas Emission Inventory Model. CARB converted output from the F-Gas model to a per person, per household or per vehicle basis, depending on use, and then applied these values to individual USCA states, including New Jersey. Reductions due to SNAP policy implementation from the USCA tool were then adjusted to align with New Jersey SNAP implementation dates based on P.L. 2019 c. 507.

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[103] NJBPU, "REPORTS - INSTALLED - November 2021.xlsx." https://njcleanenergy.com/renewable-energy/project-activity-reports/project-activity-reports

[104] The SEP was taken from NJBPU, Monthly Report on Status toward Attainment of the 5.1% Milestone for Closure of the SREC Program, February 7, 2020, and was in turn based on data provided by PJM-EIS. https://njcleanenergy.com/files/file/Notice%20on%205-1%20Percent%20Milestone.pdf

[105] https://www.eia.gov/electricity/data/state/annual_generation_state.xls

Non-Fuel Agricultural Emissions

Non-fuel agricultural emissions were found using the USPEA State Inventory Tool's 2022 Carbon Dioxide, Methane and Nitrous Oxide Emissions from Agriculture module. Default inputs were used. Emissions estimates include enteric fermentation, manure management, agricultural soils, urea fertilization, and agricultural residue burning.

Natural Gas Transmission and Distribution

Emissions from natural gas transmission and distribution were found using the USEPA State Inventory Tool's 2022 Emissions from Natural Gas and Oil Systems module. The numbers of transmission compressor stations for 2002 onward were based on the NJ Emission Statement Database. For prior years, the number was prorated from the 2002 value based on the number of miles of transmission pipeline. The number of miles of transmission pipeline, miles and types of distribution pipelines, and numbers and types of service connections were obtained from the US Department of Public Safety Hazardous Materials and Safety Administration.[106] Default values were used for other inputs to the State Inventory Tool.

Landfills

In-state landfill emissions and industrial landfill emissions were found using the USEPA State Inventory Tool 2022 Solid Waste Module. The module uses a first order decay calculation based on historical landfill deposits. Landfilled waste quantities for 1960 through 1984 were the default values provided in the module. Quantities for 1985 through 2003 were calculated from the NJ 2006 Solid Waste Management Plan Table A-1, adjusted for waste-to-energy disposal using waste incineration data from USEIA forms 906 and 923. The quantity for 2004 was the EPA SIT default, which is based on Biocycle annual solid waste survey data. Quantities for 2005 onward were provided by the NJDEP Bureau of Solid Waste Permitting. Other inputs to the module were based on default values provided in the Tool by USEPA.

For 2005 onward, the quantity of waste disposed of out of state was provided by the NJDEP Bureau of Solid Waste Permitting. For prior years, the amount was taken from the 2006 NJ Solid Waste Management Plan, Table A-1. To find emissions from out-of-state disposal, the ratio of waste disposed of out of state to waste disposed of by in-state landfill was found. Where necessary, adjustments for in-state incineration were made as noted for in-state emissions. The quantity of waste disposed of out-of-state was unavailable for 2004, so the ratio for that year was found by averaging the values for 2003 and 2005. Out-of-state emissions were then found by multiplying in-state landfill emissions by the ratio of out-of-state to in-state landfill waste disposal quantities.

Wastewater Treatment

Emissions from wastewater treatment processes were calculated using the Wastewater module from the USEPA 2022 State Inventory Tool.[107] USEPA default inputs were used for all calculations.

[106] https://www.phmsa.dot.gov/

[107] Emissions arising from consumption of fuel at water and wastewater treatment plants is included in the Commercial Sector calculations.

Non-Fuel Industrial Emissions

Releases of carbon-dioxide from industrial processes, other than those associated with consumption of fuel, were found using the Industrial Process Module from the USEPA 2022 State Inventory Tool. USEPA default values were used for all calculations.

Emissions Due to Land Clearing

The method employed is highly proximate using the land use change estimates for major land use categories based on land use land cover (LULC) data. For the developed/urban land category, a metric used in land-use zoning regulations called *floor area ratio* (FAR) is utilized. According to the planning literature, FAR is "a mathematical formula that determines how many square feet can be developed on a property in proportion to the lot area. The property area is multiplied by the FAR factor; with the result being the maximum floor area allowed for a building on the lot." FAR is the ratio of two measures: (a) average floor size, and average lot size. The source of data for these is the U.S. Census Bureau. For years since 1992, data for the Northeast are used. Prior to 1992, average data for the entire U.S. are used. For simplicity, data for new single family houses are used as proxy for building structures. The other parameter to be computed is the share of forest land against the total of bare or barren and forest land combined. This serves as proxy for vegetative cover. Multiplying the developed/urban land increase by the FAR factor and the vegetative cover parameter yields an estimate of the biomass carbon loss. This result is then added to the biomass and soil carbon losses from the other land uses as calculated in the *Sequestration* component of the inventory. This yields the aggregated carbon loss due to land conversion. The estimate is converted to the carbon dioxide equivalent by multiplying it by 3.67.

