2024

# NJ Greenhouse Gas Emissions Inventory Report Years 1990-2021

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

# REVISION NOTES

| Revision | Date | Description |
|---|---|---|
| 0 | March 2024 | Original Release |
| 1 | April 2024 | Table A-3 in Appendix A: corrected row placement for transportation data |

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# ACKNOWLEDGEMENTS


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# EXECUTIVE SUMMARY

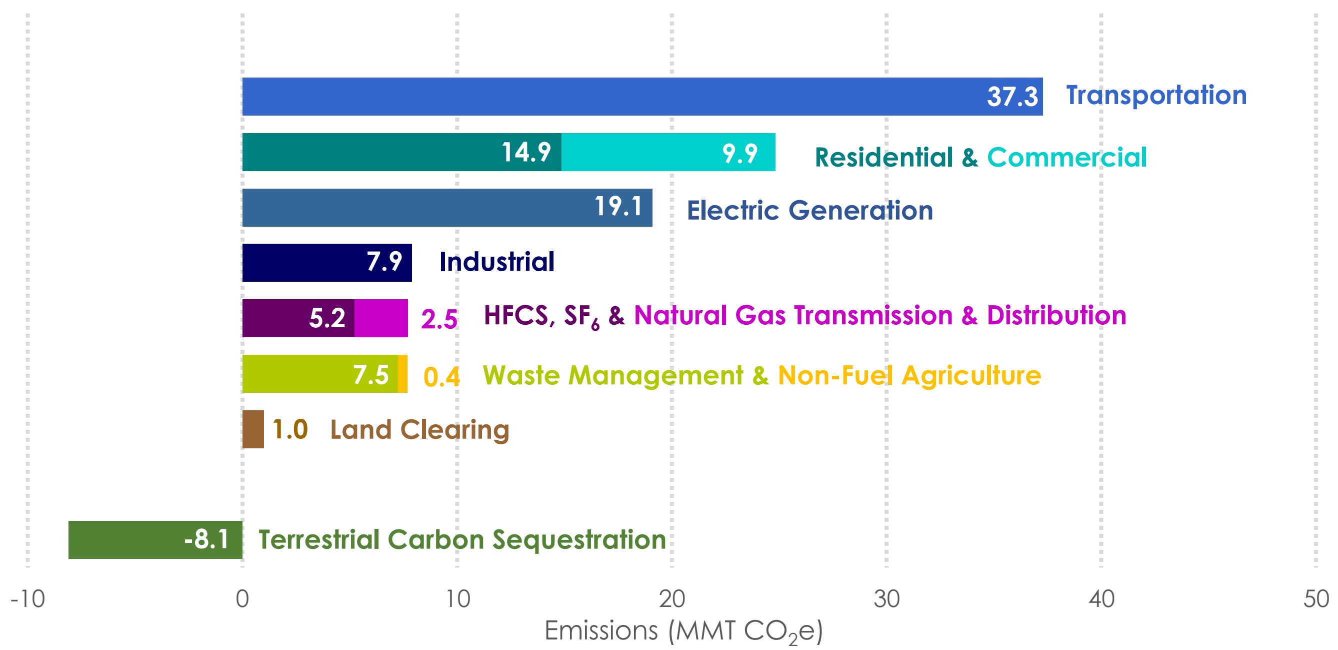
The New Jersey Greenhouse Gas Inventory Report serves as the foundation of the State's strategy to mitigate climate change. It is designed to identify the sources of greenhouse gas emissions in the State, measure progress in reducing those emissions and disseminate this information to decision makers to inform climate policy.  This report provides the most up-to-date estimation of annual emissions from 1990, and 2005-2021. New Jersey uses an inventory scope and framework consistent with international and national greenhouse gas inventory practices.

## CURRENT STATEWIDE GREENHOUSE GAS EMISSIONS

In 2021, statewide gross emissions were 105.7 million metrics tons of carbon dioxide equivalent (MMT $CO_2$e) when calculated using $GWP_{100}$ (Figure ES-1). Energy consuming sectors were the largest sources of emissions (84%), resulting from fossil fuel combustion from transportation, electric generation, residential and commercial, and fuel-consuming industrial activities. Non-energy emissions accounted for the remaining 16% 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 2021 emissions were removed via carbon sequestration from New Jersey's natural and working lands, such as forests and wetlands, resulting in a net emission total of 97.6 MMT $CO_2$e.

*Figure ES-1.  2021 Emissions by Sector ($GWP_{100}$ and $GWP_{20}$)*

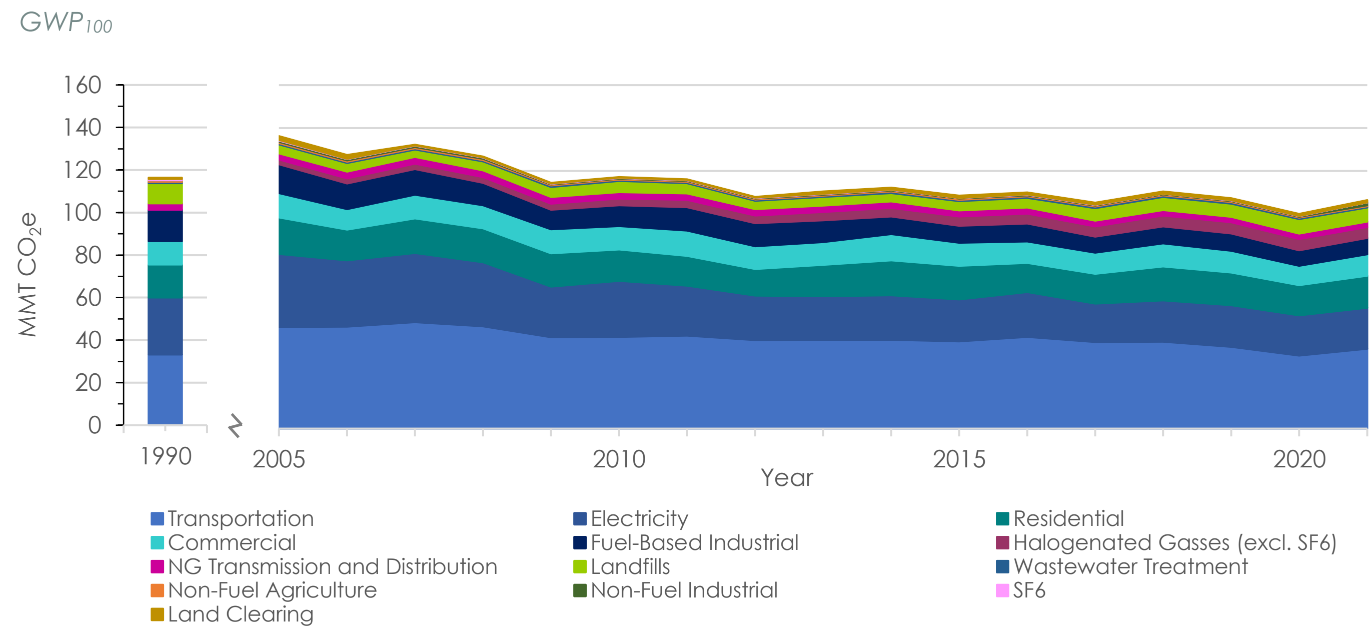
*$GWP_{100}$*

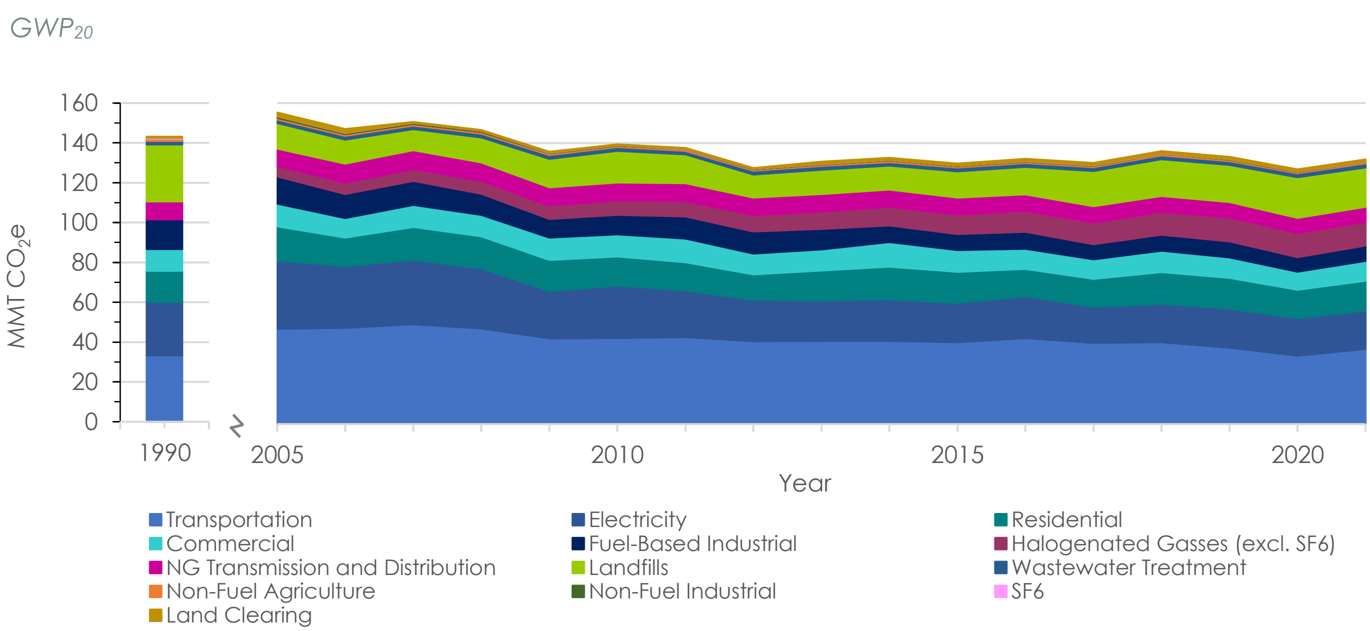



## TRENDS IN GREENHOUSE GAS EMISSIONS, 1990-2021

Since 1990, New Jersey's annual net emissions have dropped from 112.6 MMT CO2e to 97.6 MMT CO2e in 2021 (Figure ES-2). This represents a 13% reduction over the 31-year period. However, year-to-year fluctuations are superimposed on this trend due to weather and world events, the most recent example being the State's drop and rebound following the pandemic. From a low of 92.2 MMT CO2e in 2020, the lowest since the state began keeping records of GHG emissions, New Jersey's emissions rebounded 5.4 MMT CO2e by the end of 2021. But looking across the 31-year period, enduring reductions can be traced to adoption of new technologies that bring with them inherent environmental benefits. For example, aging coal-fired power plants have been entirely phased out in the State, replaced by less-polluting and more efficient combined-cycle natural gas electric systems and burgeoning renewable energy. Similarly, improvements in the fuel efficiency of passenger vehicles has further contributed to emission reductions. Even so, many of these improvements have been offset by increased consumer demand for larger trucks and sport utility vehicles. But if there is one key observation from recent experience, it is that it is possible for social behaviors to change quickly , as witnessed by the drastic reductions in worldwide climate emissions when travel patterns, shopping habits, and personal behaviors adapted to the pandemic threat. (Figure ES-2)

*Figure ES-2. Greenhouse Gas Emissions for 1990 and 2005-2021 ($GWP_{100}$ and $GWP_{20}$).* [1]



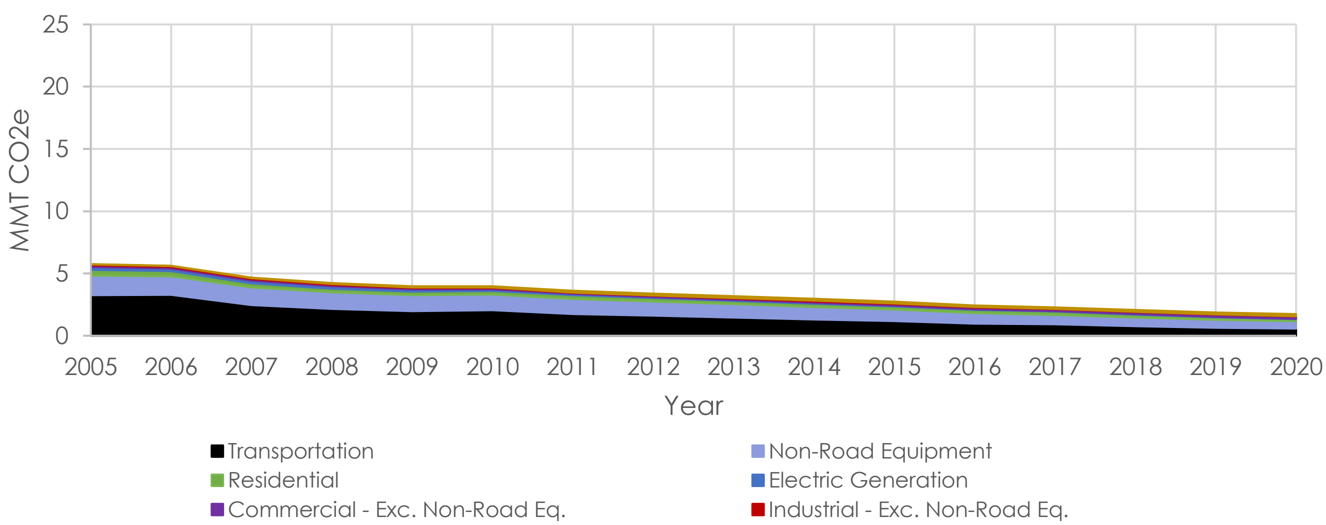

## BLACK CARBON INVENTORY

Black carbon, or soot, is a subset of fine particulate matter ($PM_{2.5}$). It is an airborne particle left behind by incomplete combustion of fuels and is closely associated with adverse respiratory impacts when respired. As such, it has been a long-standing focus of DEP regulatory efforts. Black carbon, with its dark color and low albedo, 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 2020, the most recent year for which full data is available, total black carbon emissions in the State were 1.7 MMT $CO_2e$ based on $GWP_{100}$.

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

Diesel engine exhaust, frequently occurring in and around ports and other economic hubs, is the single largest source of black carbon emissions in the State, as depicted 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 anticipated increased adoption rates of electric vehicles and the expansion of renewable energy generation, black carbon emissions are expected to drop further in 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 2005-2020 ($GWP_{100}$)* [2]




## GLOBAL WARMING POTENTIALS

In accordance with legislative requirements (P.L. 2019 c.319), the New Jersey Greenhouse Gas Inventory Report includes calculations based on both 100-year and 20-year Global Warming Potentials ($GWP_{100}$ and $GWP_{20}$, respectively). GWP allows various gases to be compared in terms equivalent to carbon dioxide, denoted as $CO_2e$. Estimates utilizing $GWP_{20}$ 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 Intergovernmental Panel on Climate Change (IPCC) recognizes that this approach overestimates the potential benefits of SLCP reductions. The United Nations Framework Convention on Climate Change (UNFCCC) and IPCC have not established any suitable timeframes for SLCP reporting 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.

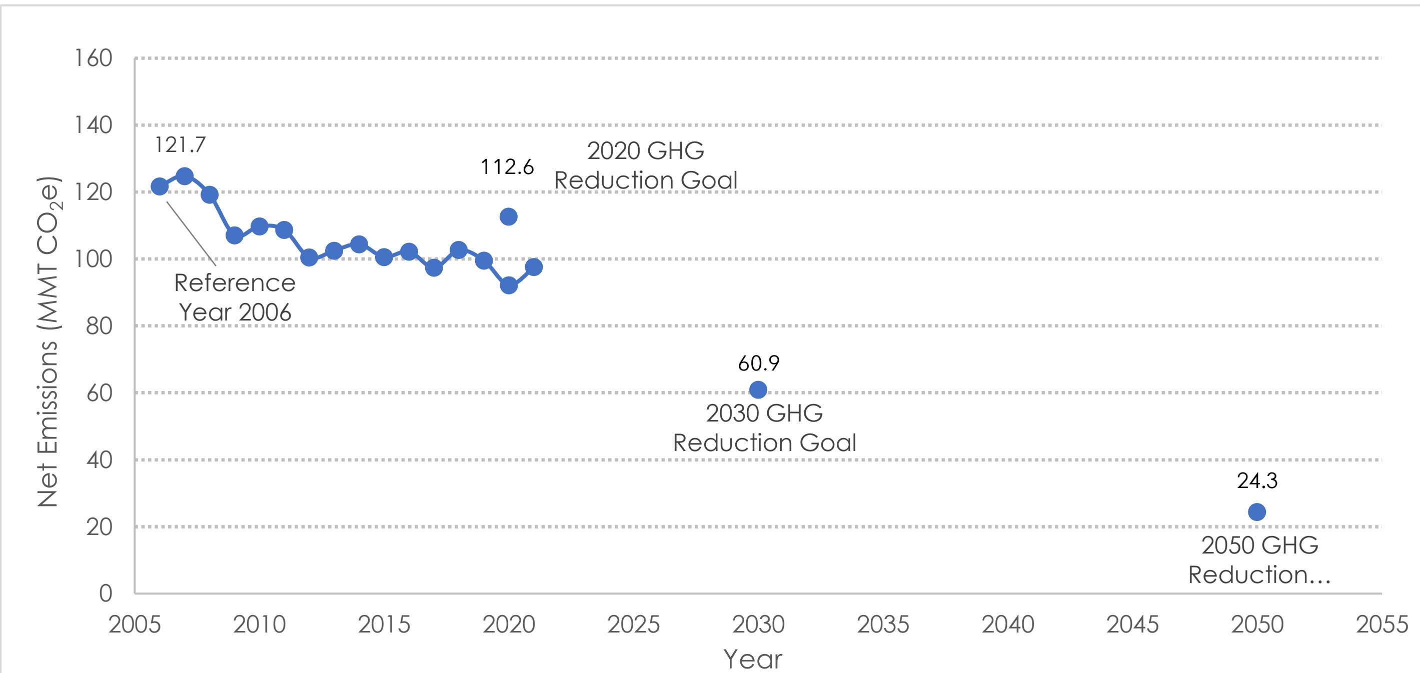
[2] $GWP_{20}$ values (not shown) are 3.5 times greater.

# 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 is the eleventh assessment in the series, the first being released in 2008. The most recent release, a mid-cycle update with emissions data through 2020, was published in December of 2022.[3] The current inventory report extends those estimates to 2021 and uses updated data and methods. Further, it includes a detailed discussion of emissions by sector, a review of greenhouse gas emissions trends, and an overview of steps taken by the State to reduce emissions.

Periodic inventory updates provide vital information for assessing the State's progress towards meeting its greenhouse gas emission objectives. 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 in 2009, eleven years ahead of schedule (Figure 1). 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 recognizing the specific levels of emissions to be reached and evaluating 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://dep.nj.gov/ghg/nj-ghg-inventory/inventory-archive/.

## 1.1 INVENTORY STRUCTURE AND PROCESS

New Jersey uses an inventory scope and framework consistent with international and national greenhouse gas inventory practices, and using the methods described in Appendix B. This inventory provides estimates of anthropogenic greenhouse gas emissions within New Jersey, and 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. 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. A comparison of this report's results with USEPA estimates for 2021 is provided in Appendix D, showing agreement to within 2% for net total in-state emissions. 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 sectors using or producing halogenated gases, the electric transmission and distribution system (using sulfur hexafluoride as an 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] Global warming potentials used in this report for methane, nitrous oxide and sulfur hexafluoride were taken from the IPCC Fifth Assessment Report Working Group I, Table 8-A, Lifetimes, Radiative Efficiencies and Metric Values. (www.ipcc.ch/report/ar5/wg1/) . GWPs for HFCs were from IPCC AR4 as applied in the California Air Resources Board F-Gas model. 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 AR5 Table 8-A for methane, nitrous oxide and sulfur hexafluoride is consistent with IPCC conventions and allows comparison of New Jersey emissions estimates with those developed by other national and international agencies. Previous releases of the NJ Greenhouse Gas Inventory Report used GWPs from the IPCC Fourth Assessment Report, consistent with IPCC guidance in effect at that time. Methane estimates based on AR5 are 12% to 17% greater than under AR4, and nitrous oxide estimates are 9% to 11% lower.

# 2.0 TRENDS IN GHG EMISSIONS

## 2.1 STATEWIDE TRENDS

Total estimated net greenhouse gas emissions for 2021 were 97.6 MMT $CO_2e$ when calculated using $GWP_{100}$ (Figure 2; tabular data is in Appendix A, Table A-1), and 124.1 MMT $CO_2e$ when calculated using $GWP_{20}$ (Figure 3; Table A-3). A recalculation of 1990 data found estimated emissions of 112.6 MMT $CO_2e$ based on $GWP_{100}$, and 139.4 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 conditions 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 160 MMT $CO_2e$ by today (using $GWP_{100}$).[5] The State has therefore managed to keep emissions far below that projected amount.

As with previous inventory years, the four leading sectors of GHG emissions in 2021 were transportation, residential, and commercial fossil fuel use, and electric generation, based on $GWP_{100}$ (Figure 4). Specifically, transportation remained the largest source of GHG emissions at 37.3 MMT $CO_2e$, or 38% of the net statewide emissions. Both the residential and commercial sectors combined totaled 24.8 MMT $CO_2e$, or 25% of net statewide emissions; and electric generation accounted for 19.1 MMT $CO_2e$, or 20% of net statewide emissions. Carbon captured by the State's natural sinks was estimated to be 8.1 MMT $CO_2e$ in 2021, "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 30%, 15%, 12% 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 GWRA sets a goal of reducing emissions by 80% from our 2006 baseline by 2050 which equals a goal of 24.0 MMT $CO_2e$ ($GWP_{100}$). If New Jersey were to continue the rate of decrease observed from 2006 through 2021, it wouldn't reach the 80% goal until 2060, thus emphasizing the need for aggressive action. The State has published detailed emissions reduction pathways in both the 2019 Energy Master Plan[8] and 2020 GWRA 80x50 report, and has initiated multiple policy actions based on these outlines.[9] However, many of the strategies will take substantial time to reach full effectiveness and are now only in their earliest stages. Future releases of this inventory report will document the degree to which those plans are successful in lowering emissions.