Sulfur Hexafluoride (SF_6)

Sulfur hexafluoride emissions were found using the USEPA State Inventory Tool's 2022 Industrial Process module with default inputs.

B.6. CARBON SEQUESTRATION

The natural carbon sequestration estimation in the NJ GHG Inventory was based on Land Use and Land Use Change (LULUC) using NJDEP GIS data for developed/urban land, crop/grass land (agricultural land), upland forest, bare land, and wetlands. The carbon stock change method was used to calculate sequestration (carbon removed per acre per year) based on land use change from one period to another. NJDEP GIS data is updated at multi-year intervals, and annual emission rates in the GHG Inventory Report are revised when updated GIS data becomes available. The most recent NJDEP GIS data is for 2015. Carbon stock changes were computed based on an estimate of forest biomass at 49 metric ton per acre is based on Lathrop et al. (2011)[108] Lathrop (2011) also concluded that forest soil carbon is 40% of the total forest carbon amount. Other biomass quantities and rate of change factors are from Chapter H of New Jersey GHG Inventory and Reference Case Projections 1990-2020 (November 2008), which in turn were adapted from IPCC and other sources.[109]

[108] R.G. Lathrop, B. Clough, A. Cotrell, J. Ehrenfeld, F. Felder, Edwin J. Green, D. Specca, C. Vail, M. Vodak, M. Xu, Y. Zhang, Assessing the Potential for New Jersey Forests to Sequester Carbon and Contribute to Greenhouse Gas Emissions Avoidance. Rutgers University, March 2011. https://crssa.rutgers.edu/projects/carbon/RU_Forest_Carbon_final.pdf. Accessed January 20, 2022.

[109] [a] Biomass carbon density: 38 metric tons (Mt)/acre (forest), 4 Mt/acre (grassland), 2 Mt/acre (bare land), 1.2 Mt/acre (cropland); [b] soil carbon density: 8 Mt/acre (bare land) and 24 Mt/acre (forest land); [c] biomass density increase: 1% per year; [d] soil carbon density increase: 1% per year; and [e] amount of carbon stored in forest products: 12 Mt/acre. Assumed 50% of forest removal converted to wood products. Factor used to convert wood volume to weight: 3 pounds per board foot.

B.7. BLACK CARBON

Black carbon is a component of the broader class of fine particulate matter having diameter of 2.5 µm or less ($PM_{2.5}$). When fine particulate matter is created, the amount of black carbon that is produced depends on the materials consumed and the process by which the particulates are created. The proportion of black carbon in a particulate emission is referred to as the speciation factor (SF), and this factor can be used to estimate black carbon emissions from $PM_{2.5}$ emissions data. Specifically, knowing the emissions of $PM_{2.5}$ from a particular activity, the black carbon can be estimated by multiplying the amount of $PM_{2.5}$ by the speciation factor:

$$BC = PM_{2.5} \times SF$$

where
BC is the mass of black carbon,
$PM_{2.5}$ is the mass of particulate matter with diameter of 2.5 µm or less, and
SF is the speciation factor.

The quantity of CO_2e is found by multiplying the mass of black carbon by its global warming potential (GWP_{100} or GWP_{20}).

The USEPA has assembled an extensive database of speciation factors based on a wide range of research studies,[110] and $PM_{2.5}$ data has been collected for many years as part of the NEI. It is therefore possible to estimate historical black carbon emissions using $PM_{2.5}$ records from the NEI. USEPA used this method to calculate black carbon emissions in the 2014 and 2017 NEIs. In most cases, this was done by directly multiplying $PM_{2.5}$ by the speciation factor. For black carbon emissions from on-road activities USEPA used the MOVES model, which applies speciation methods internally under a range of conditions.

In preparing its historical analysis, DEP applied the same speciation factors used by USEPA for the 2017 NEI to NEI $PM_{2.5}$ data[111] for 2005, 2008, 2011, and 2014. 2017 NEI data was also run as a check. However, EPA's 2017 speciation factor list did not include factors for all source categories in the 2017 NEI, and those factors were estimated by taking the ratio of black carbon and $PM_{2.5}$ in the published 2017 NEI records. Also, certain categories in older releases of the NEI were later reclassified, and in those cases speciation factors from the 2017 NEI for similar sources were applied.