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[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 remain 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 16% of emissions using $GWP_{100}$ and 34% 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 2005-2021 ($GWP_{100}$)* [10]

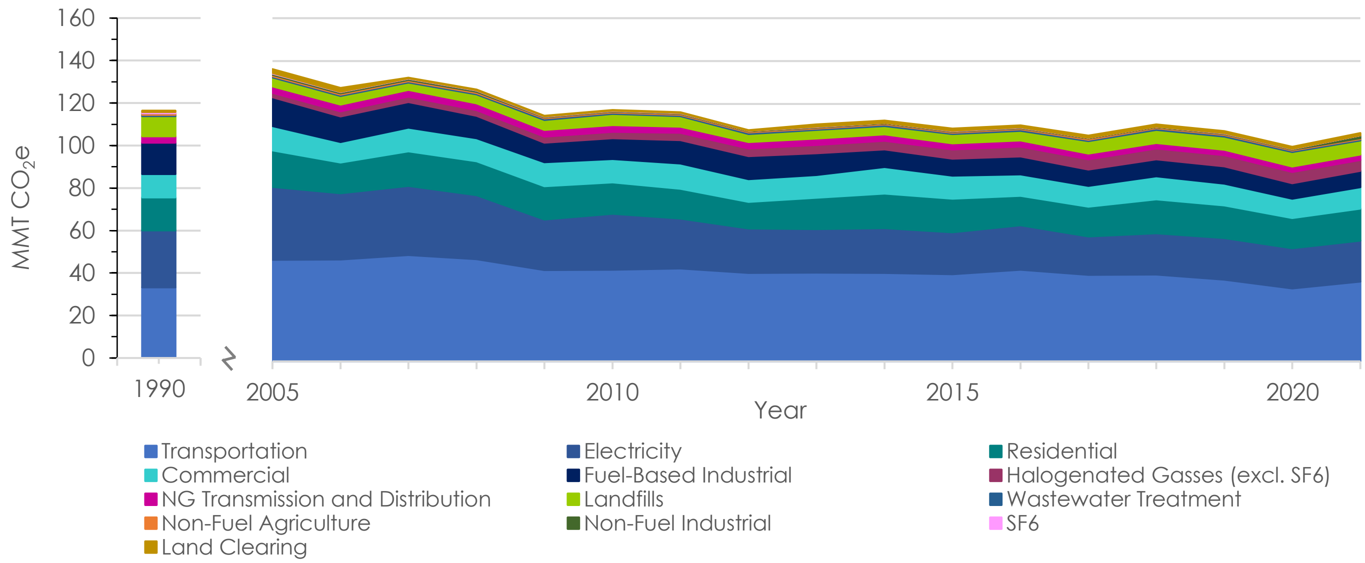
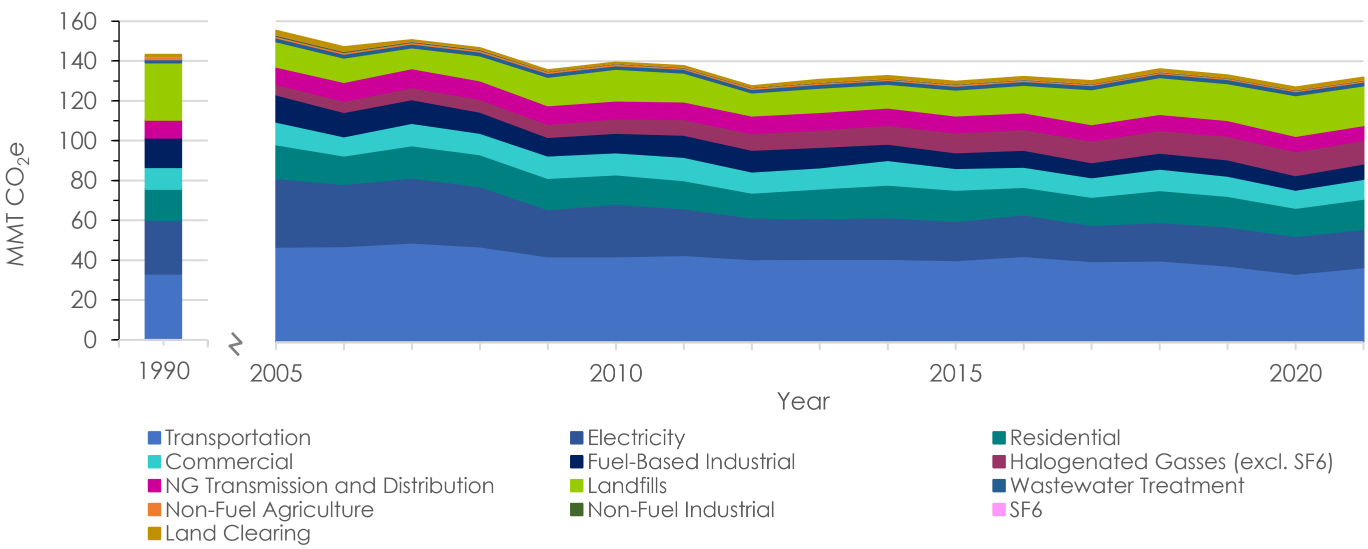



*Figure 3. Greenhouse Gas Emissions for 1990 and 2005-2021 ($GWP_{20}$)* [11]




10 Gross emissions, not adjusted for terrestrial carbon sequestration.

11 Gross emissions, not adjusted for terrestrial carbon sequestration.

*Figure 4. 2021 Emissions by Sector ($GWP_{100}$)*

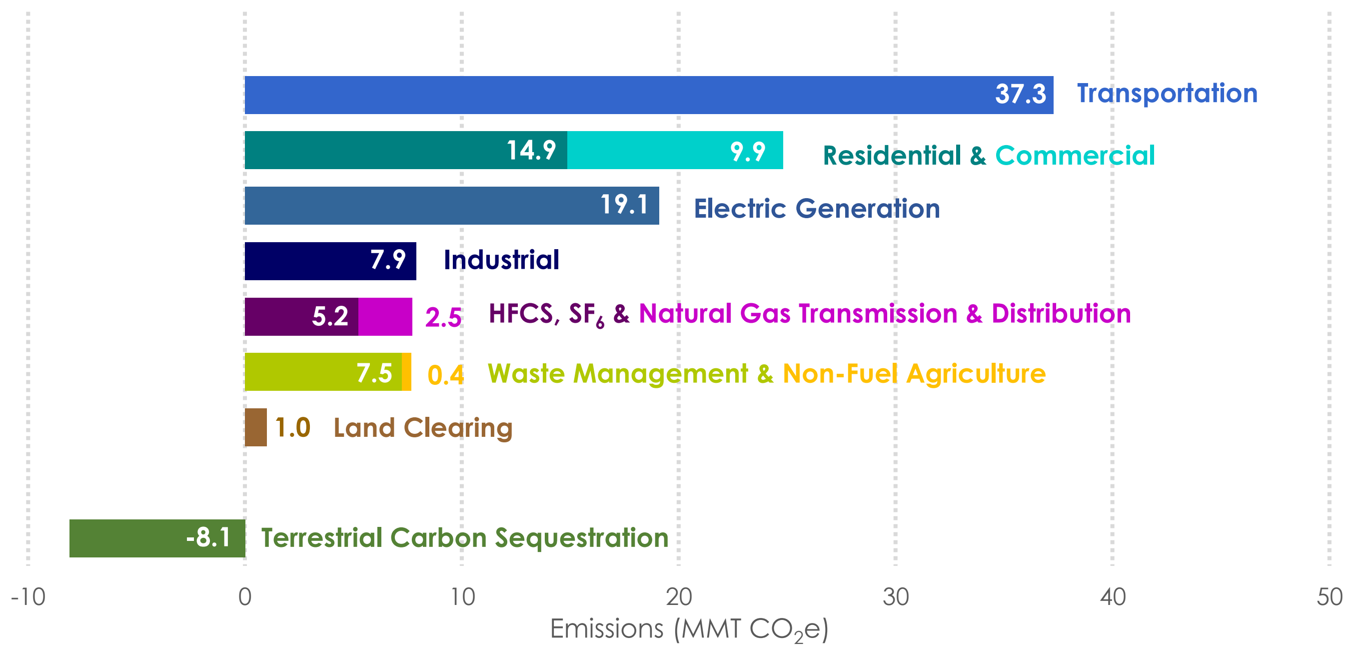
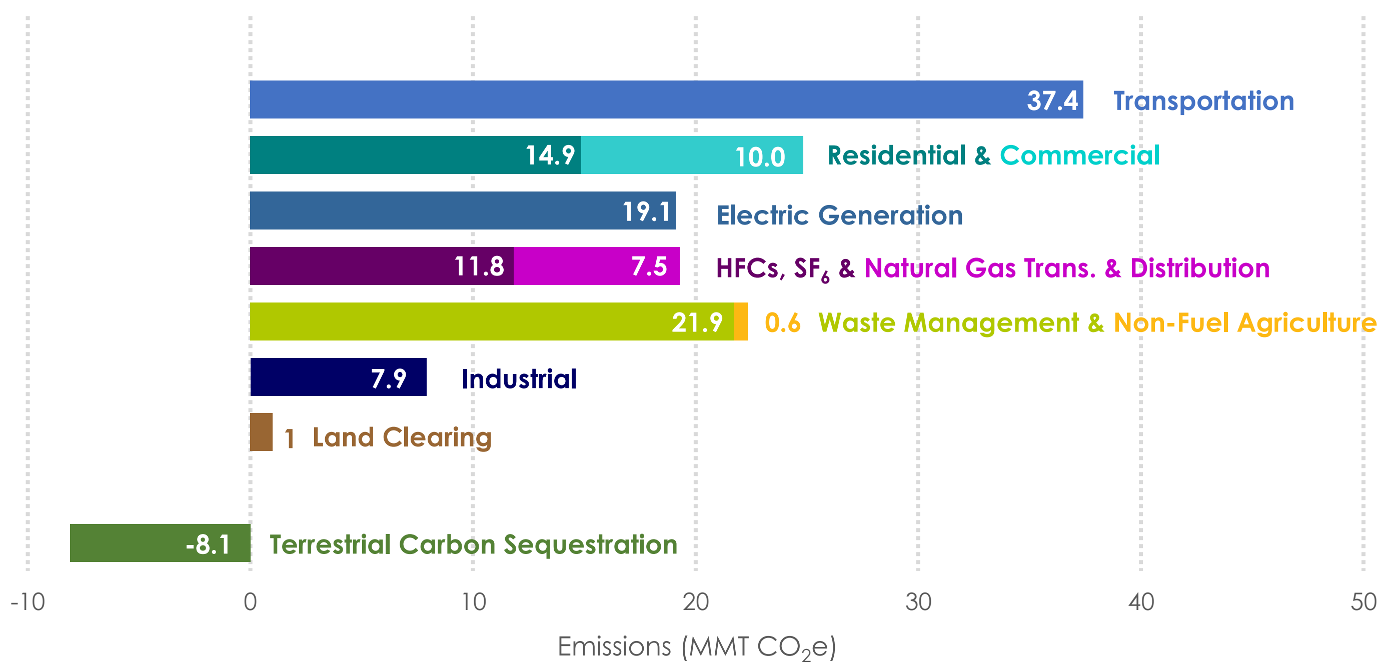



*Figure 5. 2021 Emissions by Sector ($GWP_{20}$)*



## 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 1.7% of national emissions and 0.3% of worldwide emissions (Table 2). On a per capita basis, New Jersey in-state emissions averaged 12.0 metric tons $CO_2e$ per resident between 2016 and 2021.[12] This was slightly more than half the national average of 20.0 metric tons per resident, and about double the international average of 5.0 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 | 110.3 | 6,578 | 35,524 | 1.7% | 0.3% | 12.1 | 20.4 | 4.8 |
| 2017 | 105.5 | 6,562 | 36,097 | 1.6% | 0.3% | 11.6 | 20.2 | 4.8 |
| 2018 | 110.7 | 6,755 | 36,827 | 1.6% | 0.3% | 12.1 | 20.7 | 4.8 |
| 2019 | 107.6 | 6,618 | 37,083 | 1.6% | 0.3% | 11.7 | 20.2 | 4.8 |
| 2020 | 100.3 | 6,026 | 35,264 | 1.7% | 0.3% | 10.8 | 18.2 | 4.5 |
| 2021 | 105.7 | 6,340 | 37,124 | 1.7% | 0.3% | 11.4 | 19.1 | 4.7 |

[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, 1990-2021. USEPA EPA430-R-23-002, 2023, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021. Global emissions from P. Friedlingstein, et al., Global Carbon Budget 2022. Global Carbon Project, https://www.globalcarbonproject.org/carbonbudget/22/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 2020-21 from US Census Bureau, with intervening years estimated by interpolation and subsequent years as estimated by the Census Bureau. https://www.census.gov/data/tables/time-series/dec/popchange-data-text.html; https://www2.census.gov/programs-surveys/popest/tables/2020-2022/state/totals/NST-EST2022-POP.xlsx

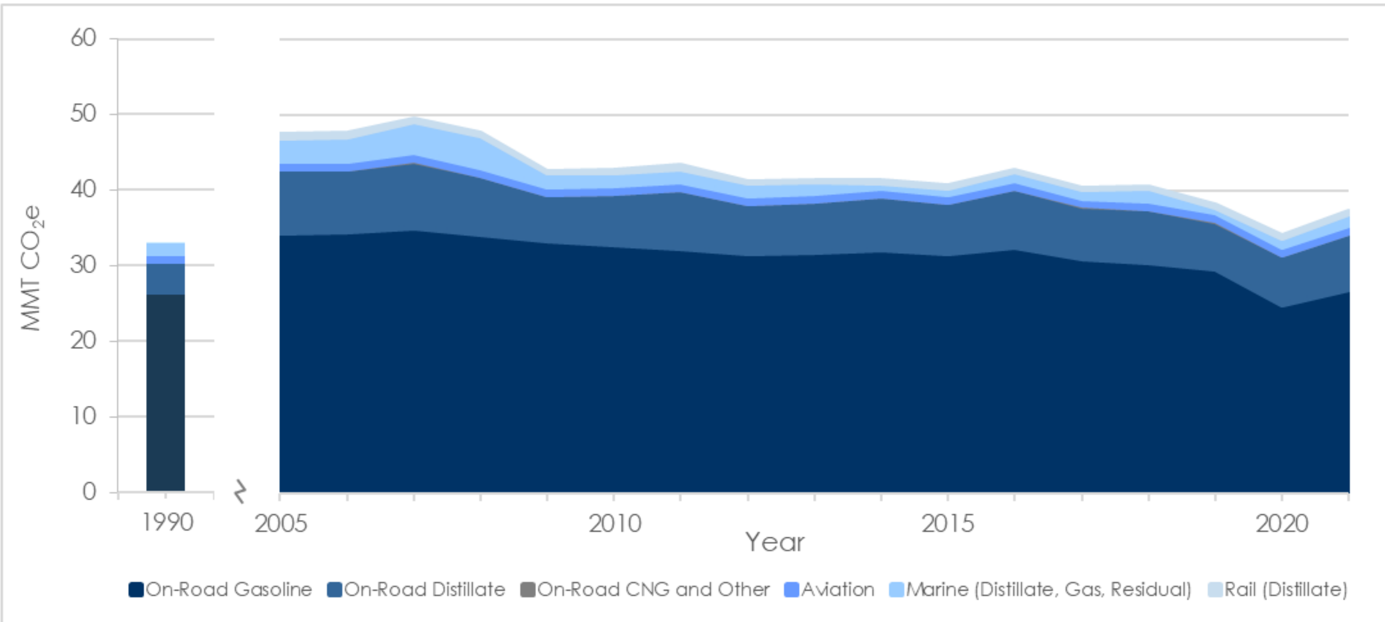
# 3.0 ENERGY EMISSIONS

## 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 light-duty passenger vehicles, 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 2021 were 37.3 MMT $CO_2e$ ($GWP_{100}$)/37.4 MMT $CO_2e$ ($GWP_{20}$). This represents a decrease of 10.3 MMT $CO_2e$ from 2006 levels, but an increase of 4.1 MMT $CO_2e$ over 1990 levels, using $GWP_{100}$. These shifts were dominated by on-road emissions and can be attributed to the transition of the passenger vehicle fleet to larger, less efficient models, offset by 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. During the pandemic, on-road emissions dropped 13% to 31.5 MMT $CO_2e$, but rebounded 9% in 2021 to 34.4 MMT $CO_2e$ (Figure 7). Throughout this period, the proportion of emissions attributed to gasoline averaged 82% (range 78% to 84%). In 2021, on-road gasoline contributed 27.0 MMT $CO_2e$, or 78% of the on-road total. The balance of on-road emissions were nearly all from diesel fuel (21%). Compressed Natural Gas (CNG) and other fuels contributed 0.1 MMT $CO_2e$ in 2021 (0.3%). Emissions from the electric generation used to supply power to electric vehicles are not included in this total but are considered part of the electric generating sector.

By far, the vehicle types contributing the greatest share of emissions in 2021 were gasoline-powered passenger vehicles, including sedans, pickup trucks, and SUVs, at 24.5 MMT $CO_2e$ (Figure 8; Tables A-5 and A-6). Diesel-powered medium- and heavy-duty vehicles followed at 5.8 MMT, not including diesel buses which emitted 0.6 MMT $CO_2e$. Gas-powered medium-

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[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.

and heavy-duty vehicles contributed 2.4 MMT $CO_2e$, followed by gasoline-powered buses which emitted less than 0.1 MMT $CO_2e$.

*Figure 7. On-road transportation greenhouse gas emissions by fuel type ($GWP_{100}$)*

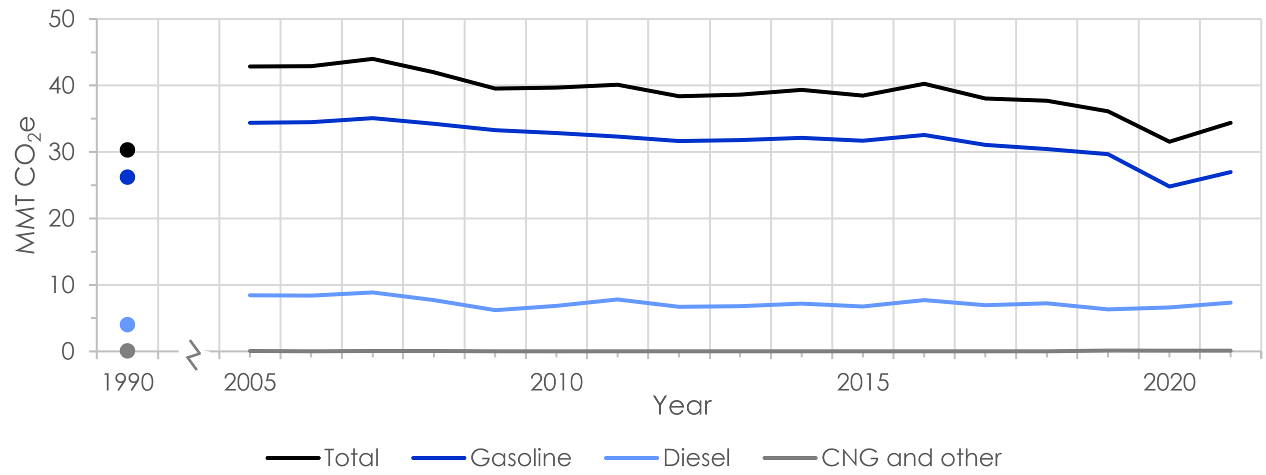
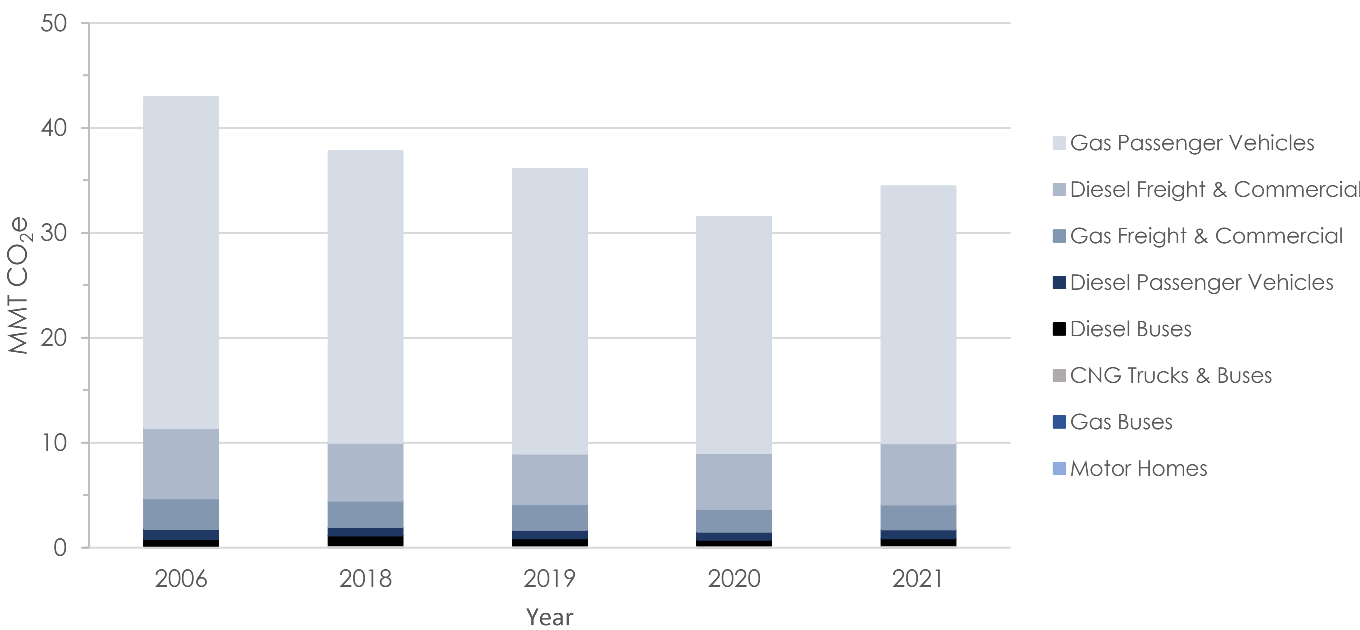



*Figure 8. On-road emissions by vehicle category ($GWP_{100}$)*



## Aviation

New Jersey is home to forty public airports, the largest being Newark Liberty International Airport in Essex County which served more than 43 million passengers in 2022, ranking 13th nationally and 23rd worldwide.[17] New Jersey also hosts Joint Base McGuire Dix Lakehurst, a major air transportation hub for the US military stretching across 42,000 contiguous acres in Burlington and Ocean Counties. New Jersey's in-state aviation emissions were estimated to be approximately 1.0 MMT $CO_2e$ based on the assessment in the 2008 NJ Greenhouse Gas Inventory Report[18] The state's estimate is in close agreement with the 2017 USEPA National Emissions Inventory (NEI), which found that in-state aviation emissions totaled 0.8 MMT $CO_2$ for that year.[19, 20] More detailed information was released in the 2020 NEI, which estimated that total flight emissions during the pandemic year were 0.6 MMT $CO_2$ (Table 3).

*Table 3. Aviation Emissions for 2020 (Metric Tons $CO_2$)*[21]

| County | General Aviation Piston | General Aviation Turbine | Air Taxi Turbine | Commercial | Military | Total |
|---|---|---|---|---|---|---|
| Atlantic | 1,008 | 3,649 | 841 | 5,104 | 13,175 | 23,776 |
| Bergen | 1,224 | 4,262 | 13,450 | 41 | 82 | 19,060 |
| Burlington | 3,020 | 11,132 | 0 | 12,220 | 8,632 | 35,005 |
| Camden | 148 | 535 | 0 | 0 | 0 | 683 |
| Cape May | 1,926 | 6,974 | 0 | 0 | 147 | 9,047 |
| Cumberland | 1,938 | 7,018 | 1 | 0 | 66 | 9,023+ |
| Essex | 1,859 | 6,655 | 17,063 | 329,217 | 1,255 | 356,050 |
| Gloucester | 1,019 | 3,691 | 0 | 0 | 0 | 4,711 |
| Hudson | 0 | 0 | 0 | 0 | 0 | 0 |
| Hunterdon | 1,763 | 6,383 | 0 | 0 | 0 | 8,146 |
| Mercer | 3,020 | 10,935 | 921 | 2,871 | 284 | 18,032 |
| Middlesex | 417 | 1,508 | 0 | 0 | 0 | 1,925 |
| Monmouth | 1,482 | 5,362 | 3,155 | 1 | 0 | 10,000 |
| Morris | 2,746 | 9,940 | 2,325 | 15 | 90 | 15,115 |
| Ocean | 1,512 | 5,305 | 132 | 5 | 50,236 | 57,191 |
| Passaic | 433 | 1,569 | 0 | 0 | 0 | 2,002 |
| Salem | 291 | 1,054 | 0 | 0 | 0 | 1,345 |
| Somerset | 2,778 | 10,061 | 1,485 | 0 | 0 | 14,325 |
| Sussex | 1,327 | 4,807 | 0 | 0 | 0 | 6,134 |
| Union | 1,581 | 5,725 | 0 | 0 | 309 | 7,615 |
| Warren | 1,156 | 4,185 | 0 | 0 | 0 | 5,340 |
| Total | 30,649 | 110,752 | 39,375 | 349,474 | 74,276 | **604,526** |

[17] Port Authority of New York and New Jersey, 2022 Airport Traffic Report, and 2009 Air Traffic Report, https://www.panynj.gov/airports/en/statistics-general-info.html. Accessed August 29, 2023.

[18] The 1.0 MMT $CO_2e$ emissions estimate is based on the analysis described in Appendix C of *New Jersey Greenhouse Gas Inventory and Reference Case Projections 1990-2020*, November 2008. The estimate is limited to landing-and-takeoff activity within the state's territorial boundary. Because aviation emissions are a result of combustion, carbon dioxide is the dominant climate pollutant and only small amounts of methane and nitrous oxide are produced. Estimates based on $GWP_{100}$ or $GWP_{20}$ are therefore nearly identical.

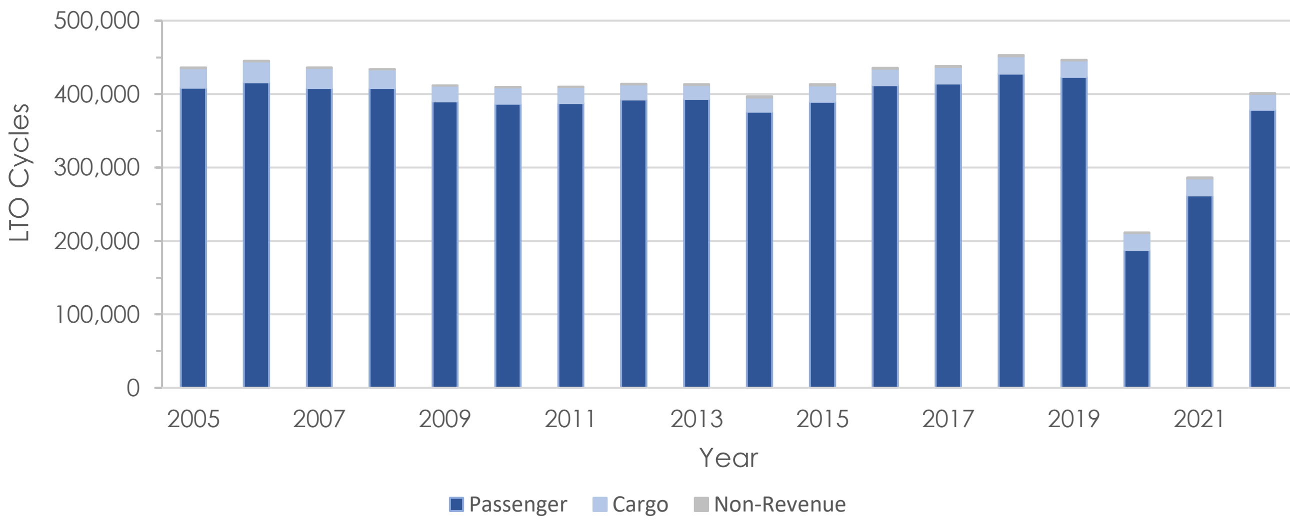
[19] Actual emissions were likely greater than indicated in the 2017 NEI because it did not include $CO_2$ emissions from all aviation sources. The assessment in the 2020 NEI addressed most if not all of those missing sources.

[20] 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
The NEI reported $CO_2$ emissions without $CH_4$ or $N_2O$, but because fuel is combusted, very little $CH_4$ and $N_2O$ are released and the estimated $CO_2e$ is nearly identical to $CO_2$.

[21] USEPA, 2020 National Emissions Inventory. https://www.epa.gov/air-emissions-inventories/2020-nei-supporting-data-and-summaries

The impact of the COVID-19 pandemic is reflected in air traffic activity at Newark Liberty International Airport. Flights dropped by more than half between 2019 and 2020, primarily due to fewer passenger flights, but by 2022 the number of landing-and-takeoff cycles had nearly recovered to pre-pandemic levels. (Figure 9). Aviation emissions across the State likely followed a similar trend as reflected in the NEI data.

*Figure 9. Landing-and-Takeoff Cycles at Newark Liberty International Airport*[22]



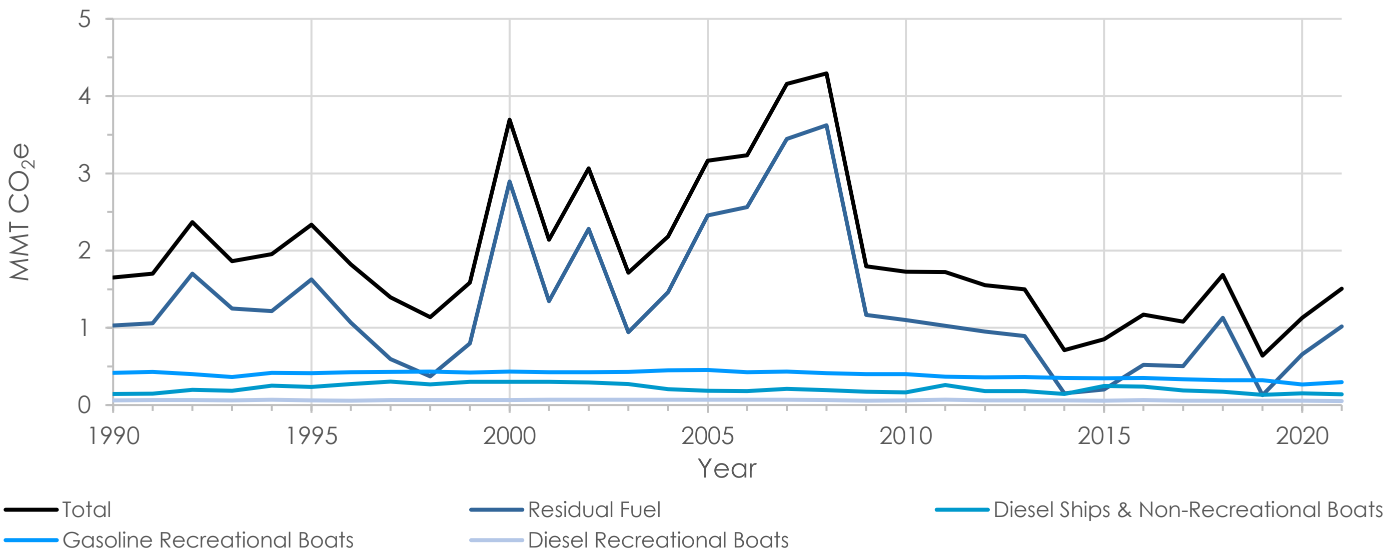

## Marine Transportation

Marine transport includes large ocean-going vessels, recreational watercraft, and regional transportation such as passenger ferries. Three types of fuel commonly used in this sector are residual oil, distillate (diesel), and gasoline. For ocean-going vessels, the largest part of their emissions take place outside the territorial waters of the United States. Therefore, these international emissions are excluded in the State's emissions estimates in accordance with IPCC guidelines. Services provided at ports such as cargo handling are included in the Commercial sector since they use equipment that is not specifically a means of transportation.

Since 1990, estimates of marine emissions have varied significantly (Figure 10; Table A-7), starting at 1.7 MMT $CO_2e$ in 1990 and reaching a high of 4.3 MMT in 2008. Estimated emissions for 2021 were 1.5 MMT, of which 1.0 MMT was from residual fuel oil; 0.2 MMT was from diesel fuel; and 0.3 MMT was from gasoline.[23] Much of the variability may be attributed to the limitations of leveraging 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 used later when a ship is away from the state. Comparing 2020 estimates with the 2020 NEI, both New Jersey and the NEI found emissions from gasoline to be 0.3 MMT. Diesel emissions estimated by NJ were 0.2 MMT while the NEI estimated 0.5 MMT. The NEI did not include estimates of emissions from residual fuel oil.

[22] Port Authority of New York and New Jersey, 2022 Airport Traffic Report, and 2009 Air Traffic Report, https://www.panynj.gov/airports/en/statistics-general-info.html. Accessed August 29, 2023.
[23] 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 10. Marine Emissions ($GWP_{100}$)*




## Rail Transportation

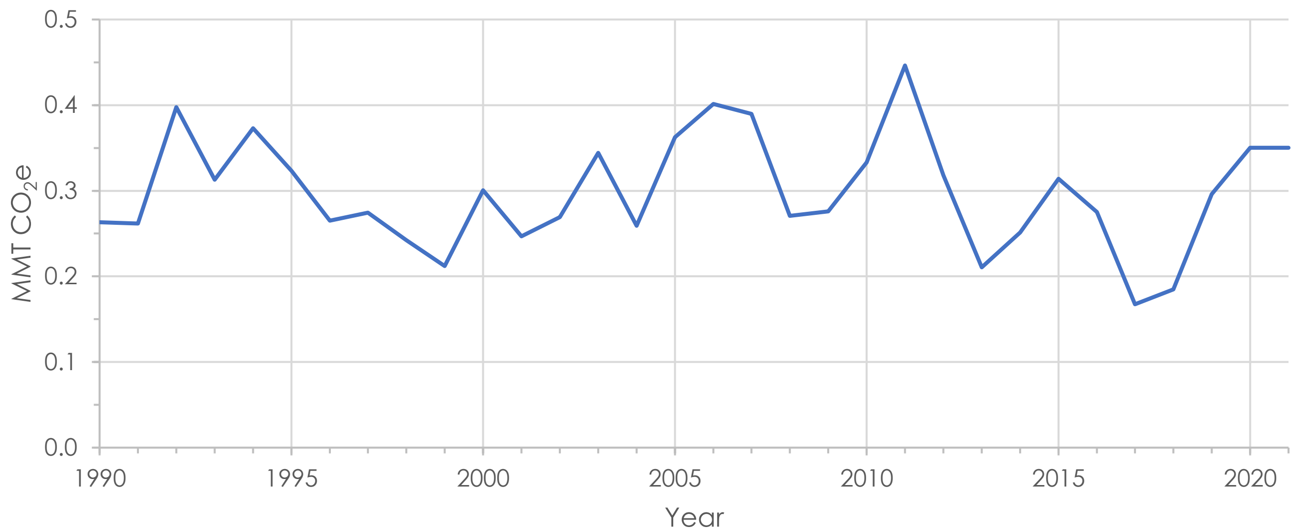
Rail transportation plays a major role in facilitating economic activity within the State. NJ Transit operates the State's public transportation system and has more than 500 miles of track, 166 rail stations, and provides almost 90 million passenger trips a year.[24] With respect to emissions, electrified rail service is well-established in the State, but considerable traffic still relies on diesel-powered locomotives, especially for freight service. Diesel-powered rail emissions remained relatively stable from 1990 through 2020, fluctuating between 0.2 and 0.4 MMT $CO_2e$ across all years (Figure 11; Table A-8).[25] Fossil-powered freight and passenger rail accounted for 0.3% of New Jersey's gross emissions in 2020.[26] For comparison, the 2020 NEI reported rail emissions of 0.23 MMT $CO_2e$ based on railroad activity data while NJ estimated 0.35 MMT $CO_2e$ based on fuel consumption.

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

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

[26] Due to a technical issue, the USEIA has suspended release of the underlying fuel sales data used to estimate rail emissions. As a result, 2021 emissions are assumed to be unchanged at 0.4 MMT $CO_2e$ for 2021. https://www.eia.gov/pressroom/releases/press532.php

*Figure 11. Estimated New Jersey Rail GHG emissions from Diesel Fuel ($GWP_{100}$)*




## 3.2 ELECTRIC GENERATION

Electric generation, which includes dedicated in-state generation; in-state resource recovery facilities; and imported electricity, has consistently ranked as the State's second largest source of emissions after transportation. In 2021, emissions for the sector were 19.1 MMT $CO_2$e,[27] a decrease of 14.9 MMT $CO_2$e from the 2005 peak emissions of 34.0 MMT $CO_2$e (Figure 12; Table A-9). With respect to in-state generation (including resource recovery), emissions have dropped from the peak of 20.6 MMT $CO_2$e in 2005 to 14.3 MMT $CO_2$e in 2021, while at the same time in-state power output increased from 60,565 GWh to 64,512 GWh.[28] These shifts were largely due to reduced reliance on coal, expanded reliance on high-efficiency combined-cycle natural gas systems, and surging growth in renewable energy. In particular, the greater availability of clean energy in-state resources since 2005 has reduced demand for electricity imports, which tend to come from facilities with higher emissions rates.

In New Jersey's in-state energy mix, the dominant fossil fuel was natural gas which, combined with nuclear energy, provided 89.4% of in-state electric generation in 2021 (Figure 13, with incorporated table). Coal continued to decline, while renewable energy output[29] more than quadrupled since 2006. In 2021, renewables generated 5,202 GWh of electric power, or 8.1% of New Jersey's 64,512 GWh of in-state electric power generation.

[27] Emissions estimates are based on $GWP_{100}$. Estimates based on $GWP_{20}$ are within 0.1 MMT $CO_2$e of the $GWP_{100}$ values.

[28] 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.

[29] 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. Emissions from Electricity Generation (GWP₁₀₀)*

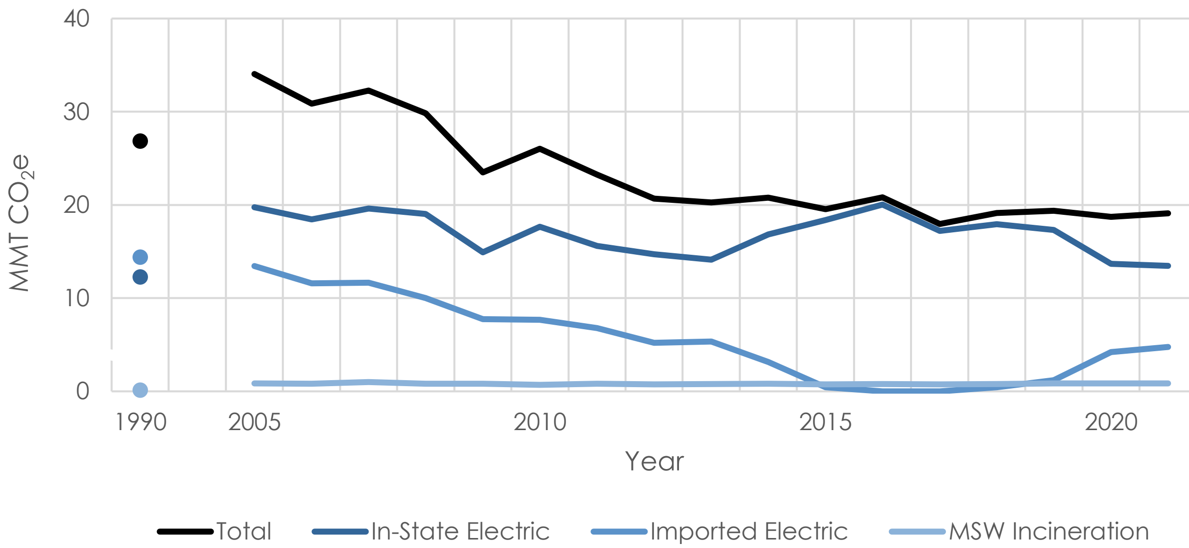
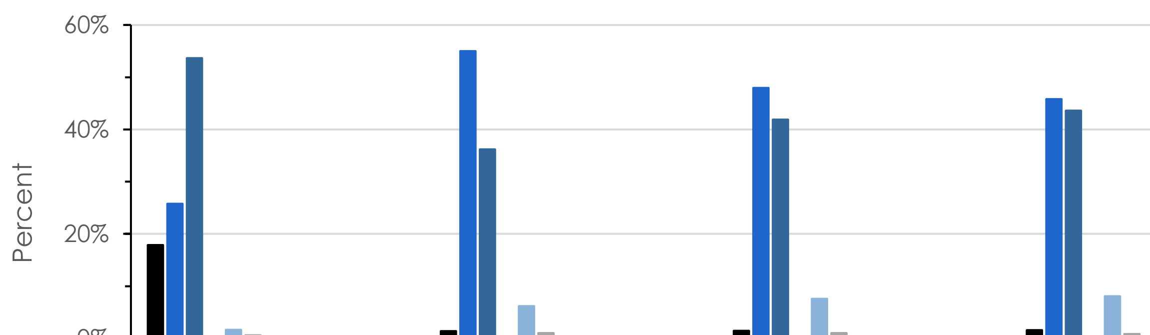



*Figure 13. Percent of In-State Electricity Generated by Major Energy Sources*

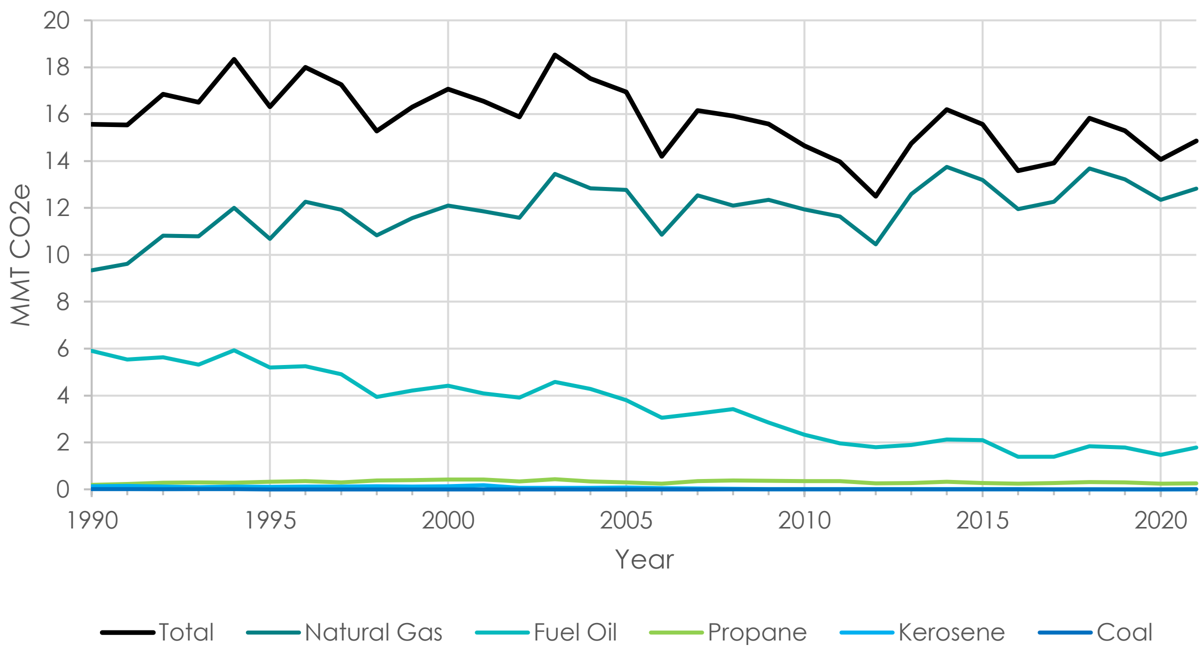



| | 2006 | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Coal | 17.9% | 1.4% | 1.4% | 1.6% |
| Natural Gas | 25.8% | 55.0% | 48.0% | 45.8% |
| Nuclear | 53.6% | 36.2% | 41.9% | 43.6% |
| Petroleum | 0.4% | 0.2% | 0.1% | 0.1% |
| Renewables | 1.6% | 6.2% | 7.6% | 8.1% |
| Others | 0.6% | 1.0% | 1.1% | 0.9% |

## 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.[30] In 1990, emissions based on $GWP_{100}$ totaled 15.6 MMT $CO_2e$, rose to 18.5 MMT by 2003, and fell to a low of 12.5 MMT in 2012. Most recently, 2021 emissions were 14.9 MMT (Figure 14; Table A-10).[31] 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 12.8 MMT in 2021, fuel oil 1.8 MMT, and the balance, propane (0.3 MMT).

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




## 3.4 COMMERCIAL SECTOR

The Commercial sector includes service-providing facilities, business equipment, government activities, institutional living quarters, colleges, and religious institutions. Examples of sources that 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 this sector, as are those from cargo handling services at ports, warehouses and similar service providers. Methane emitted from biological processes at landfills and wastewater treatment plants is distinct in that it does not arise from combustion of fossil fuels, and therefore are discussed in later sections of this report specific to those activities.