For on-road source categories, NJDEP used the MOVES3 transportation emissions model for years 2006, 2018 and 2019. MOVES3 is the current standard for regulatory submissions to the USEPA, and is the successor to earlier models such as MOBILE and MOVES 2014.[112] For other years, on-road emissions estimates were taken from the USEPA EQUATES program.[113] On-road emissions from the EQUATES program are also based on MOVES3, but because of its national scope it relies on representative data and national default inputs. In particular, input data available to USEPA for years prior to 2011 were limited, increasing the level of uncertainty in those results. DEP developed input data and ran MOVES3 for each individual county, while EQUATES estimated emissions rates for six representative counties and then applied those rates to the remaining parts of the State. A further consideration is that EQUATES only ran MOVES3 for the NEI years (2002, 2005, 2008, 2011, 2014 and 2017) and then adjusted those figures to find values for the adjacent years. In particular, their 2006 estimate is based on 2005 results that were adjusted for the later year. The adjustments for adjacent

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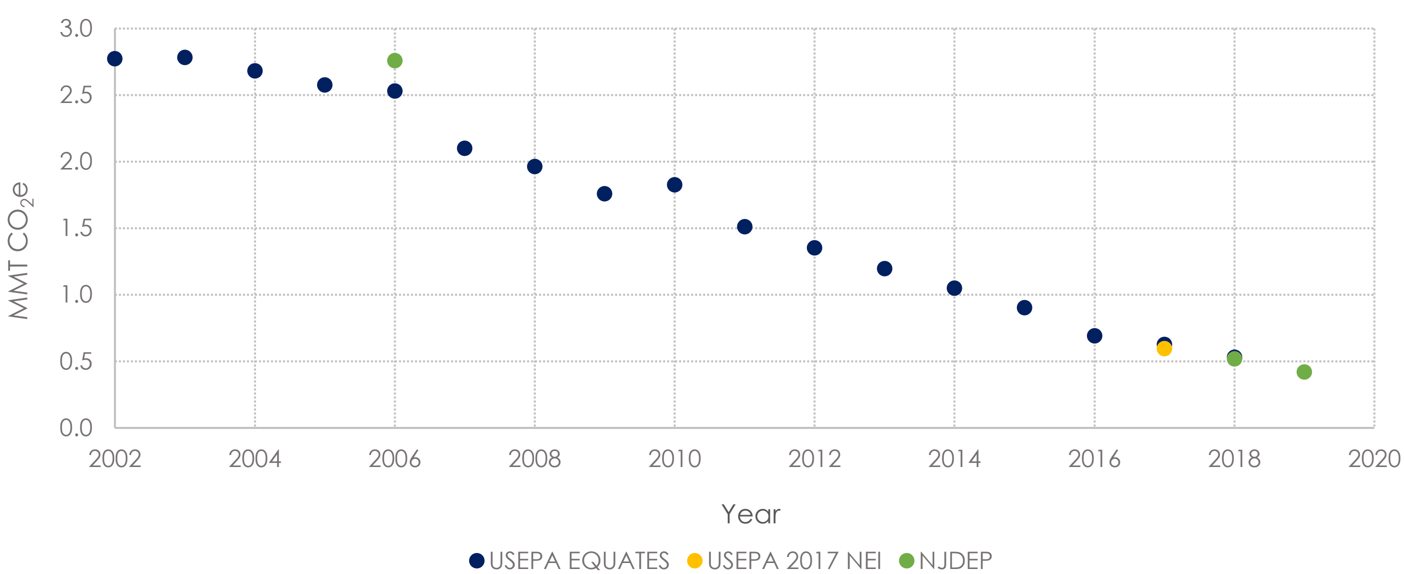
[110] https://www.epa.gov/air-emissions-modeling/speciate-4
[111] The list is formally known as the Augmentation Profile Assignment Factors list. NJDEP accessed the list May 11, 2021, and the file included any updates through that time. Factors may therefore have differed slightly from those used in the 2017 NEI.
[112] https://www.epa.gov/moves
[113] https://www.epa.gov/cmaq/equates

years created small discontinuities in the EQUATES output where estimates for three years appear to move up and down together. Nonetheless, the EQUATES data provides valuable insight into overall emissions trends and is used for those years where DEP MOVE3 data is not available. 2017 NEI on-road data was not used because it relied on the earlier MOVES 2014b model. Otherwise, the methods used for on-road estimates from EQUATES and the 2017 NEI were similar, and their results differed by only 4.8% (Figure B-3).