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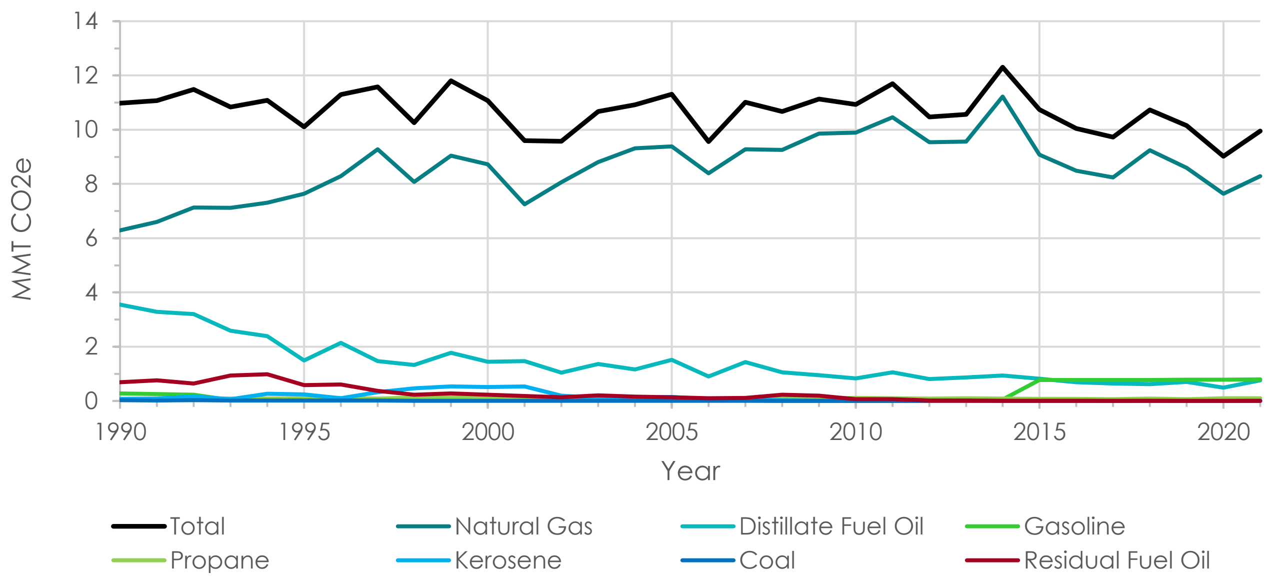
[30] US Energy Information Agency, Glossary, Residential Sector, https://www.eia.gov/tools/glossary/. Accessed December 7, 2021.
[31] Estimates based on $GWP_{20}$ are within 0.1 MMT $CO_2e$ of the $GWP_{100}$ values.

Emissions from the commercial sector have been stable since 1990, beginning the period at 11.0 MMT $CO_2e$ ($GWP_{100}$).[32] Values reached a low of 9.6 in 2006, and climbed to a high of 12.3 in 2014. By 2021, emissions had fallen to 9.9 MMT $CO_2e$. (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.

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




## 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.[33] Emissions arise from energy use, such as from powering manufacturing equipment, tractors, logging equipment, and commercial fishing vessels. 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,[34] 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 14.7 MMT $CO_2e$ in 1990,[35] but dropped to a low of 7.5 MMT $CO_2e$ by 2017.[36] Emissions for 2021 were 7.6 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 near 2 MMT $CO_2e$ since 2009. In 2021 they were the second largest source of emissions in the sector at 1.8 MMT $CO_2e$.

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

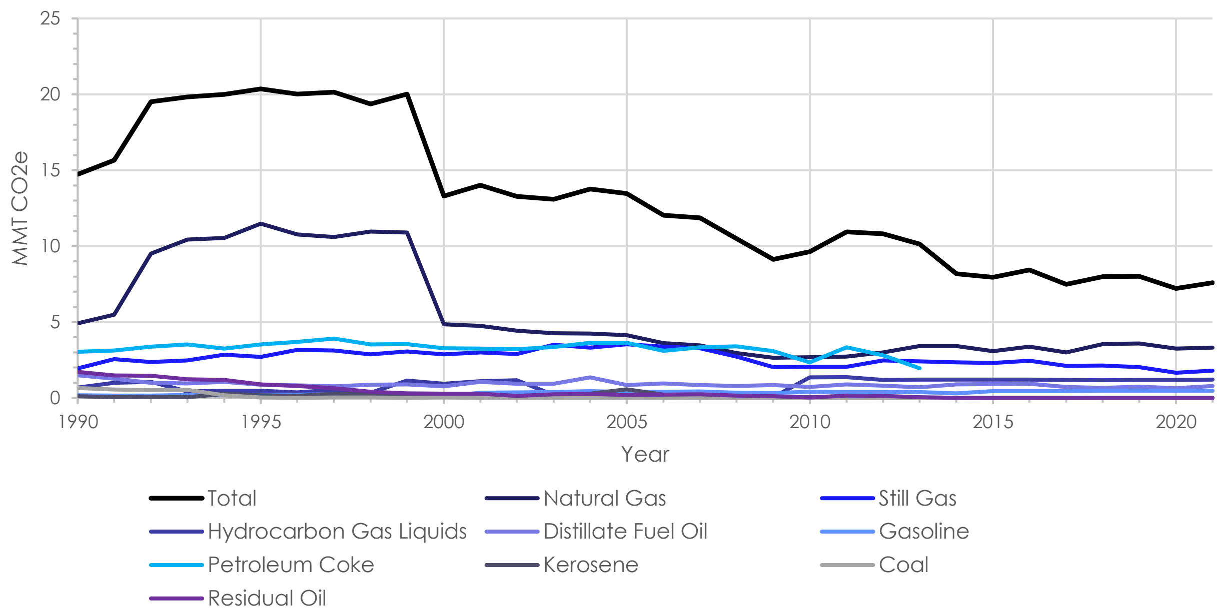
[33] USEIA Glossary, https://www.eia.gov/tools/glossary/index.php?id=I

[34] 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.

[35] $GWP_{100}$ 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.

[36] 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 a peak of 5.3 MMT $CO_2e$ ($GWP_{100}$) in 2020, but decreased to 5.2 MMT $CO_2e$ in 2021 due to adoption of policies phasing out use of these materials (Figure 17; Tables A-13). The three largest source types in 2021 were commercial refrigeration (1.8 MMT $CO_2e$), light-duty motor vehicle air conditioning (0.6 MMT $CO_2e$) and small commercial air conditioning units (0.7 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 a peak of 12.0 MMT $CO_2e$ ($GWP_{20}$) in 2020, but dropped to 11.8 MMT $CO_2e$ in 2021. Commercial refrigeration accounted for 4.1 MMT $CO_2e$ ($GWP_{20}$) in 2021, light-duty motor vehicle air conditioning 1.5 MMT $CO_2e$ ($GWP_{20}$), and small commercial air conditioning equipment 1.5 MMT $CO_2e$ (Figures 19 and 20; Table A-14).

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

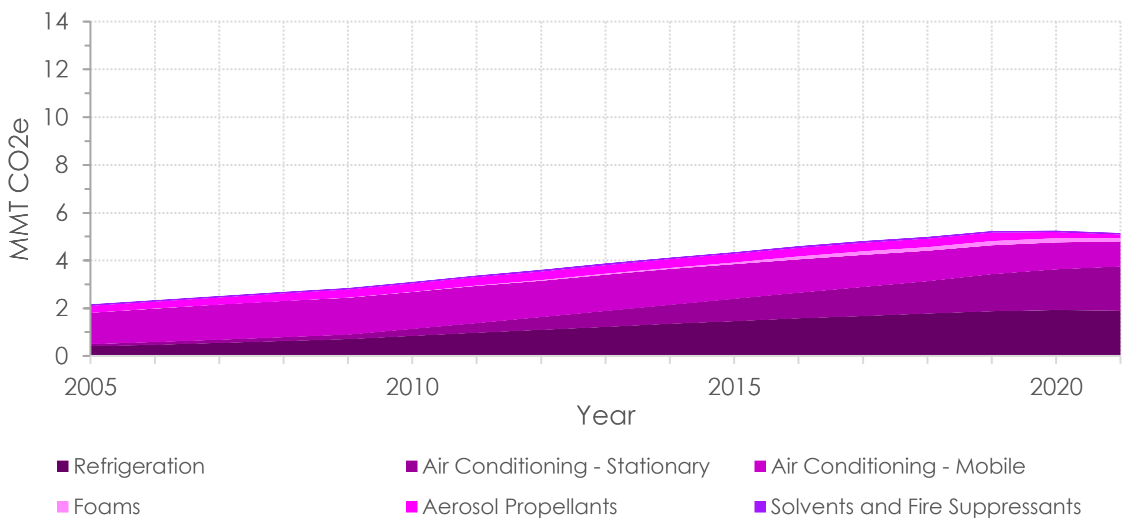


*Figure 18. 2021 HFC emissions profile (GWP100)*

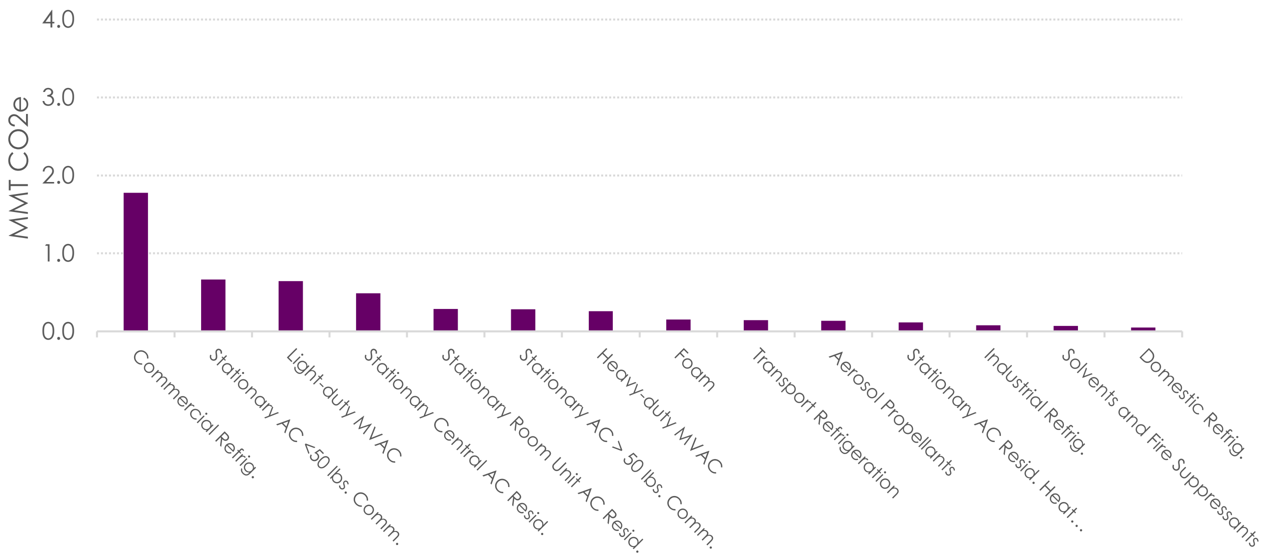



*Figure 19. HFC emissions by category (GWP20)*

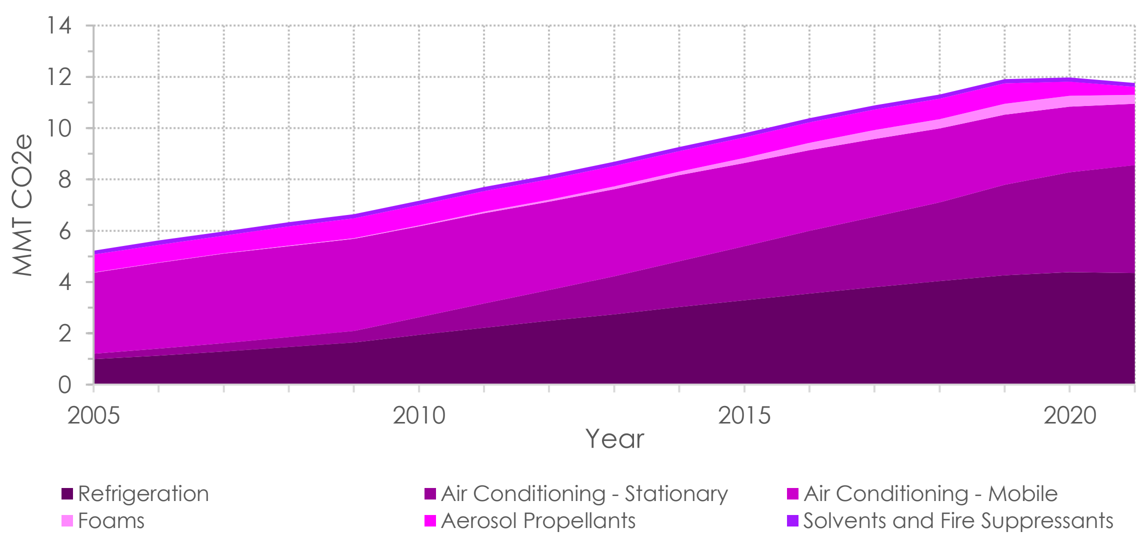
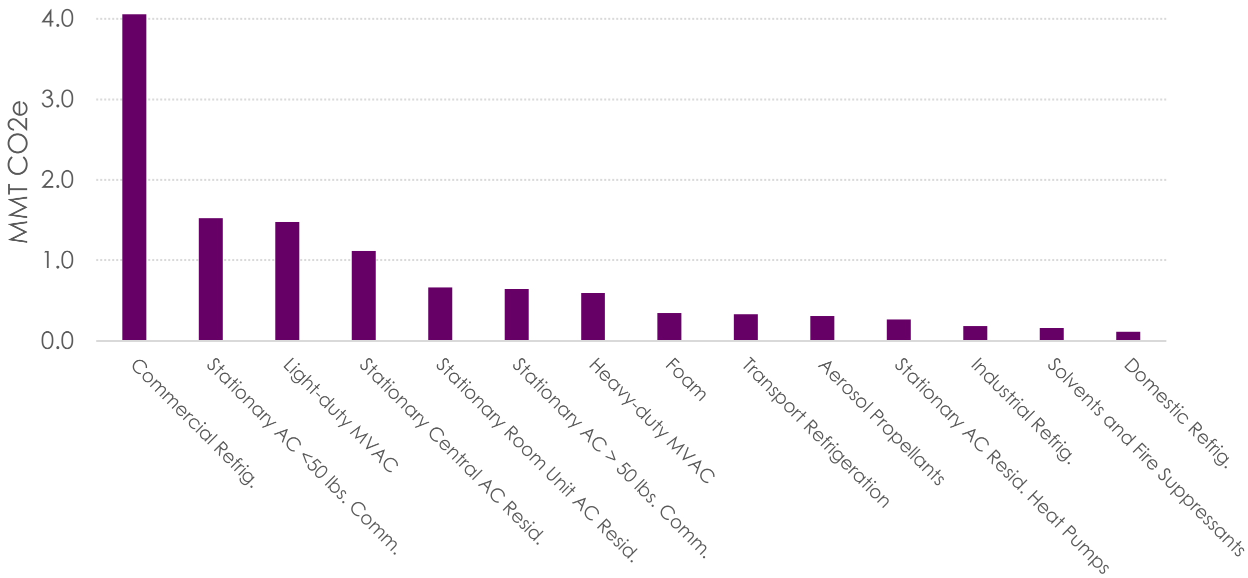


*Figure 20. 2021 HFC emissions profile ($GWP_{20}$)*




## 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 2021, over 1,600 miles of long-distance transmission pipelines crossed the state, and over 35,700 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 are used to minimize releases. Equally important, 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 2021, emissions from New Jersey's natural gas transmission and distribution system decreased 19%, from 3.1 MMT $CO_2e$ at the outset to 2.5 MMT $CO_2e$ in 2021 based on $GWP_{100}$, or from 9.4 to 7.5 MMT $CO_2e$ based on $GWP_{20}$ (Figures 21 and 22, Table A-15). Emissions arise primarily from 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 utility 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.

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

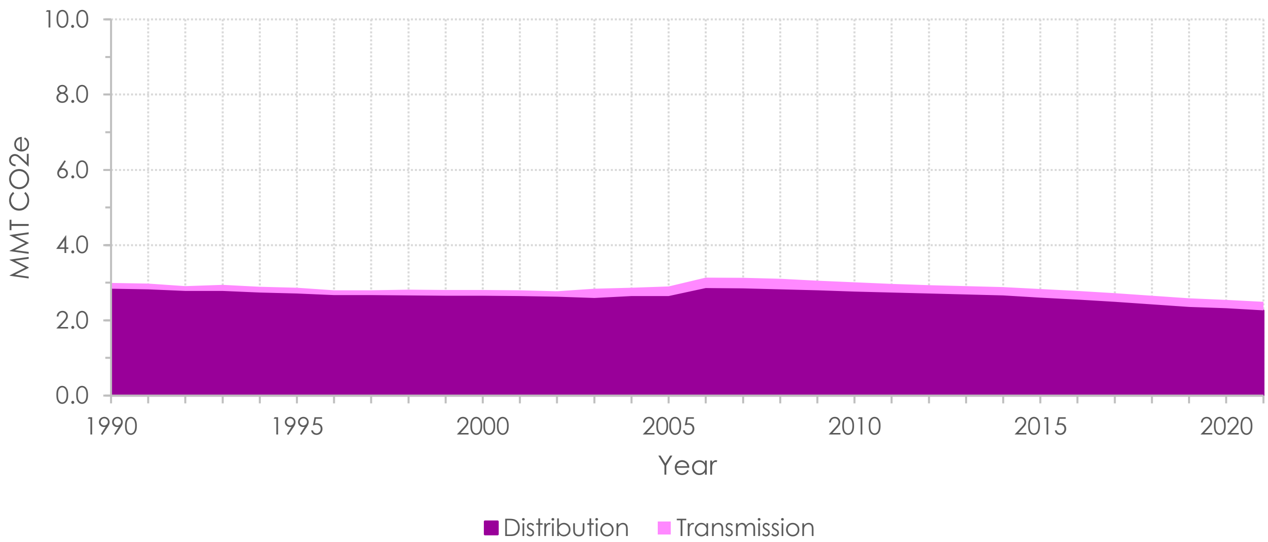
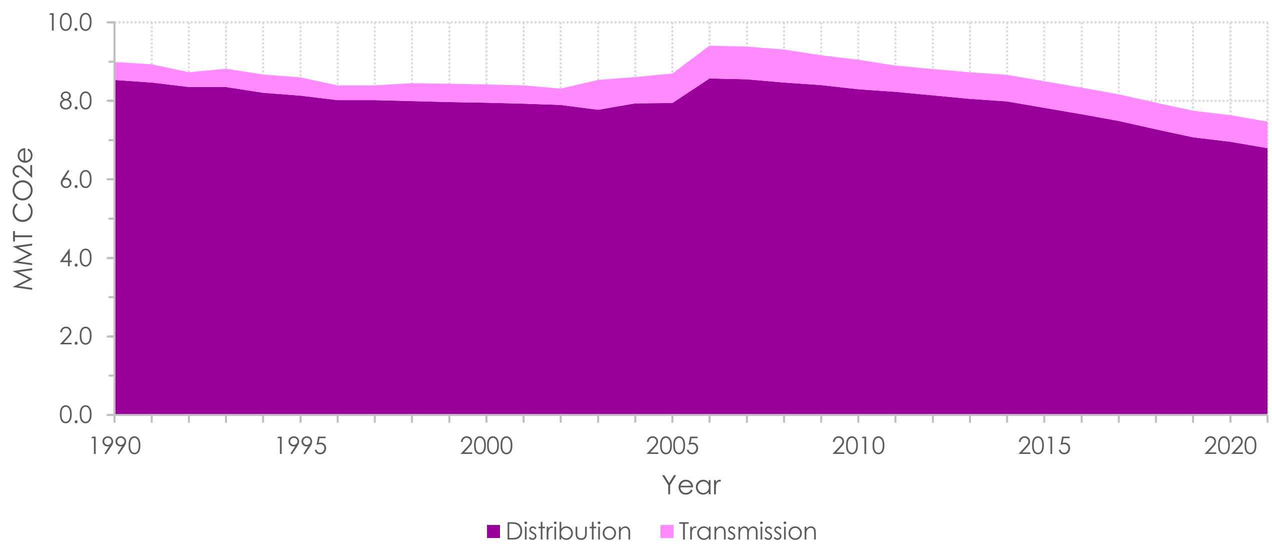



Figure 22. Natural gas transmission and distribution ($GWP_{20}$)




## 4.3 LANDFILLS

Disposal of solid waste by landfill results in anaerobic decomposition that in turn produces landfill gas, a mixture of approximately equal parts methane and carbon dioxide by weight. Because carbon dioxide in landfills arises almost entirely from the decomposition of plant matter (which in turn grew using atmospheric carbon dioxide), its return to the atmosphere does not represent a net addition and is therefore not included in the State's greenhouse gas emissions. This approach is consistent with international convention as well as USEPA policy.[37] On the other hand, the methane produced in landfills is many times more potent as a greenhouse gas than the atmospheric carbon dioxide absorbed by plants when the organic matter was created, and it is therefore included in the state's greenhouse gas inventory.

[37] The impacts of land use change associated with forestry and other agricultural practices are addressed separately under the land clearing and carbon sequestration categories in this report.

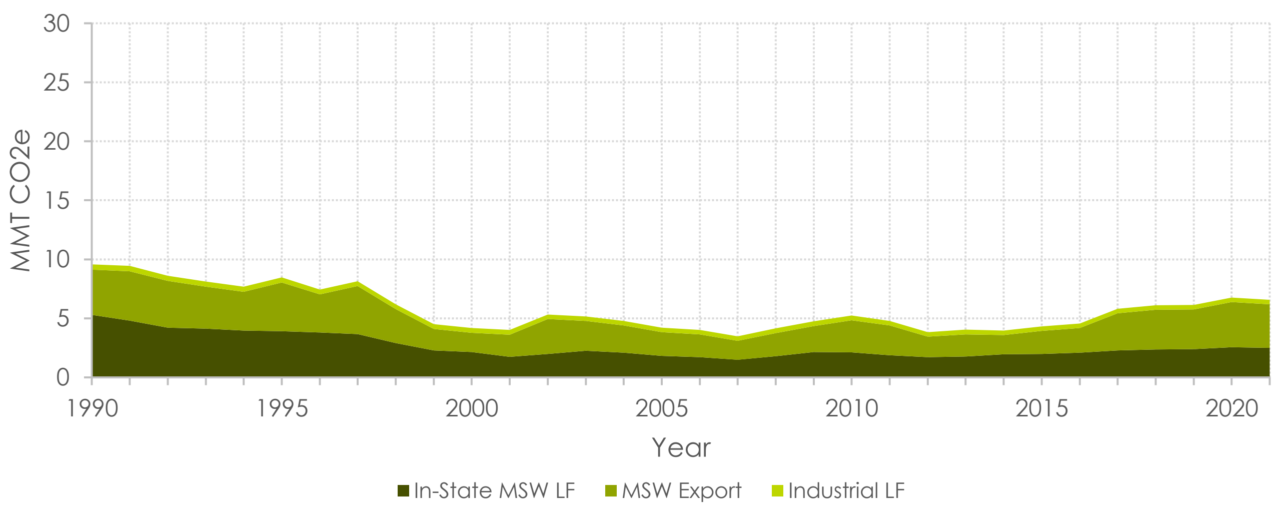
Modern landfills include systems to collect landfill gas and either directly vent it to the atmosphere, burn the gases by flaring, or, when sufficient quantities are available, combust the gases onsite for electricity generation. Methane emissions reported here are those directly vented to the atmosphere. If the methane is burned in a flare or electric generating system, the resulting carbon dioxide is not considered to represent a net increase to the atmosphere, just as for carbon dioxide released directly from the landfill. 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.