Taking the economy as a whole, DEP was able to compare its estimated black carbon emissions with those published in the 2017 NEI and found exceptionally close agreement. Overall, the total combined black carbon emissions from all sectors calculated by DEP for 2017 was 0.9% higher than the published total in the 2017 NEI. This difference can be attributed to changes in speciation factors made after publication of the 2017 NEI, and to DEP's use of EPA EQUATES estimates for that year's on-road emissions. DEP's estimated total black carbon for 2014 was 7.2% lower than EPA's published total. In addition to the factors influencing the 2017 results, USEPA implemented a substantial revision to their model for evaluating wildfires and prescribed burns after the 2014 data was released. DEP used speciation factors derived from the 2017 NEI, and these were significantly different from those associated with the published 2014 NEI data.

For New Jersey's GWRA reference year of 2006 DEP estimates that black carbon emissions from on-road sources were 2.8 MMT CO_2e based on GWP_{100}. DEP 2006 estimated emissions were 9% higher than the EPA EQUATES estimate of 2.5 MMT CO_2e for the same year. As noted above, this difference arose from DEP's use of detailed county-specific data rather than national default values, running the model individually for each county as opposed to only six representative counties, and calculating 2006 emissions directly rather than extrapolating from 2005 model data as USEPA had done. DEP therefore believes that its calculations for 2006 provide a more accurate estimate of emissions during that year. In more recent years, EPA and DEP estimates are very close, largely because EPA and DEP both used more highly detailed input. As noted above, subsequent calculations are based on DEP on-road data for 2006, 2018 and 2019 and EPA EQUATES for the remaining years. The 2017 NEI data was not used. Also, the tendency of the EQUATES data to group into three-year trends can be seen clearly for the years adjacent to 2008, and this may influence results for other non-NEI years.

Figure B-3. Comparison of EPA EQUATES and DEP MOVES3 On-Road Black Carbon Estimates, 2002-2019 (GWP_{100})