Methane emissions from landfill disposal decreased from 9.6 MMT $CO_2e$ ($GWP_{100}$)/ 28.7 MMT $CO_2e$ ($GWP_{20}$) in 1990 to 3.5 MMT $CO_2e$ ($GWP_{100}$)/ 10.5 MMT $CO_2e$ ($GWP_{20}$) in 2007.[38] By 2021, emissions increased to 6.6 MMT $CO_2e$ ($GWP_{100}$)/19.7 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 2021, out-of-state sources accounted for 56% of emissions, in-state sources 38%, and industrial landfills 6%.

### State Action: Waste Management

New Jersey has passed a series of laws to reduce the amount of food waste entering the municipal waste stream in the state. The Food Waste Reduction Act (P.L. 2017, c.136) establishes a specific goal of reducing food waste generated in the state by 50% by 2030.[39] As part of this effort, the Department of Environmental Protection has developed the New Jersey Food Waste Reduction Plan, quantifying food waste production and establishing short-term and long-term strategies to achieve the 50% goal.[40] Following on the heels of the Food Waste Reduction Act, in 2020, the Food Waste Recycling and Waste-to-Energy Production Act (P.L. 2020, c.24) was passed, requiring large food waste generators (those who produce 52 tons or more of food waste per year) located within 25 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 ($GWP_{100}$)*

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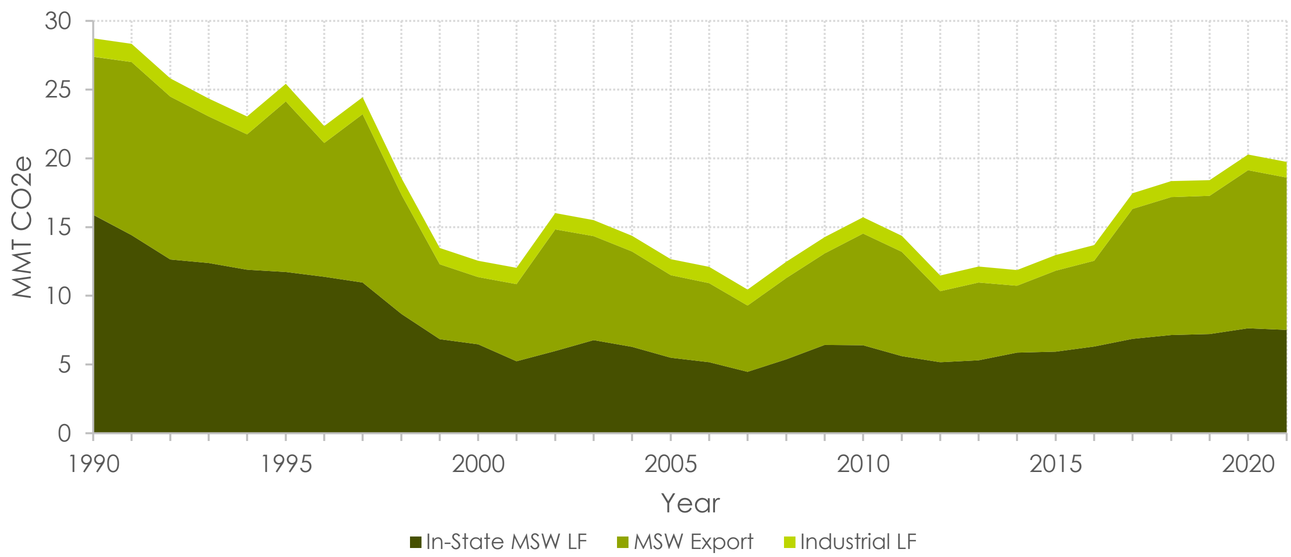
[38] Totals listed in the text may not agree exactly with sums of the numbers shown in the tables in Appendix A due to rounding of estimates in the tables.

[39] https://www.nj.gov/dep/dshw/food-waste/pl_2017_136.pdf, July 21, 2017. The statute calls for a 50% reduction below 2017 levels. Accessed December 14, 2023.

[40] https://www.nj.gov/dep/dshw/food-waste/food_waste_reduction_plan.pdf, October 2023. The plan concluded that New Jersey generated 1.48 million tons of food waste in 2017, comprising about 22% of all municipal solid waste disposal. Accessed December 14, 2023.

*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 0.7 MMT $CO_2e$/1.8 MMT $CO_2e$ (GWP20) in 1990 to 0.9 MMT $CO_2e$ ($GWP_{100}$)/2.2 MMT $CO_2e$ ($GWP_{20}$) in 2021 (Figures 25 and 26; Table A-17). 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 ($GWP_{100}$)*

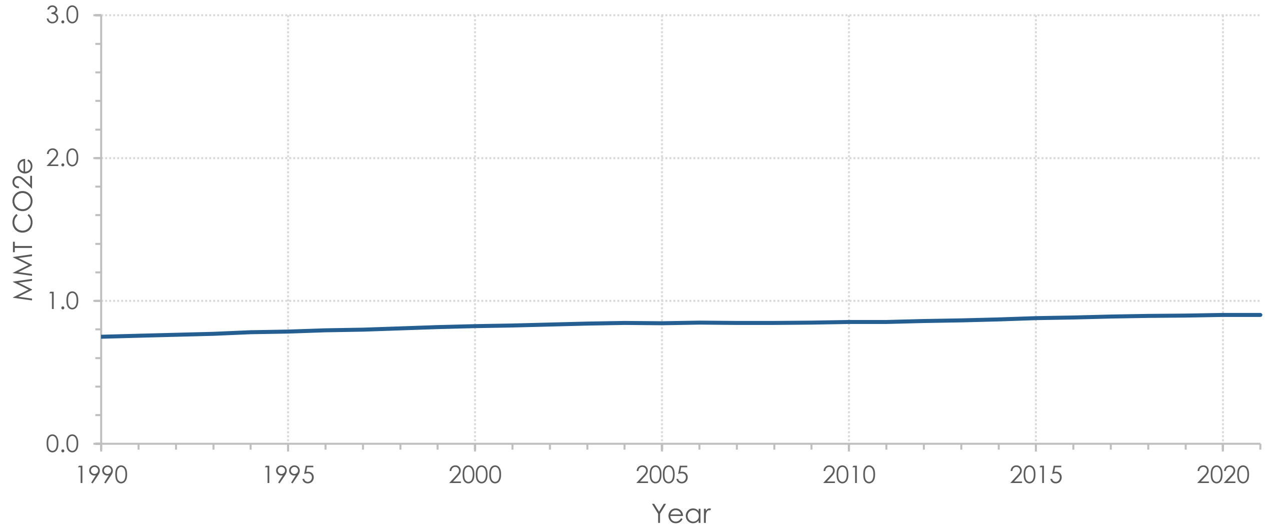
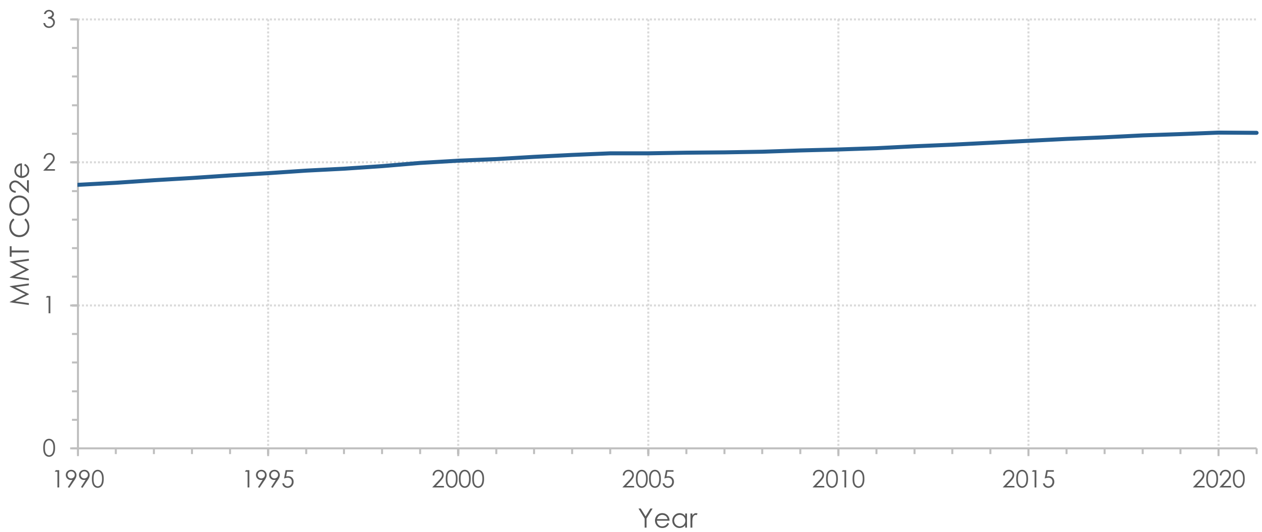


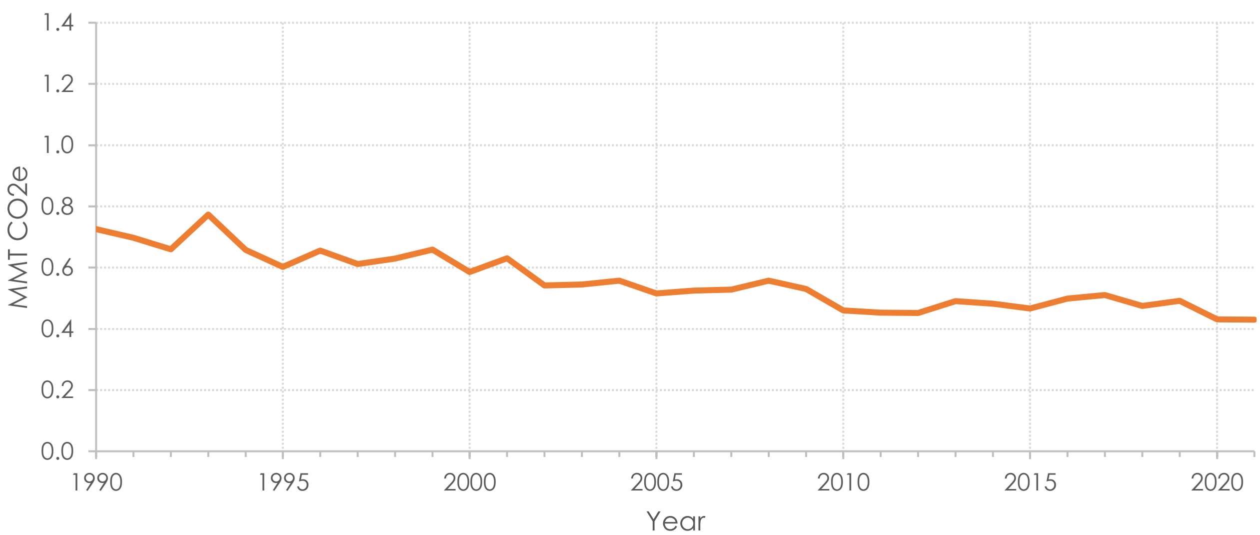

*Figure 26. Wastewater treatment emissions ($GWP_{20}$)*



## 4.5 AGRICULTURE (NON-FUEL)

New Jersey's 9,900 farms have an average size of only 76 acres, and yet they make the state a national leader in production of fruits and vegetables.[41] This success is largely a consequence of the state's favorable climate and proximity to major population centers. Livestock operations also take place, but to a much smaller extent than in many other agriculturally-intensive states.[42] Overall, farm activities in the state produce modest non-fuel greenhouse gas emissions. Between 1990 and 2021, these ranged annually from 0.4 to 0.8 MMT $CO_2e$ ($GWP_{100}$), with a general downward trend across the period (Figure 27, Table A-18). Using a 20-year GWP, emissions ranged from 0.6 to 1.2 MMT $CO_2e$ ($GWP_{20}$) across the same period (Figure 28, Table A-18). Emissions for 2020 were 0.4 MMT $CO_2e$ ($GWP_{100}$)/0.6 MMT $CO_2e$ ($GWP_{20}$).[43] Examples of non-fuel emissions include release of nitrous oxide from the soil, carbon dioxide from agricultural lime used to neutralize soil acids, and methane emissions from livestock and manure management. Emissions from fuels consumed at farms, for example to power farm equipment, are included in the fuel-based industrial sector emissions described above, pursuant to the classification method of the US Energy Information Agency (US EIA).

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

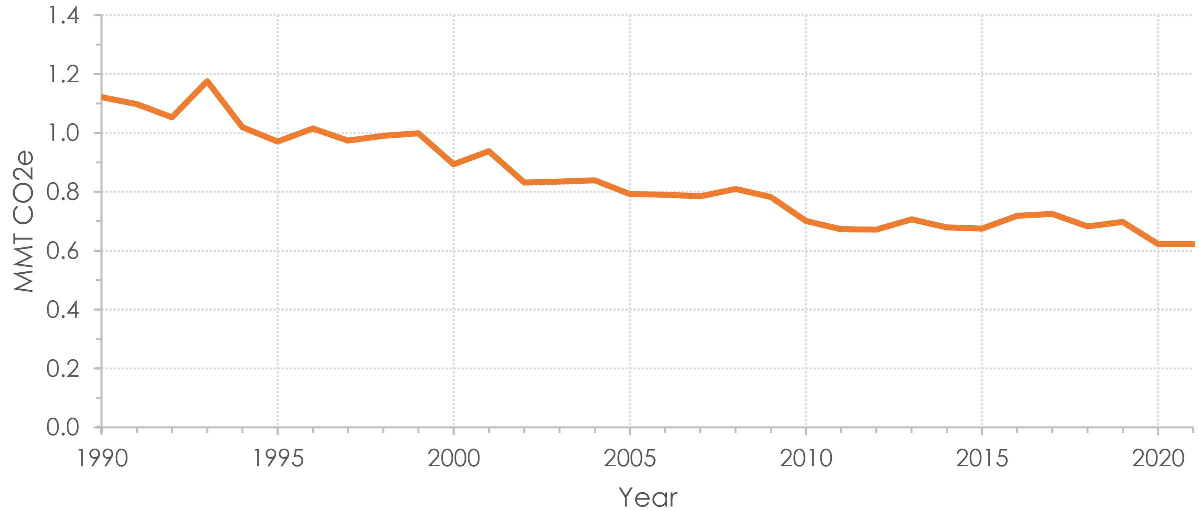



[41] New Jersey is a top producer of eggplant (#1 nationally); spinach (#3); tomatoes (#3); cranberries (#3); asparagus (#4); bell peppers (#3); peaches (#3); blueberries (#6); cucumbers (#6); squash (#7); and sweet corn (#9). The state is also ranked fourth in floriculture sales. Source: 2022 Annual Report and Agricultural Statistics, NJ Department of Agriculture, 2022. https://www.nj.gov/agriculture/pub/general.html. Accessed December 15, 2023.

[42] In January 2021, New Jersey had approximately 25,000 head of cattle and 7,500 hogs. In contrast, Texas cattle numbered in the range of 12.7 million and Iowa hogs 24 million. Livestock agriculture in New Jersey therefore contributes less to climate change than in many other agricultural states. However, New Jersey is committed to reducing climate impacts wherever feasible while maintaining a prosperous agricultural community. Sources: 2022 Annual Report and Agricultural Statistics, NJ Department of Agriculture, 2022. https://www.nj.gov/agriculture/pub/general.html; USDA Annual Cattle Review, Texas, 2023, https://www.nass.usda.gov/Statistics_by_State/Texas/Publications/Current_News_Release/2023_Rls/tx-cattle-review-2023.pdf; 2020 Iowa Pork Industry Report, May 2020, https://www.iowapork.org/filesimages/Documents/Full_Iowa-Pork-Industry-Report.pdf Accessed December 15, 2023.

[43] Non-fuel agricultural emissions data for 2021 was not available from the USEPA State Inventory Tool at the time of this report's preparation. These emissions were therefore assumed to have remained constant since 2020.

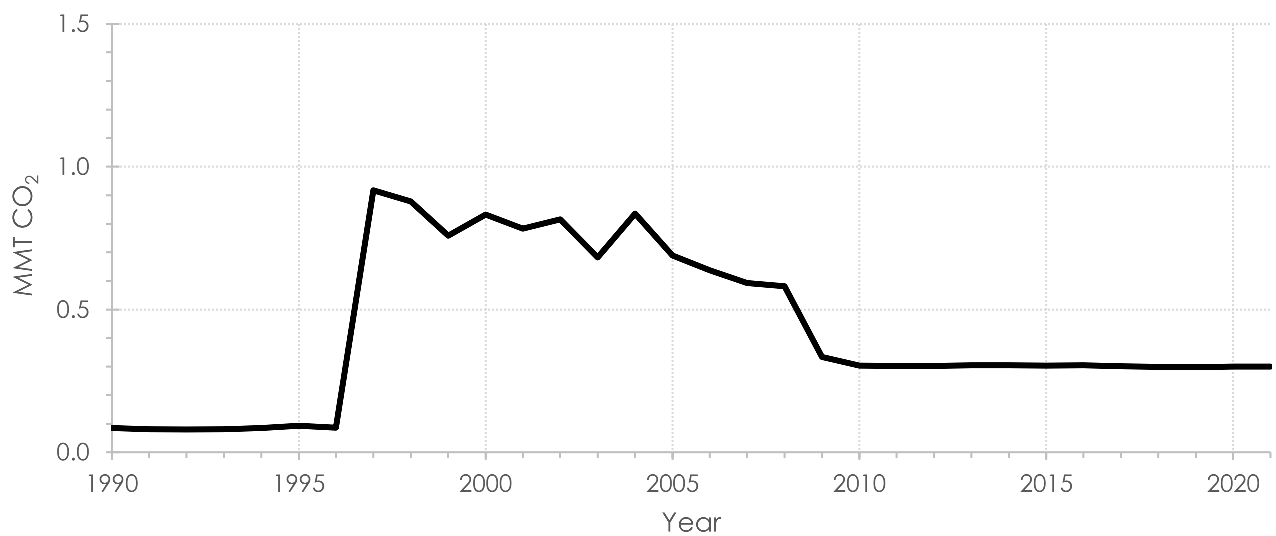
Figure 28. Agriculture (Non-fuel) emissions ($GWP_{20}$)




## 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 2020 were approximately 0.3 MMT $CO_2e$ (Figure 29; Table A-19).[44] Because the emissions are carbon dioxide, the values are independent of GWP.

Figure 29. Non-fuel Industrial Emissions




[44] Non-fuel industrial emissions data for 2021 was not available from the USEPA State Inventory Tool at the time of this report's preparation. These emissions were therefore assumed to have remained constant since 2020.

## 4.7 EMISSIONS DUE TO LAND CLEARING

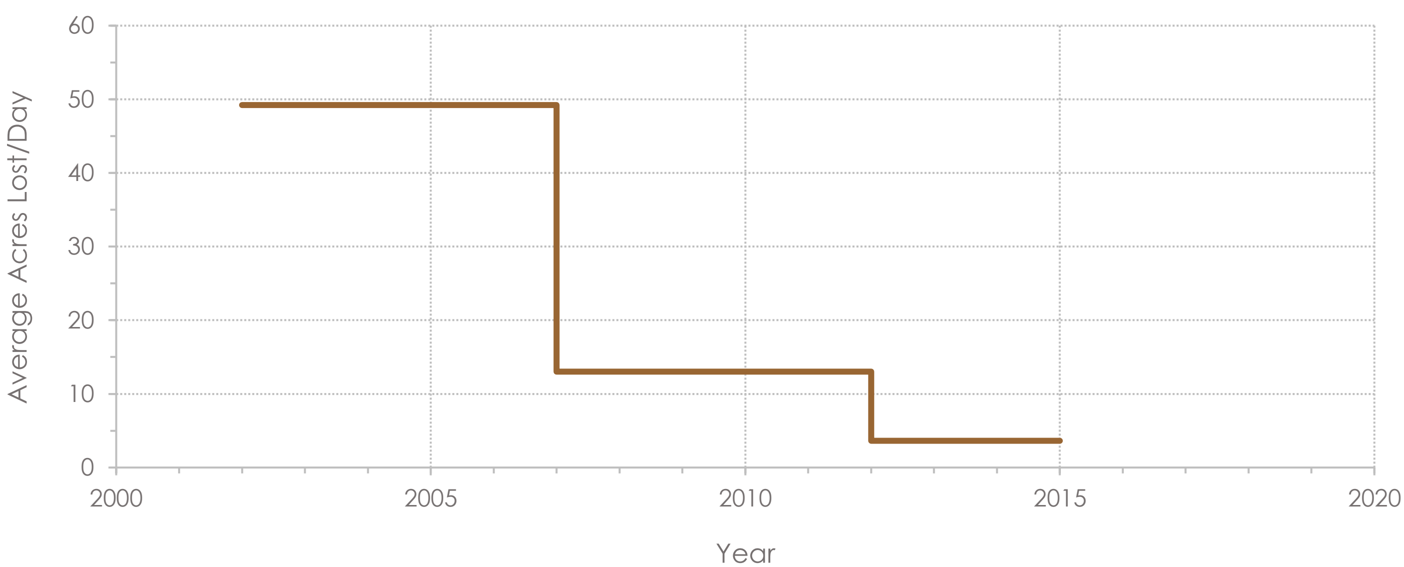
Large stores of carbon exist in the state's forests, wetlands and other biological reserves. When these lands are disturbed through development and urbanization, much of their stored carbon is released to the atmosphere as carbon dioxide, thereby accelerating climate change. The rate at which land is 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.[45]

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.[46]




## 4.8 SULFUR HEXAFLUORIDE

Sulfur hexafluoride ($SF_6$) is a long-lived climate pollutant with an exceptionally high global warming potential of 23,500, 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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[45] 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

[46] 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 0.6 MMT $CO_2e$ ($GWP_{100}$) in 1990 to 0.08 MMT $CO_2e$ ($GWP_{100}$) in 2020 (Figure 31; Table A-20).[47] 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 2021 (Figure 32; Table A-20).