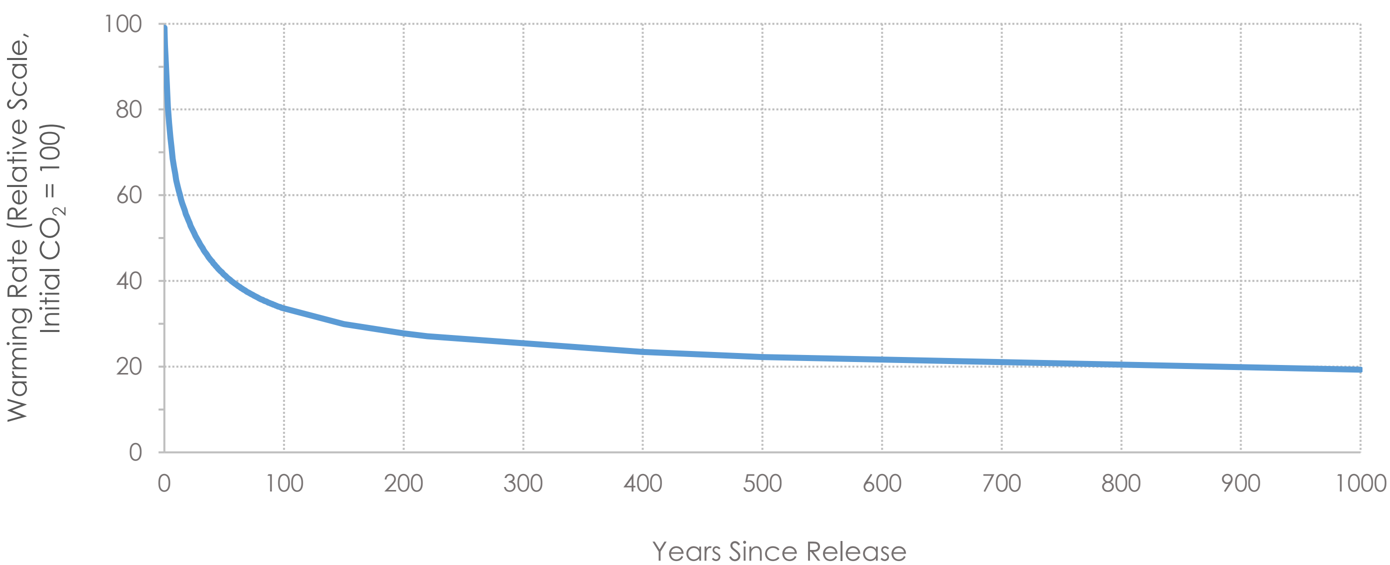


APPENDIX C. GLOBAL WARMING POTENTIAL

Technical basis for GWP and alternative measures for comparing SLCPs

Carbon dioxide (CO_2) is by far the dominant gas contributing to climate change in the United States, and is responsible for 80% of the nation's climate impact.[114] In addition to being released in large quantities by the US and by human civilization as a whole, once CO_2 has been released to the atmosphere only about 66% is removed by oceanic and terrestrial processes. The remaining 34% stays in the atmosphere for very long periods, on the order of centuries and even millennia.[115] Over shorter lengths of time, CO_2 appears as an almost constant source of warming because the atmospheric concentration declines so gradually. In other words, after a given amount of CO_2 is released to the atmosphere, it adds more and more heat to the environment every year for centuries afterward (Figure C-1). Stopping avoidable releases of CO_2 is therefore the primary focus to reducing the amount of global damage.

Figure C-1. Persistence of Warming Impacts from a Pulse Release of CO_2.[116]



Other gases contribute to global warming in much the same way as CO_2. For example, they can influence the heat balance of the earth by absorbing incoming solar radiation (in particular, visible and infrared light), and they can also block the earth from radiating energy back into space. But the exact frequencies of radiation that are captured by a molecule depend on its structure, so each greenhouse gas has its own unique absorption spectrum. Greater absorption, or increased concentration, leads to greater warming. The sum across all relevant wavelengths, referred to as radiative forcing, is a major determinant of how much impact a gas will have on the environment.

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[114] USEPA, 2021. Inventory of U.S. Greenhouse Gas Emissions and Sinks, EPA430-R-21-005, Table 2-1.

[115] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. Section 5.2.1.2.

Archer, David; Eby, Michael; Brovkin, Victor; Ridgwell, Andy; Cao, Long [Carnegie Institution ; Mikolajewicz, Uwe ; Caldeira, Ken; Matsumoto, Katsumi; Munhoven, Guy; Montenegro, Alvaro; Tokos, Kathy, 2009; Annual Review of Earth and Planetary Sciences; Volume 37, Pages117-134. https://orbi.uliege.be/handle/2268/12933. Accessed 8/23/2021

[116] Hansen, J., et al., Dangerous human-made interference with climate: a GISS model E study. Atmos. Chem. Phys., 7, 2287–2312, 2007 www.atmos-chem-phys.net/7/2287/2007/

However, one critical difference between GHGs is the time scales of their impacts. Specifically, while CO_2 acts over very long time scales, many other climate gases are removed relatively quickly from the atmosphere. For example, methane only remains in the atmosphere about 9 years, and many HFCs act over time spans of days to decades.[117] Such compounds are referred to as short lived climate pollutants (SLCPs) or short lived climate forcers (SLCFs). Conversely, there are long-lived greenhouse gases (LLGHGs) such as carbon tetrafluoride (CF_4) that remain in the atmosphere for thousands of years.

Because SLCPs only remain in the atmosphere a relatively short time, they do not mix completely throughout the planet's atmosphere before they break down. As a result, regional and hemispheric differentials exist with respect to warming effects induced by these gases. This stands in contrast to carbon dioxide and LLGHGs that eventually become well mixed throughout the atmosphere.

From a practical perspective, these diverse properties and behaviors challenge policymakers in that it is difficult to grasp how the climate will react to changes in emissions of different gases. For example, how can one nation's commitment to reduce a GHG be compared to another nation's commitment to reduce a different gas? Having a way to equate the impacts from different gases is necessary in order to allow diverse stakeholders to work towards the common goal of climate protection, utilizing the same weighted scale.

Methods for Comparing Impacts

The most widely-adopted strategies for comparing different gases do so by weighing their impacts against that of carbon dioxide. For example, the UN Framework Convention on Climate Change mandates that all participating states use the 100-year global warming potential (GWP_{100}) approach when reporting national climate goals and emissions,[118] and in accordance with the UN requirement, the USEPA[119] reports national emissions to the IPCC using GWP_{100}. US states and agencies, including the NJDEP, and most private enterprises and organizations, also present emissions data in terms of GWP_{100} so that results can be easily compared with data from around the world. Emissions based on GWP_{100} are found by multiplying the mass of the gas by its GWP_{100} factor to find the equivalent amount of CO_2, or CO_2e (Figure C-2).