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

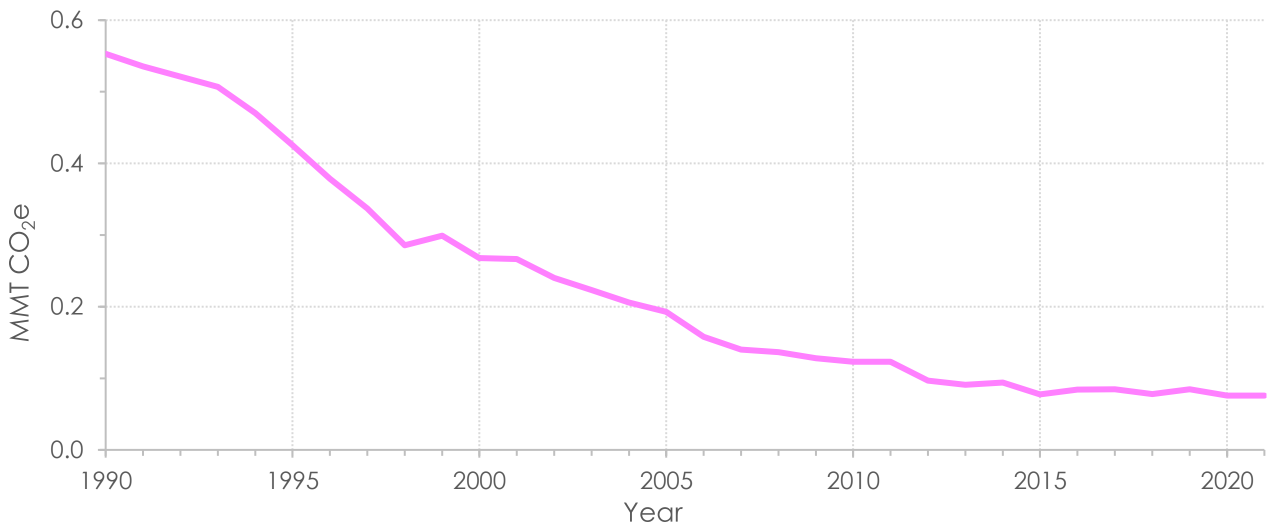
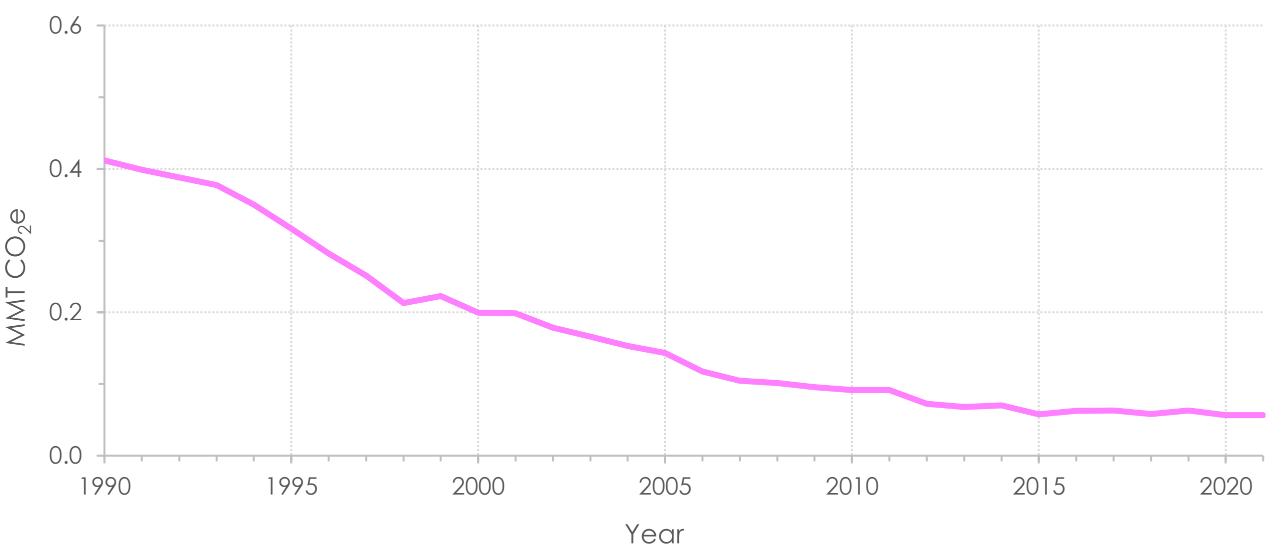



*Figure 32. Sulfur hexafluoride emissions ($GWP_{20}$)*




[47] Sulfur hexafluoride emissions data for 2021 was not available from the USEPA State Inventory Tool at the time of this report's preparation. These emissions were therefore assumed to have remained constant since 2020.

# 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 approximately 8% of 2021 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.

# 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 such as acids and vapors onto its surface.

Several variants of black carbon are known carcinogens in addition to being 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.[48] It also does not remain suspended long enough to mix completely with the global atmosphere. As a result, its effects are greatest close to the source.

Beginning with the public release of the 2014 National Emissions Inventory (NEI)[49], 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, past estimates are not updated to reflect improved assessment methodologies. Thus, this report provides a comprehensive black carbon inventory for New Jersey, covering years 2005 through 2020 (Tables A-2 and A-4; and Appendix E). The methods used to calculate the inventory are comparable to those applied in the 2020 NEI. Additional data for on-road transportation is provided for 2021 based on NJDEP modeling.[50] 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 is approximately 77%, but when natural gas is consumed in a turbine, only about 7% of the fine particulate matter is black carbon.[51] 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. For example, natural gas produces less $PM_{2.5}$ to begin with compared to diesel, and of that, a smaller fraction of the $PM_{2.5}$ is black carbon.

Substantial reductions in black carbon emissions in the State occurred between 2005 and 2020 due to decreases from the two largest sources, transportation and non-road equipment (Figures 33 and 34; Table A-21). 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 5.8 MMT $CO_2e$ ($GWP_{100}$)/20.2 MMT $CO_2e$ ($GWP_{20}$) to a low in 2020 of 1.7 MMT/6.1 MMT $CO_2e$ ($GWP_{20}$).[52]

Although there is insufficient data to develop sector-specific estimates for 2018 and 2019, extrapolation of the 2017 to 2020 trend would lead to a continuing decrease, with a 2021 projected total of 1.6 MMT $CO_2e$ ($GWP_{100}$)/5.4 MMT $CO_2e$ ($GWP_{20}$) if the historic pattern continued. Given the continuing replacement of diesel truck and light-duty engines with cleaner technologies, a continued downward trend in black carbon emissions is anticipated.

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[48] 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

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

[50] NJ uses PM2.5 data from the NEI to calculate black carbon emissions beginning in 2005 using the most recent emissions factors from EPA. However, the NEI is only published every three years, so estimates are not yet available for 2021. However, NJ onroad modeling provides black carbon estimates for 2021, which are presented here.

[51] USEPA SPECIATE 5.2 database. https://www.epa.gov/air-emissions-modeling/speciate-4

[52] 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 the use of speciation factors from the 2020 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.

*Figure 33. Black Carbon Emissions 2005-2020 ($GWP_{100}$)*

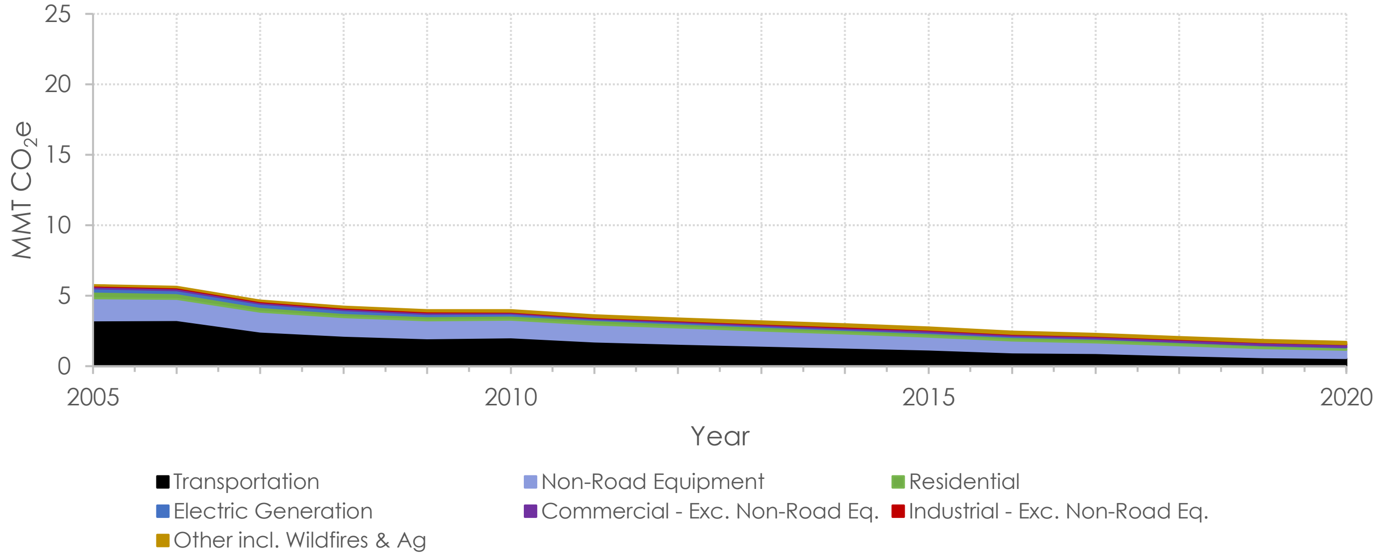
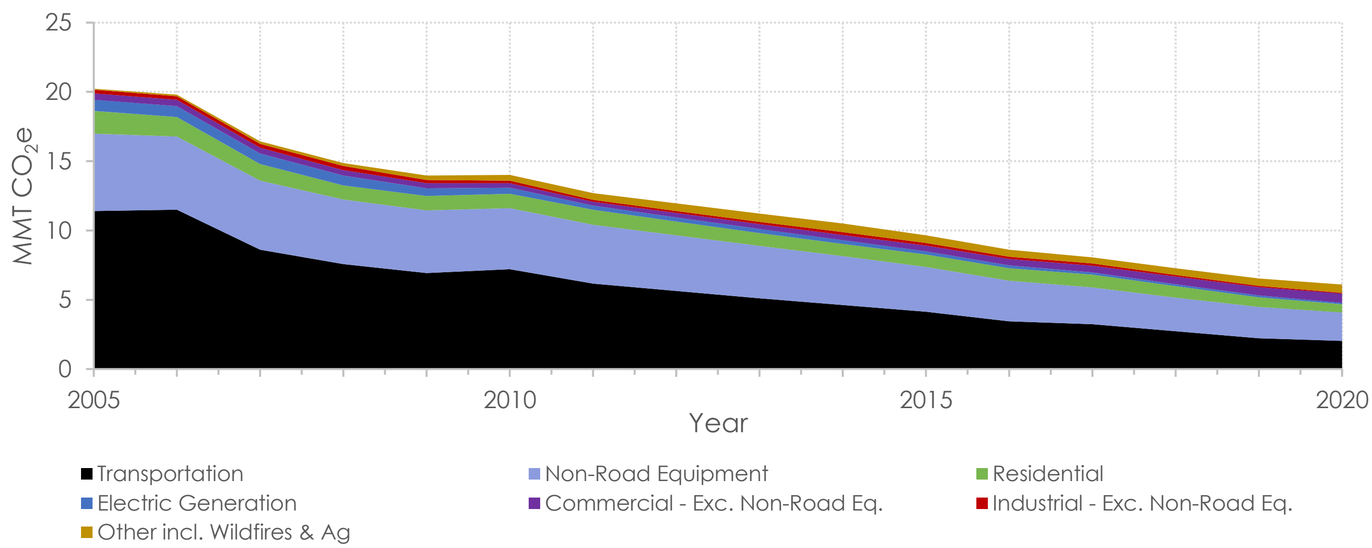



*Figure 34. Black Carbon Emissions 2005-2020 ($GWP_{20}$)*




### 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 $CO_2e$ ($GWP_{100}$)/11.4 MMT $CO_2e$ ($GWP_{20}$). However, due to aggressive policies requiring cleaner burning engines, emissions from this sector have dropped dramatically. In 2020, black carbon emissions decreased more than eighty percent to 0.58 MMT $CO_2e$ ($GWP_{100}$)/2.0 MMT $CO_2e$ ($GWP_{20}$) with transportation accounting for 33% of total black carbon emissions (Figures 35 and 36).

Figure 35 Transportation Sector Black Carbon Emissions (GWP100)

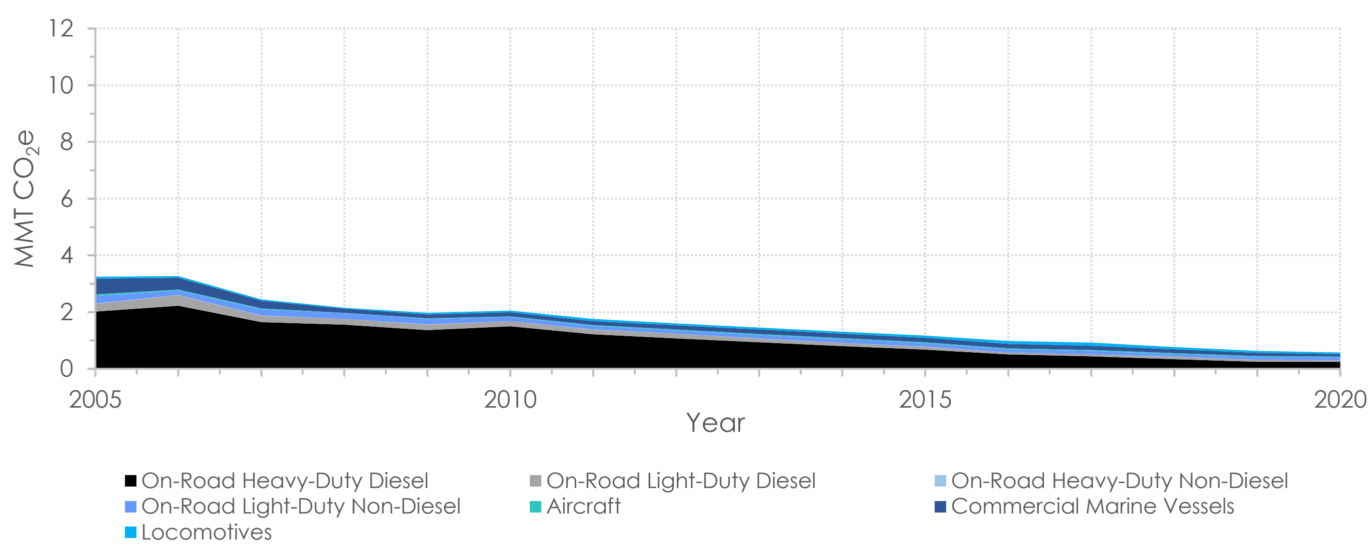
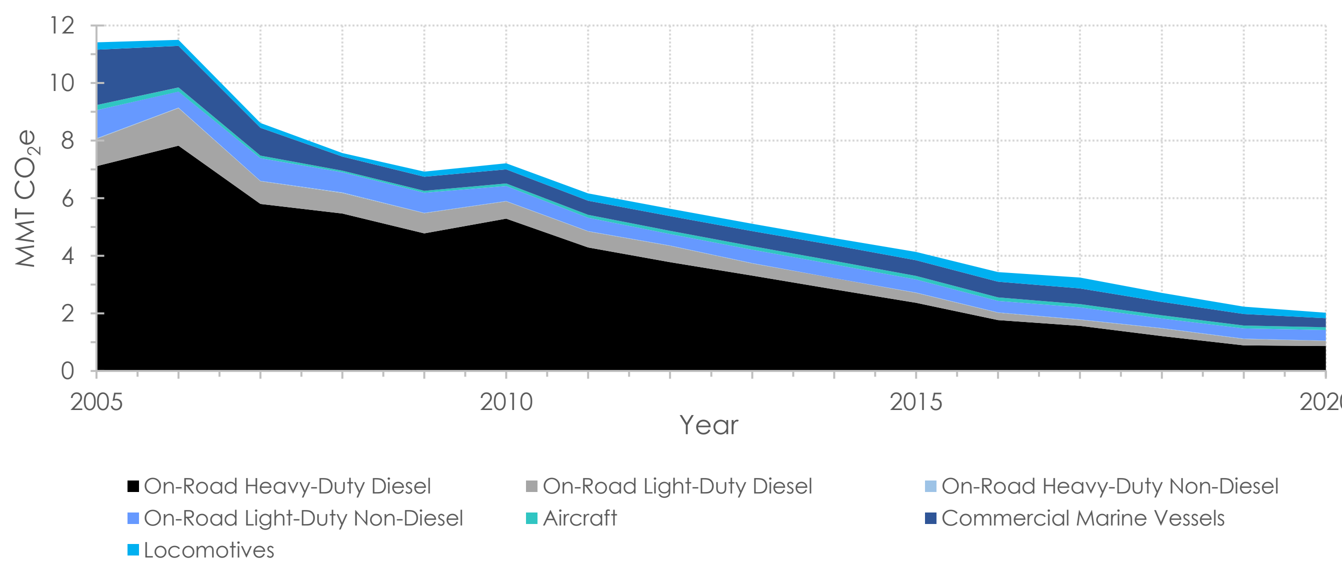



Figure 36 Transportation Sector Black Carbon Emissions (GWP20)




### 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 85% to 0.40 MMT $CO_2e$ ($GWP_{100}$)/1.4 MMT $CO_2e$ ($GWP_{20}$) in 2021 (Figures 37 and 38; Table A-22). 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-23). The chief force behind these improvements was the federal mandate calling for cleaner engines, coupled with targeted programs facilitating replacement of older equipment. Diesel vehicle emission dropped from 2.6 MMT $CO_2e$ ($GWP_{100}$)/9.1 MMT $CO_2e$ ($GWP_{20}$) in 2006 to 0.28 MMT $CO_2e$ ($GWP_{100}$)/1.0 MMT $CO_2e$ ($GWP_{20}$) in 2021. Gasoline-powered (non-diesel) vehicles have also seen steady reductions, dropping from 0.16 MMT $CO_2e$ ($GWP_{100}$)/ 0.58 MMT $CO_2e$ ($GWP_{20}$) in 2005 to 0.12 ($GWP_{100}$)/0.41 MMT $CO_2e$ ($GWP_{20}$) in 2021.