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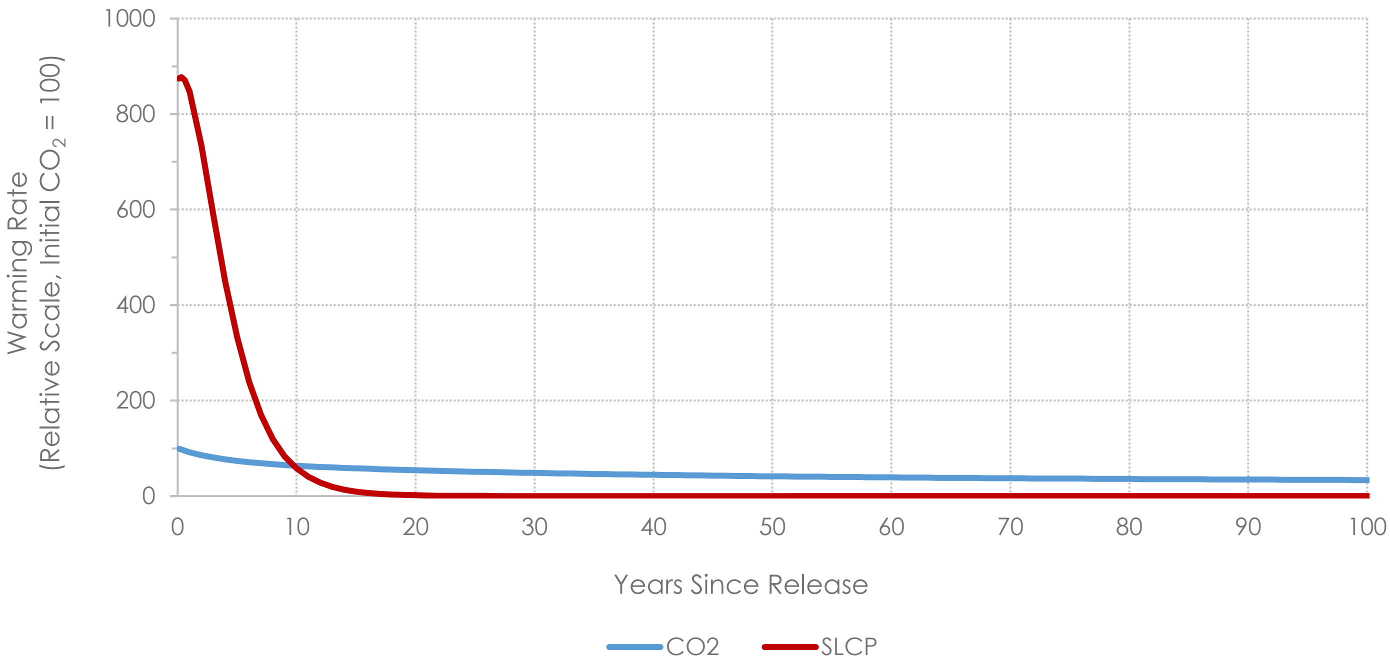
[117] IPCC, 2021: Climate Change 2021: The Physical Science Basis. Tables 6.1 and 6.2, and Section 6.3.1.

[118] United Nations Framework Convention on Climate Change, 2014. Report of the Conference of the Parties on its Nineteenth Session, held in Warsaw from 11 to 23 November 2013; Addendum, Part two: Action taken by the Conference of the Parties at its nineteenth session. FCCC/CP/2013/10/Add.3. http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf. Accessed 8/23/2021.

[119] USEPA, 2021. Inventory of U.S. Greenhouse Gas Emissions and Sinks, EPA430-R-21-005, page 1-9.

Figure C-2. Impacts from a short-lived climate pollutant (SLCP) and CO_2 using a 100-year time horizon. [120] *The areas under the lines represent the total cumulative impacts from each gas. In this example, the impact from CO_2 after 100 years is the same as the impact from the SLCP (in other words, the areas under each of the two lines are equal.) The ratio of the SLCP impact to the CO_2 impact (the GWP) is therefore 1.0.*



Mathematically, the GWP is defined as[121]

$$GWP_i = \frac{\int_0^{TH} a_i \cdot [C_i(t)]\,dt}{\int_0^{TH} a_r \cdot [C_r(t)]\,dt}$$

where

GWP_i	is the global warming potential for gas i;
TH	is the time horizon, for example 100 years;
a_i	is the ability of the gas being studied to absorb radiation per unit mass (radiative efficiency);
$[C_i(t)]$	is the amount of gas present. Because the gas can decay or otherwise be removed from the atmosphere, the amount available changes over time, hence it is a function of time t;

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[120] The SLCP lifetime is modeled here as a log-normal distribution with peak at t=0. CO_2 lifetime is from Hanson, et al., 2007. The SLCP is hypothetical and is for illustrative purposes.

[121] IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Section 2.10.

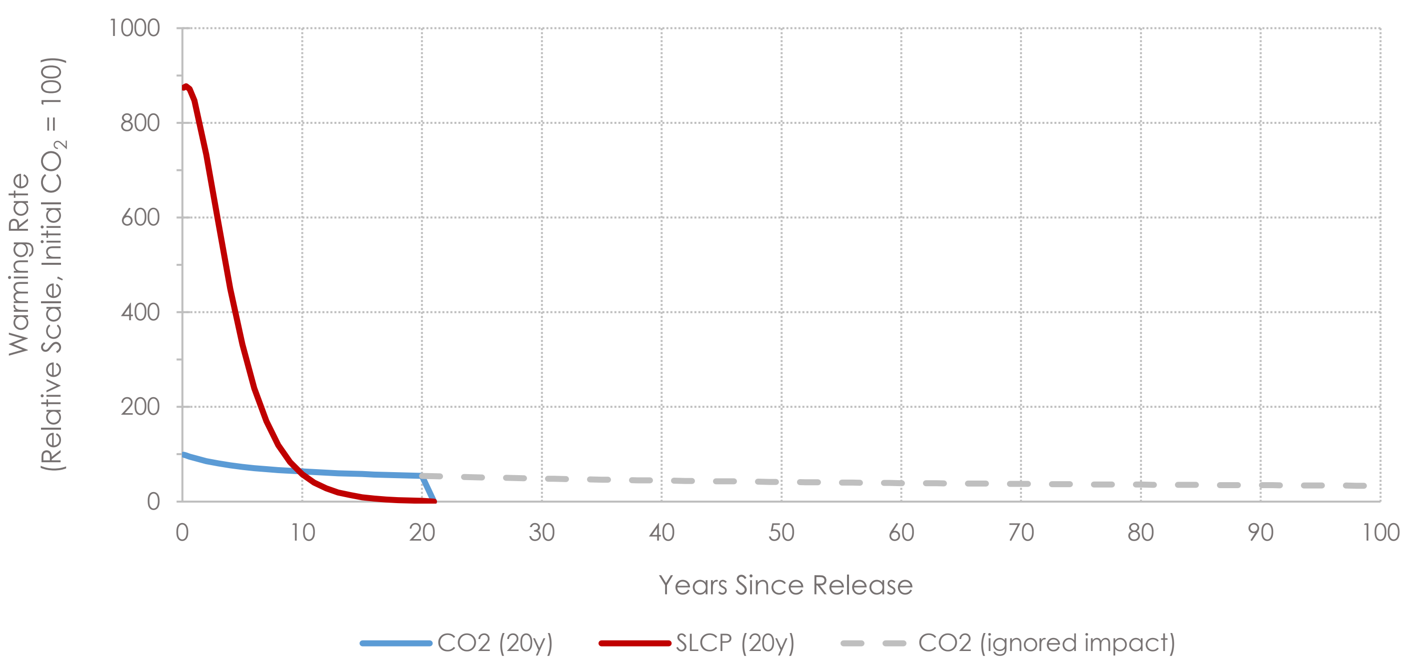
a_r is the radiative efficiency for the reference gas, CO_2;

$[C_r(t)]$ is the amount of the reference gas, CO_2. Again, the amount in the atmosphere can change over time, so it is a function of time t. At the start (t=0), the amount of reference gas is the same as the amount of the gas under study.

The top of the equation first finds the amount of energy absorbed by the gas under study by multiplying the gas's ability to absorb energy by the amount of gas present. Since the amount of gas changes over time, the annual impact is calculated for each year between the time of release and the time horizon. The values are then summed up (or integrated) to find the total radiative forcing for the gas. The bottom of the GWP equation does the same for carbon dioxide. When the top and bottom are divided, it provides an estimate of how the climate impact of the gas compares to carbon dioxide over the time period under study.

Because the GWP_{100} method does not explicitly account for the fact that SLCPs are removed from the atmosphere much more quickly than CO_2, concerns have been raised that it may underestimate the benefits of reducing emissions of SLCPs.[122] One approach to address these concerns, referred to as GWP_{20}, takes the same equation but reduces the time horizon from 100 years to 20 years. However, stopping the comparison at 20 years means that only a small part of CO_2's total impact is accounted for (Figure C-3). With a smaller number on the bottom of the GWP equation, the GWP_{20} becomes substantially larger.