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

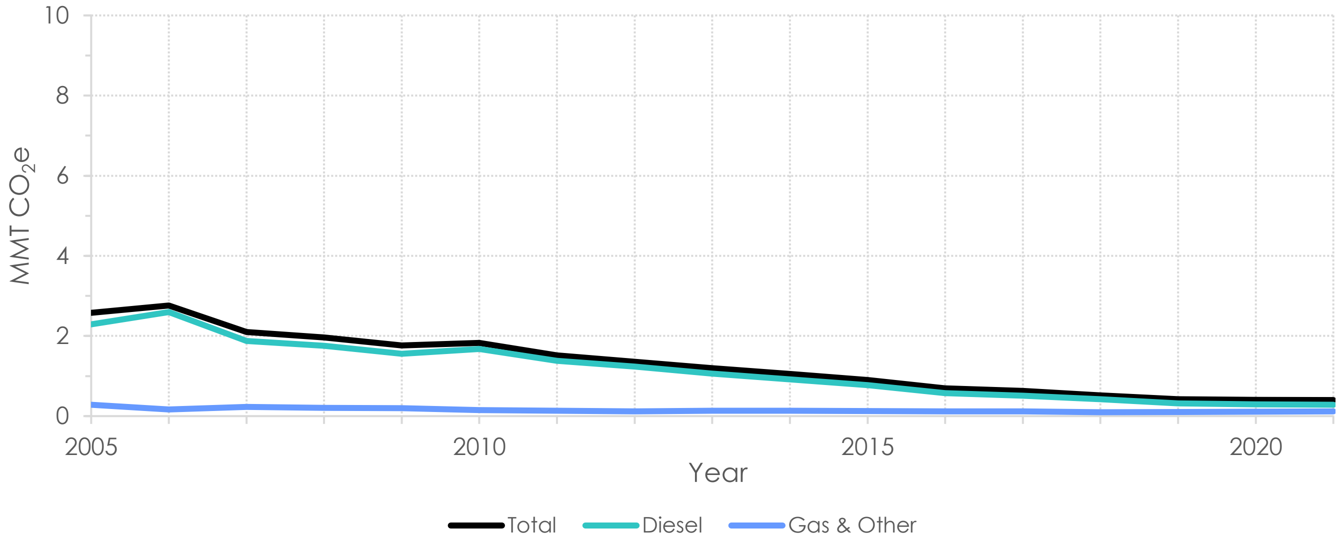



*Figure 38. On-Road Black Carbon Emissions by Fuel Type ($GWP_{20}$)*

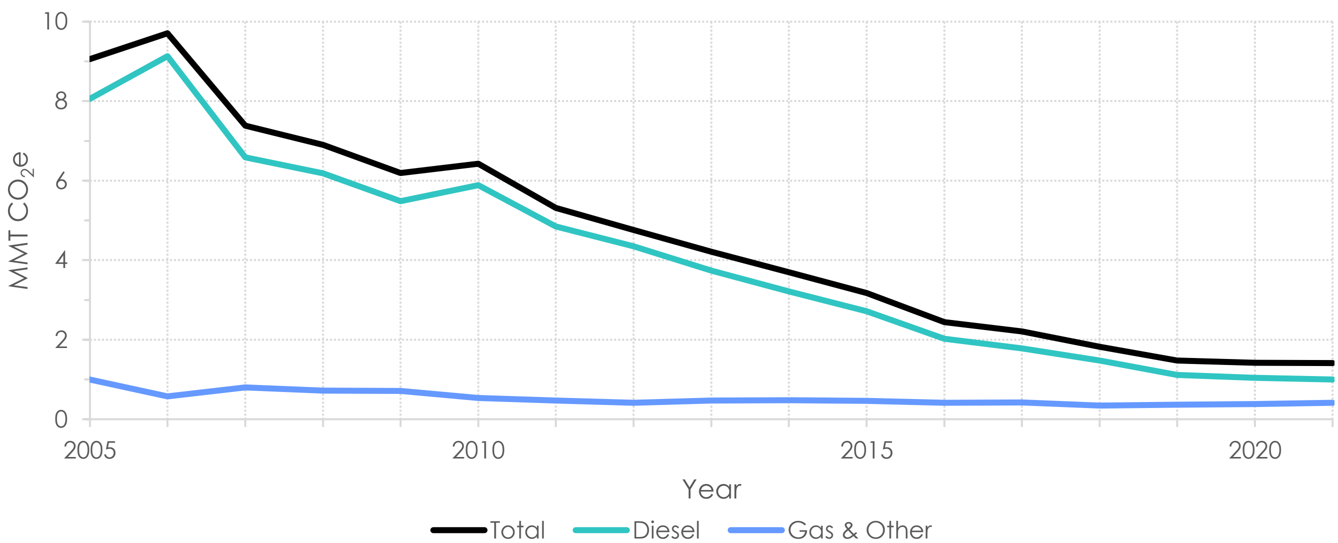


*Figure 39. Black Carbon Emissions from Diesel Vehicles ($GWP_{100}$)*

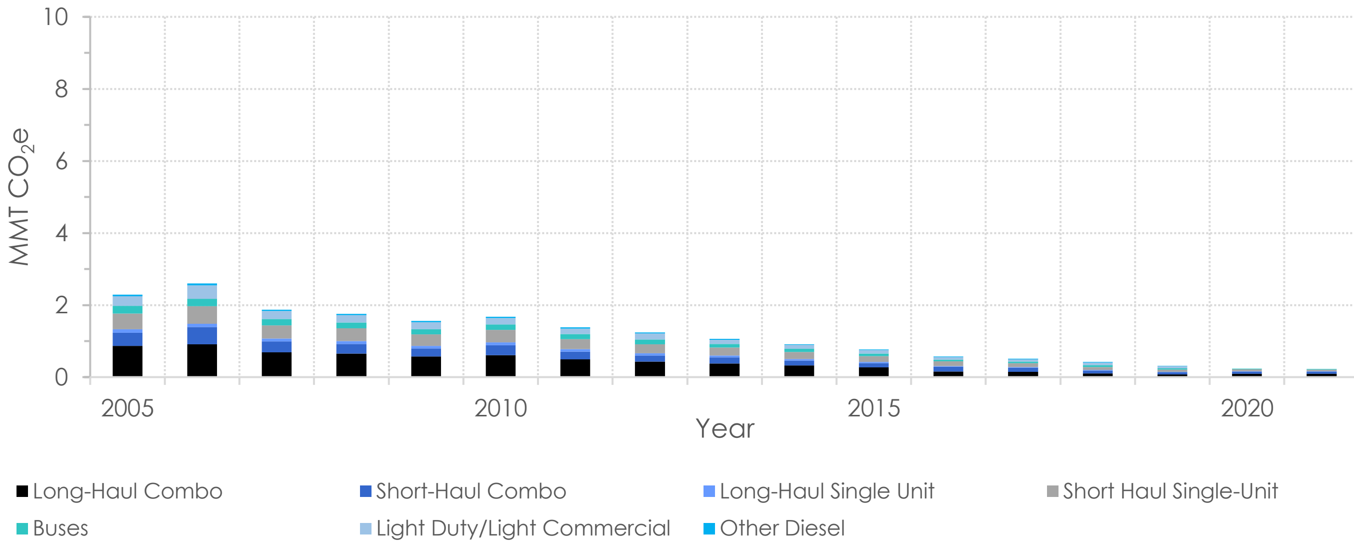
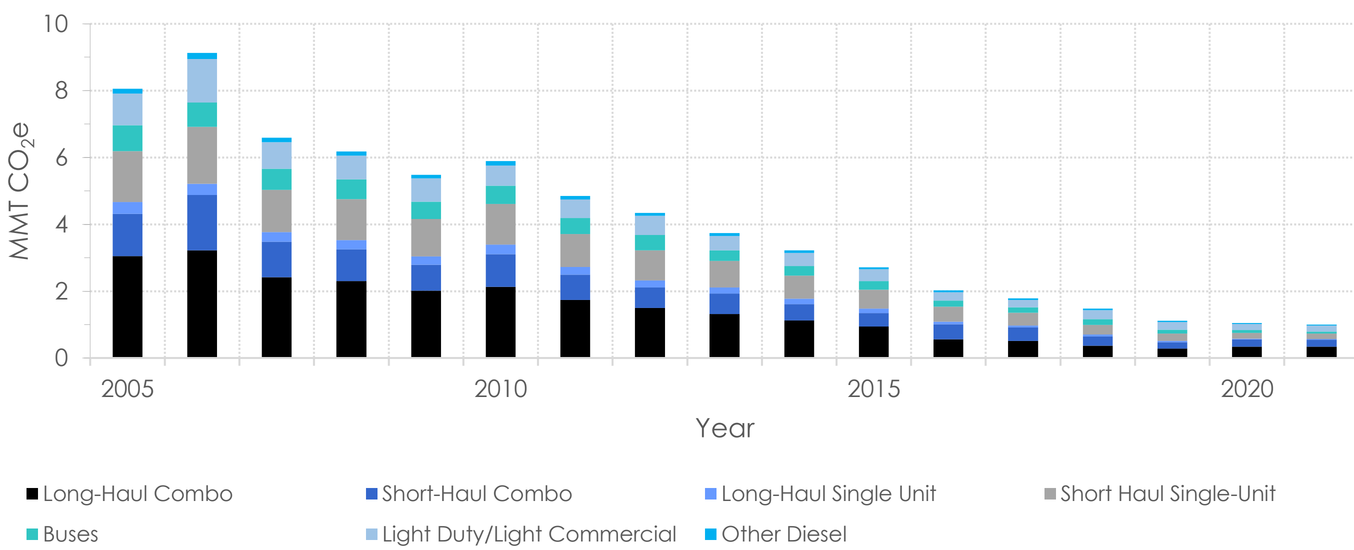



*Figure 40. Black Carbon Emissions from Diesel Vehicles ($GWP_{20}$)*




### *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-24). In 2020, marine emissions accounted for 52% of the non-road transportation total.

Peak black-carbon emissions in-state aviation emissions occurred in 2005 at 0.05 MMT $CO_2e$ ($GWP_{100}$)/ 0.18 MMT $CO_2e$ ($GWP_{20}$), dropped to a low of 0.01 MMT $CO_2e$ ($GWP_{100}$)/0.05 MMT $CO_2e$ ($GWP_{20}$) in 2008, a year marked by a sharp financial downturn, and then rebounded by 2014 to 0.04 MMT $CO_2e$ ($GWP_{100}$)/ 0.13 MMT $CO_2e$ ($GWP_{20}$). In the years since, black carbon emissions from the aviation sector have changed only slightly, reaching 0.03 MMT $CO_2e$ ($GWP_{100}$)/0.10 MMT $CO_2e$ ($GWP_{20}$) in 2020. Overall, current emissions are 47% below the 2005 peak. It should be noted that these emissions calculations were based on landings and take offs, and therefore not include emissions occurring as these flights travel across other states, nor do they include emissions from flights that do not stop in New Jersey.

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, 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. However, by 2020 emissions had dropped to 0.06 MMT $CO_2e$ ($GWP_{100}$)/ 0.19 MMT $CO_2e$ ($GWP_{20}$). Some of this decrease may reflect pandemic-related closures and curtailments, in addition to the increased use of lower-emitting equipment.

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

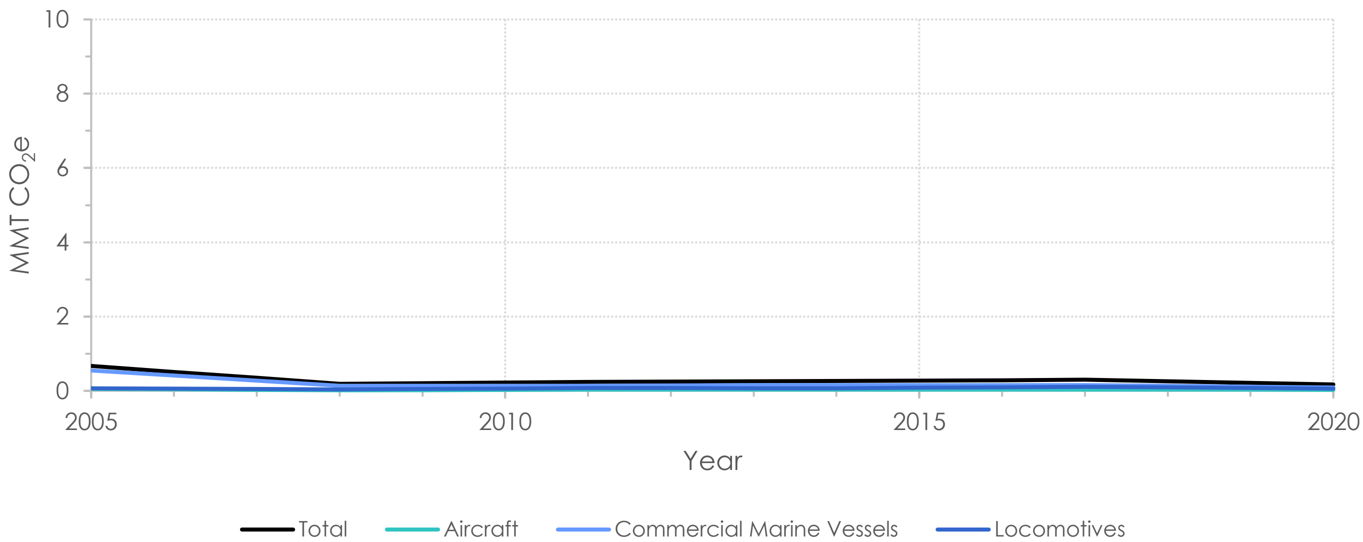
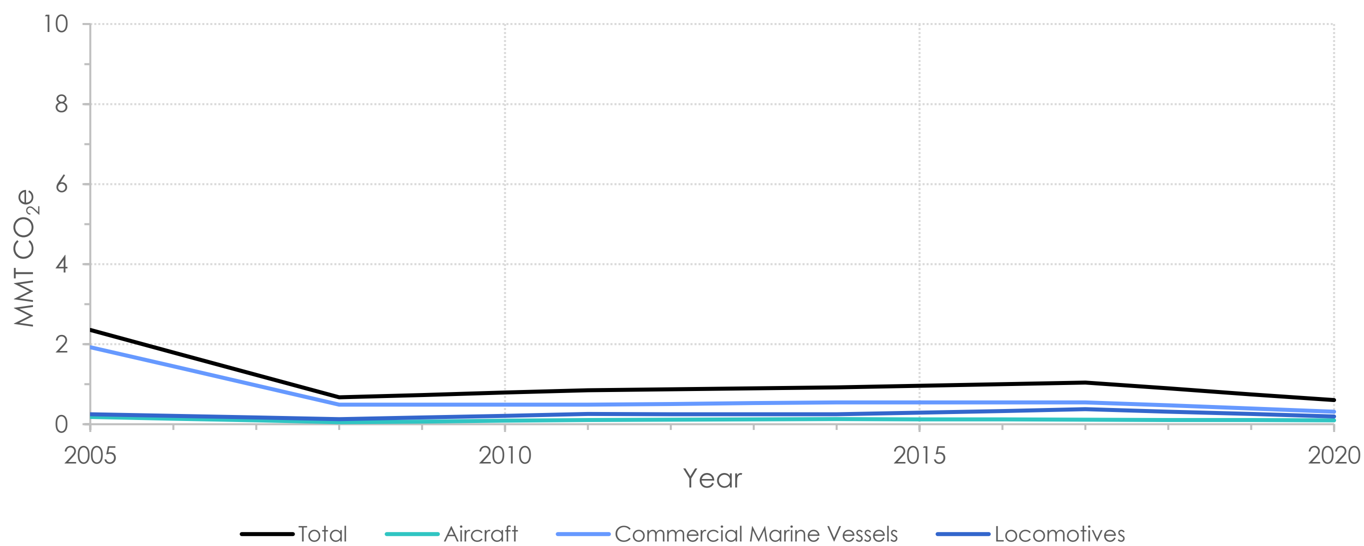



*Figure 42. Black Carbon from Non-Road Transportation ($GWP_{20}$)*



### Non-Road Equipment Sector

Non-road equipment includes bulldozers, excavators, cranes, and other non-road devices moving goods and personnel on site, and generally not used for conventional transportation between sites. Emissions from non-road equipment now equal the total black carbon emissions from the entire transportation sector, reflecting a slower adoption of new, low-emitting diesel technology. However, emissions in this category dropped by more than half between 2005 and 2020, from 1.6 MMT $CO_2e$ ($GWP_{100}$)/ 5.6 MMT $CO_2e$ ($GWP_{20}$) at the outset to 0.58 MMT $CO_2e$ ($GWP_{100}$)/ 2.1 MMT $CO_2e$ ($GWP_{20}$) in 2020 (Figures 43 and 44; Table A-25). Diesel-powered equipment was responsible for 81% of the black carbon emissions in this category, suggesting that wider use of low-emitting technologies is in fact leading to greater reductions.

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

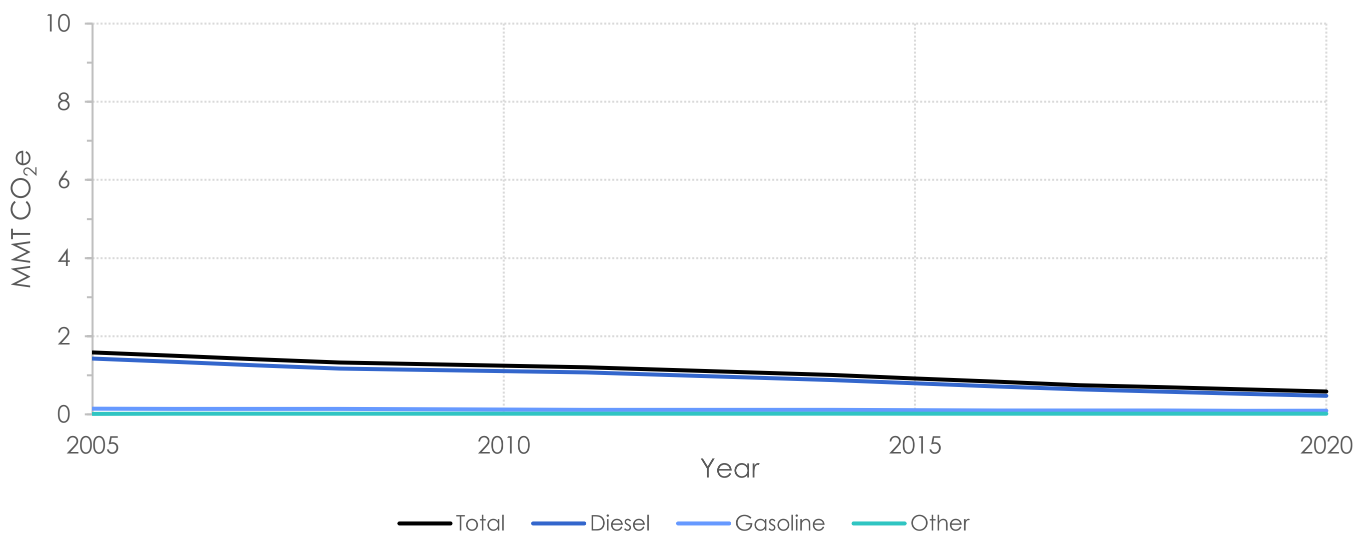
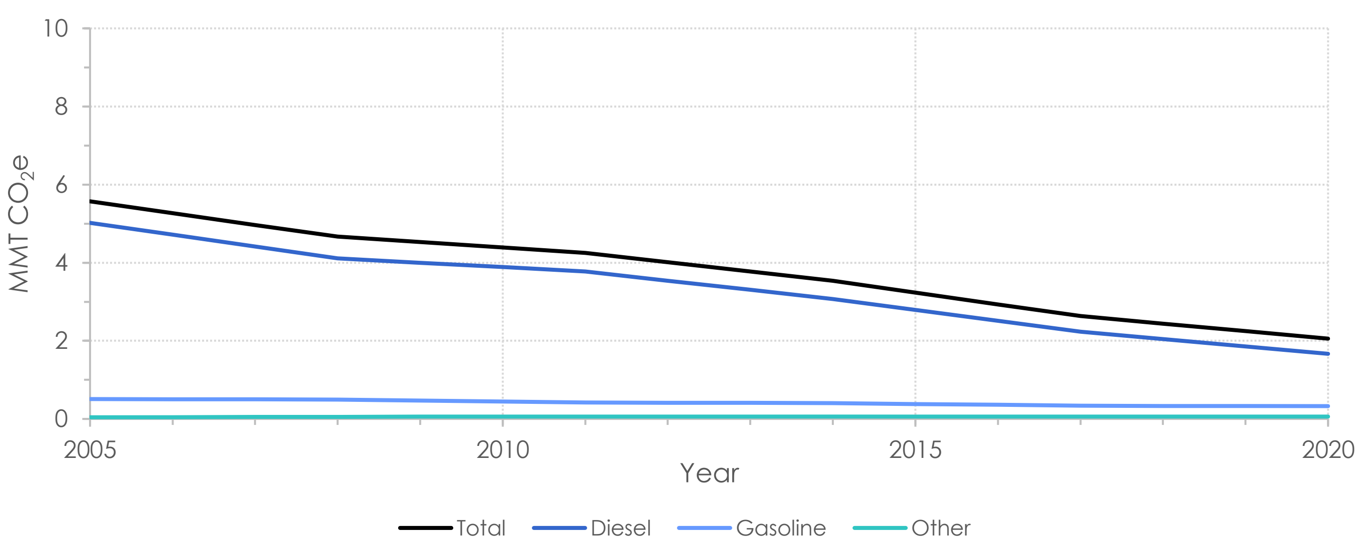



*Figure* 44. Black Carbon from Non-Road Equipment ($GWP_{20}$)



### Electric Generation Sector

In 2020, black carbon from the electric generation sector accounted for 1.7% 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 2020 (Figures 45 and 46; Table A-26). The total amounts of black carbon are very small because the state relies heavily on nuclear power and relatively clean combined cycle natural gas technology. Overall, black carbon emissions for the sector fell 87%, from an initial emissions rate of 0.23 MMT $CO_2e$ ($GWP_{100}$)/ 0.82 MMT $CO_2e$ ($GWP_{20}$) in 2005 to 0.03 MMT $CO_2e$ ($GWP_{100}$)/ 0.07 MMT $CO_2e$ ($GWP_{20}$) in 2020. Black carbon reductions through 2011 can be attributed to the dramatic decline in coal-fueled electric generation, with coal generation dropping from 11.6 TWh in 2005 to 1.9 TWh in 2012. Meanwhile, natural gas generation rose from 15.4 TWh in 2005 to 28.3 TWh in 2012, and peaked at 43.8 TWh in 2016. Overall, 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 0.02 MMT $CO_2e$ ($GWP_{100}$)/ 0.07 MMT $CO_2e$ ($GWP_{20}$) in 2020; this is due in part to increased efficiency of generating sources. Other fuel sources accounted for less than 0.002 MMT $CO_2e$ ($GWP_{100}$)/ 0.007 MMT $CO_2e$ ($GWP_{20}$) across the period. Black carbon emissions from waste management practices are categorized separately from electricity generation in the underlying EPA data, but may overlap with the Electric Generation sector's "Other Fuels" category with respect to solid waste incineration and the use of landfill gas as a generation fuel. In 2020, waste incineration emitted 0.002 MMT $CO_2e$ ($GWP_{100}$)/ 0.007 MMT $CO_2e$ ($GWP_{20}$), and landfills emitted 0.001 MMT $CO_2e$ ($GWP_{100}$)/ 0.004 MMT $CO_2e$ ($GWP_{20}$). These sources were similarly small throughout the period of record.