Figure C-3. CO_2 vs. SLCP climate impacts using 20-year GWP. By ignoring all warming from CO_2 that occurs after 20 years, the cumulative impact of the SLCP in this example (the area under the SLCP curve) appears to be 3 times greater than the impact from the CO_2. The 20-year GWP for this SLCP would therefore be 3. However, the long-term impact from the CO_2 will be greater than this suggests because of its long lifetime in the atmosphere (dashed line). In this example, both gases will cause the same amount of warming overall.



While the use of GWP_{20} highlights the value of reducing SLCP emissions in the near term by making the impact appear larger, the IPCC recognizes that this approach overestimates the potential benefits of SLCP reductions.

[122] IPCC, 2021: Climate Change 2021: The Physical Science Basis, Section 7.6.

More importantly, GWP values are highly sensitive to the time horizon chosen and there is no clear agreement on what the optimal time horizon should be for evaluating their climate impacts.[123] The UNFCCC and IPCC do not establish any suitable timeframes for SLCPs other than 100 years.

With these limitations in mind, estimated emissions based on GWP_{20} are presented in this report alongside GWP_{100} emissions to assist policymakers and the public in recognizing the disparate impacts of SLCPs compared to CO_2 and LLGHGs, pursuant to P.L. 2019 c319.

Step-Pulse Analysis of SLCP Impacts

Given the limitations of global warming potentials when assessing the consequences of SLCP emissions, climate researchers have reexamined the behavior of these gases to better characterize their impacts. The starting point for this reassessment is the recognition SLCPs released in a pulse to the environment (for example as a single mass of 1 kg) decay over time, but a 1 kg pulse release of CO_2 will create a nearly constant, continuing impact that remains active over long periods. This difference in behavior is what makes the GWP approach problematic when applied to SLCPs. If, instead of a pulse release, there is a continuous release of an SLCP (or a step increase in the rate of an existing release), the concentration of SLCP in the atmosphere will rise until reaching a point of equilibrium where new additions of the gas are balanced by removals. Once at equilibrium, the gas will exert a steady climate impact in much the same way that a pulse release of CO_2 does. Under these conditions, the impacts from the continuous SLCP release and the instantaneous release of CO_2 can be compared directly. This method is referred to as a step-pulse comparison.

One metric cited by the IPCC for creating this comparison is the Combined Global Temperature Potential,[124] or CGTP, having units of kg/(kg/yr), or yr^{-1}

$$\textit{Cumulative equivalent } CO_2 \textit{ emissions} = \textit{CGTP x Emission Rate of SLCP}$$

For example, the 50-year CGTP for methane is 2823 yr^{-1}. The impact of a 1 kg/yr release of methane over 50 years would therefore be equivalent to the impact of a one-time CO_2 release of 2823 kg. The 100-year CGTP for methane is 3531 yr^{-1}, indicating that a 1 kg/yr release that lasts 100 years would have an impact equivalent to a one-time CO_2 release of 3531 kg. Note that the emissions rate of the SLCP is entered as the mass of gas per unit time, not as the amount of CO_2e per unit time. To convert backwards from CO_2e, first divide CO_2e by the GWP factor used in the original calculation. A second step-pulse metric, GWP*, has also been proposed and may be suitable for quantifying historical and future consequences where SLCP emissions rates decrease over time.[125] The IPCC will further consider step-pulse assessments in the context of climate change mitigation as part of the AR6 Working Group III contribution scheduled for release in March, 2022.[126] NJDEP will continue to track IPCC and UNFCCC recommendations in regards to emissions metrics and inventory accounting.

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[123] IPCC, 2021: Climate Change 2021: The Physical Science Basis, Section 7.6.
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APPENDIX D. DETAILED BLACK CARBON EMISSIONS ESTIMATES

Table D-1. Black carbon emissions by Source Classification Code (SCC), 100-year GWP

Table D-2. Black carbon emissions by Source Classification Code (SCC), 20-year GWP

Table D-3. Black Carbon Emissions by Sector, 100-year GWP

Table D-4. Black Carbon Emissions by Tier, 100-year GWP

Table D-5. Black Carbon Emissions by Sector, 20-year GWP

Table D-6. Black Carbon Emissions by Tier, 20-year GWP

Table D-7. Speciation Factors and Source Classification Code Descriptions

Please refer to https://dep.nj.gov/wp-content/uploads/ghg/2022-nj-ghg-inventory-report-appendix-d-black-carbon-data.xlsx to review Appendix D.