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

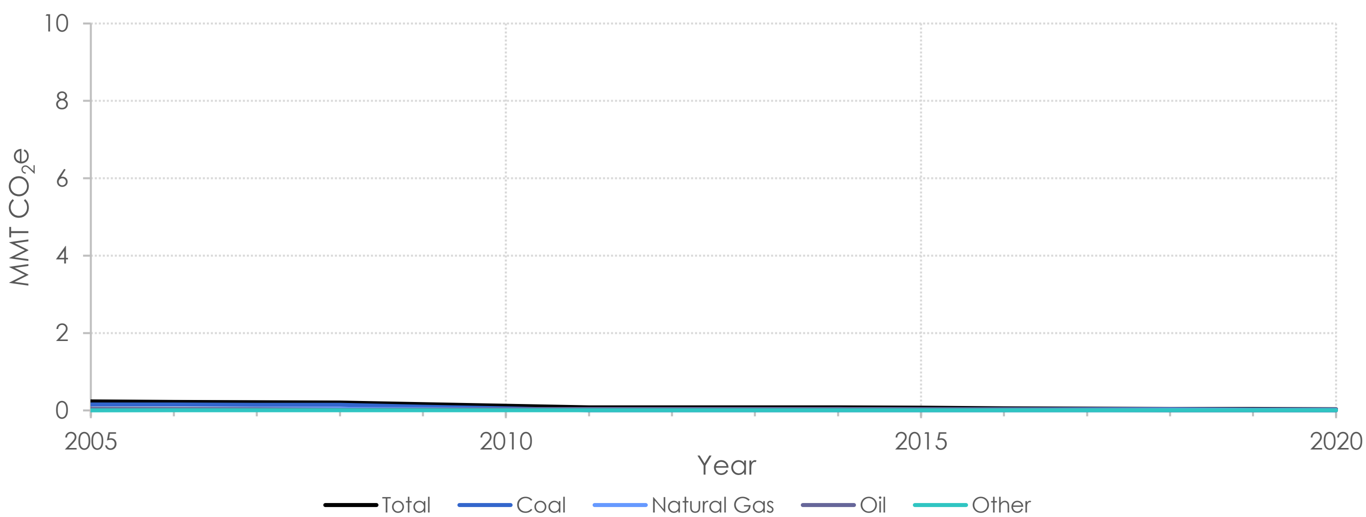
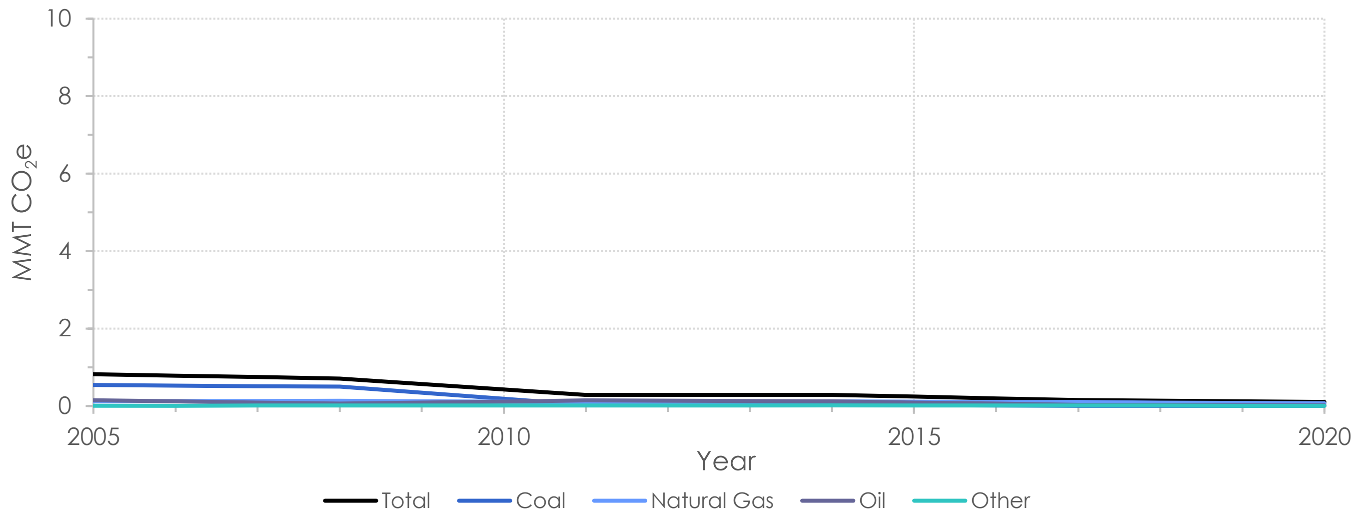


Figure 46. Electric Generation Sector Black Carbon Emissions ($GWP_{20}$)




### Residential Sector

In 2020 black carbon emissions from the residential sector made up 10% of total emissions. Residential sector black carbon emissions decreased by over 64%, from an initial total of 0.47 MMT $CO_2e$ ($GWP_{100}$)/ 1.6 MMT $CO_2e$ ($GWP_{20}$) in 2005 to 0.17 MMT $CO_2e$ ($GWP_{100}$)/ 0.59 MMT $CO_2e$ ($GWP_{20}$) in 2020 (Figures 47 and 48; Table A-27). 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 emissions, 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 ($GWP_{100}$)

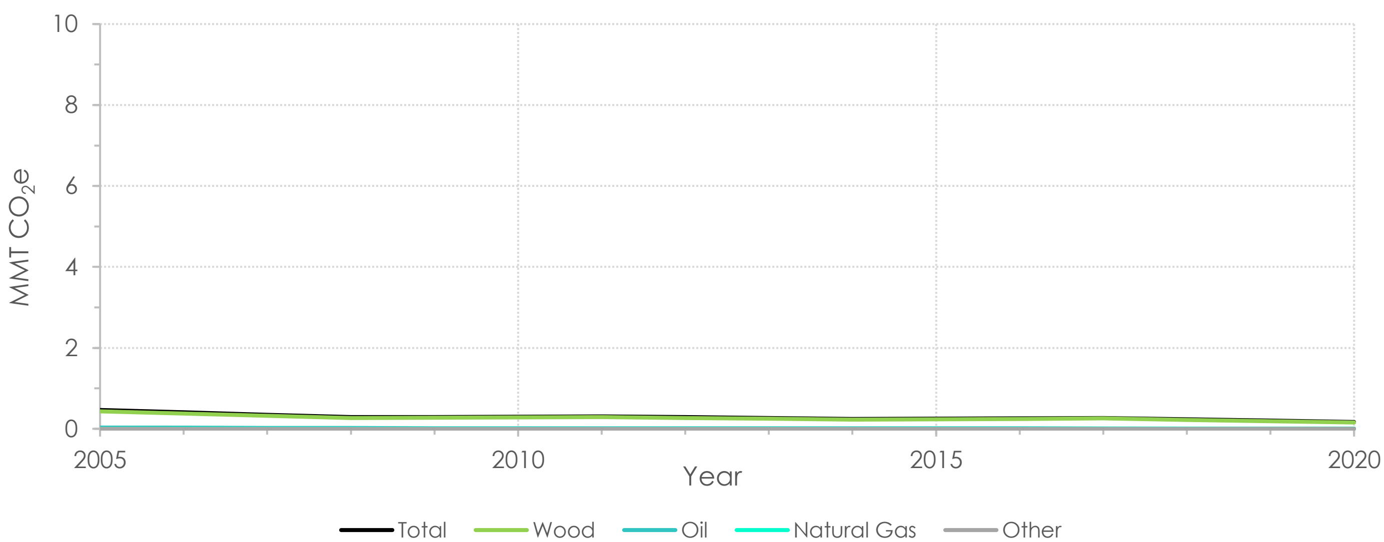
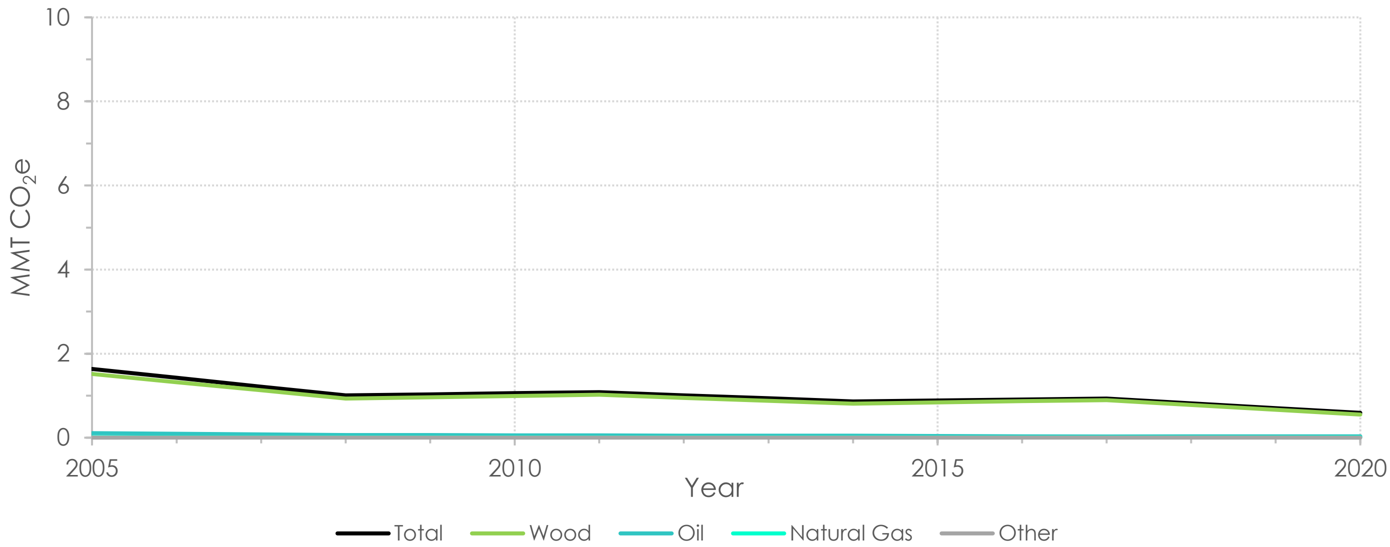


*Figure 48.  Residential Black Carbon Emissions ($GWP_{20}$)*




### Commercial Sector, Except Non-Road Equipment

Emissions from the commercial sector increased slightly across the period, from 0.13 MMT $CO_2e$ ($GWP_{100}$)/ 0.46 MMT $CO_2e$ ($GWP_{20}$) in 2005 to 0.19 MMT $CO_2e$ ($GWP_{100}$)/ 0.66 MMT $CO_2e$ ($GWP_{20}$) in 2020 (Figures 49 and 50; Table A-28). However, the role of commercial cooking has steadily increased during this timeframe, initially accounting for 57% of emissions in 2005 but rising to 95% by 2020.  The corresponding emissions from commercial cooking were 0.08 MMT $CO_2e$ ($GWP_{100}$)/ 0.26 MMT $CO_2e$ ($GWP_{20}$) in 2005 and 0.18 MMT $CO_2e$ ($GWP_{100}$)/ 0.63 MMT $CO_2e$ ($GWP_{20}$) in 2020.  In contrast, emissions from combustion of oil dropped from 0.05 MMT $CO_2e$ ($GWP_{100}$)/ 0.18 MMT $CO_2e$ ($GWP_{20}$) in 2005 to only 0.004 MMT $CO_2e$ ($GWP_{100}$)/ 0.02 MMT $CO_2e$ ($GWP_{20}$) in 2020.  Black carbon emissions from other fuels and activities were negligible.

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

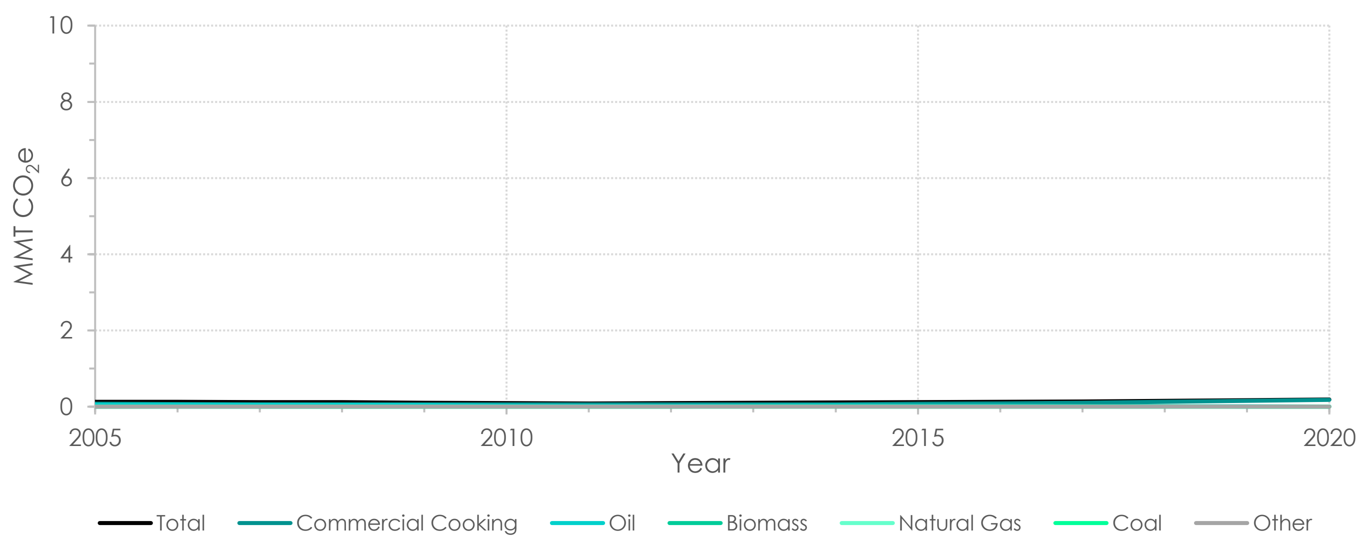
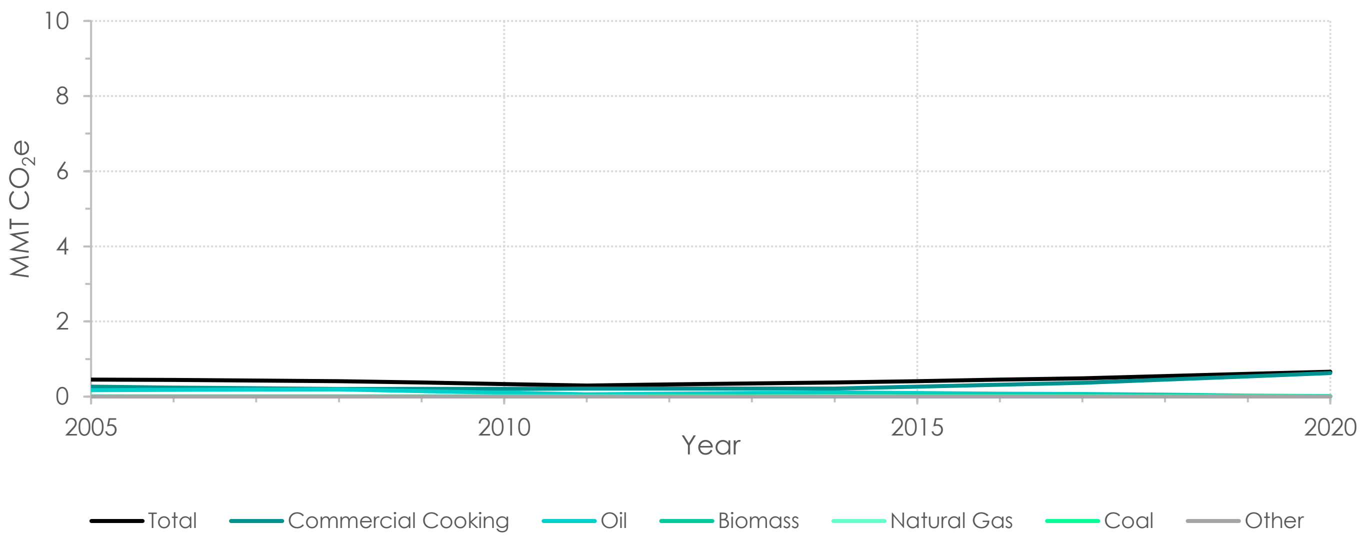


*Figure 50. Commercial Sector Black Carbon, Excluding Non-Road Equipment ($GWP_{20}$)*

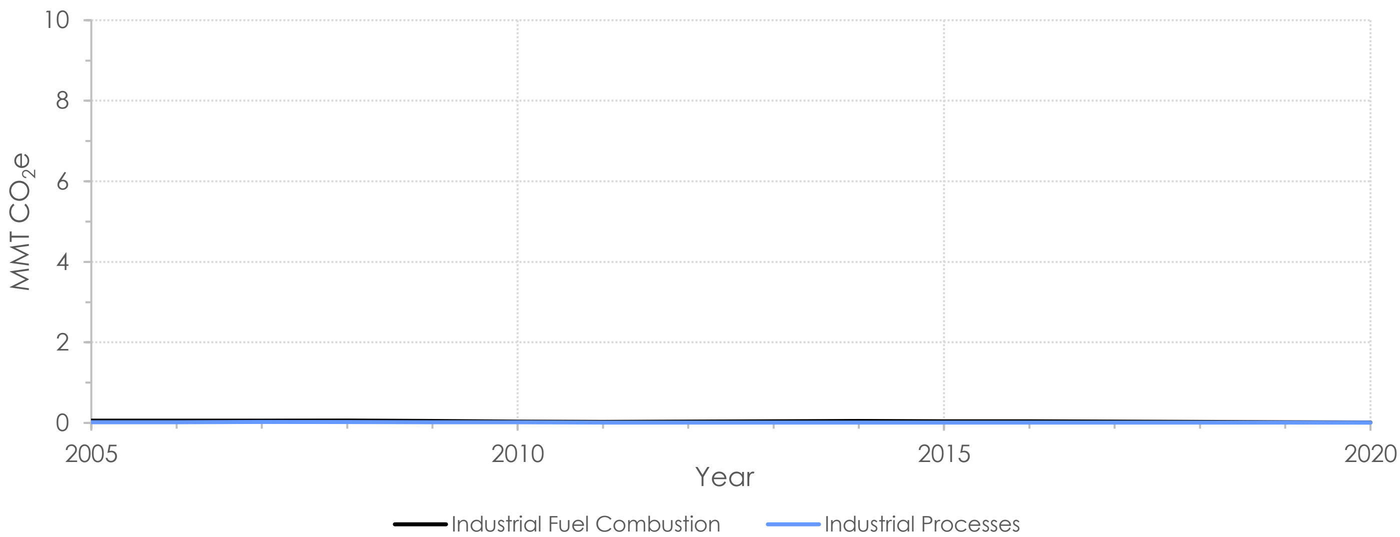



### Industrial Sector, Except Non-Road Equipment

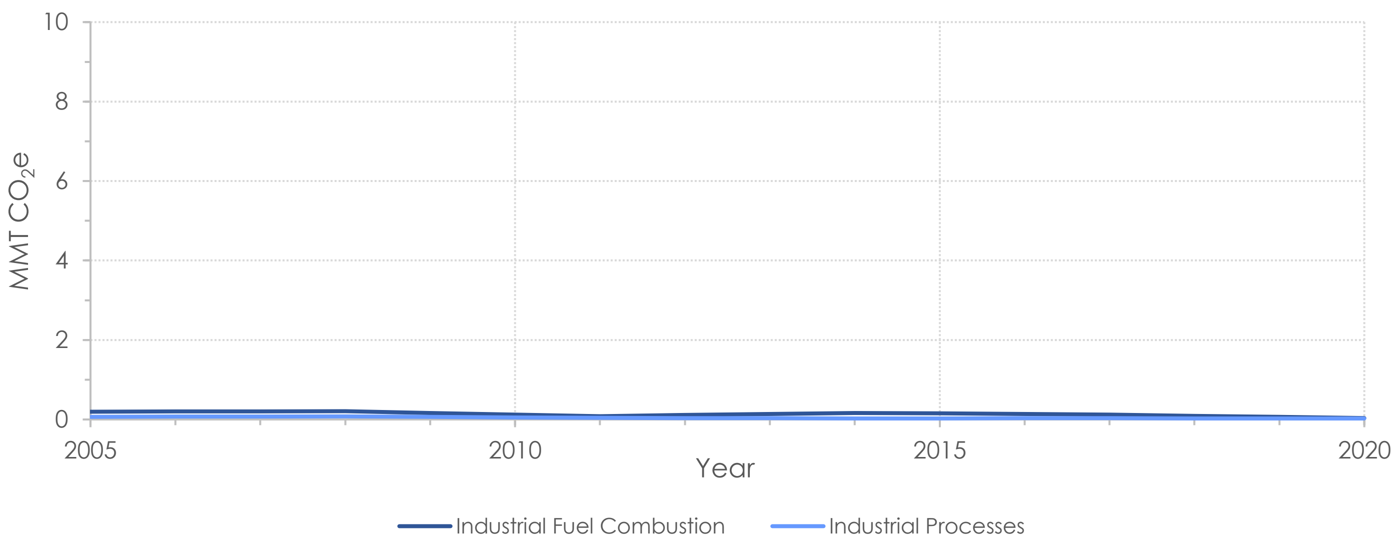
Combined emissions of black carbon from fuel combustion and process operations in the industrial sector were negligible at 0.02 MMT $CO_2e$ ($GWP_{100}$)/ 0.06 MMT $CO_2e$ ($GWP_{20}$) in 2020, 77% below 2005 emissions of 0.07 MMT $CO_2e$ ($GWP_{100}$)/ 0.26 MMT $CO_2e$ ($GWP_{20}$) (Figures 51 and 52, 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 0.01 MMT $CO_2e$ ($GWP_{100}$)/ 0.04 MMT $CO_2e$ ($GWP_{20}$) in 2020, although emissions fluctuated during this time (Figures 53 and 54; Table A-29). The bulk of emissions can be attributed to oil fuel, which has gradually fallen out of favor as in industrial energy source. In 2008, oil accounted for 93% of black carbon emissions from industrial fuel combustion, but as its role in this sector ebbed its share of emissions dropped to only 43% by 2020. 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 smaller and experienced a similar decline. In 2005, process emissions were 0.02 MMT $CO_2e$ ($GWP_{100}$)/ 0.07 MMT $CO_2e$ ($GWP_{20}$), and fell to 0.007 MMT $CO_2e$ ($GWP_{100}$)/ 0.02 MMT $CO_2e$ ($GWP_{20}$) by 2020 (Figures 55 and 56; Table A-30). 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 the storage and transfer of materials.

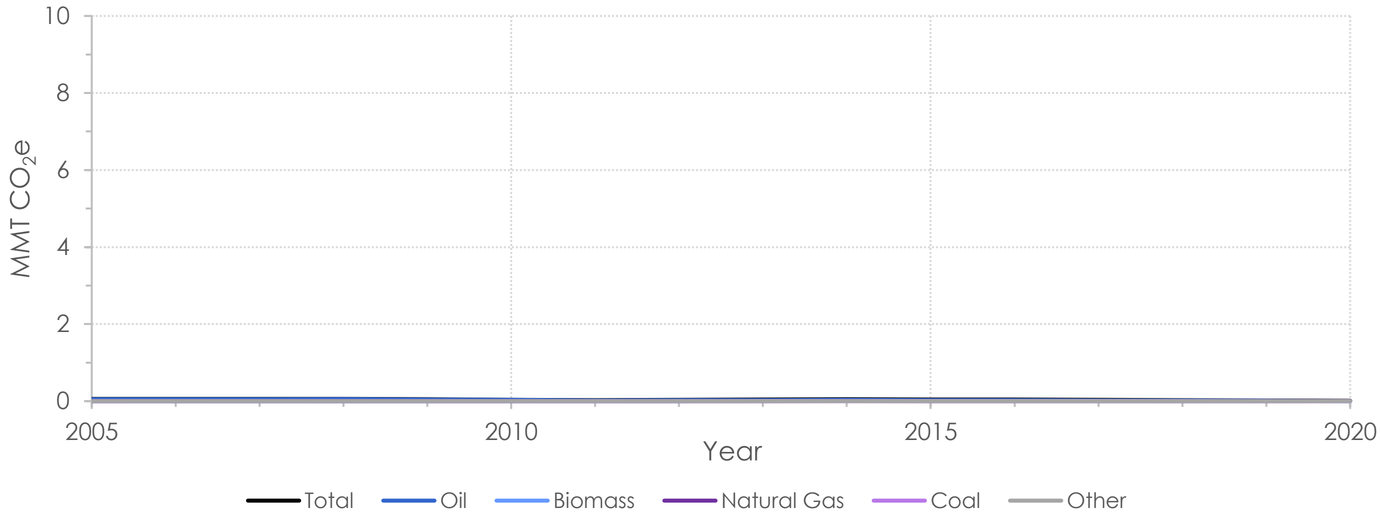
*Figure 51. Total Industrial-Sector Black Carbon Emissions, including Fuel Combustion and Process Operations ($GWP_{100}$)*




*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 ($GWP_{20}$)*

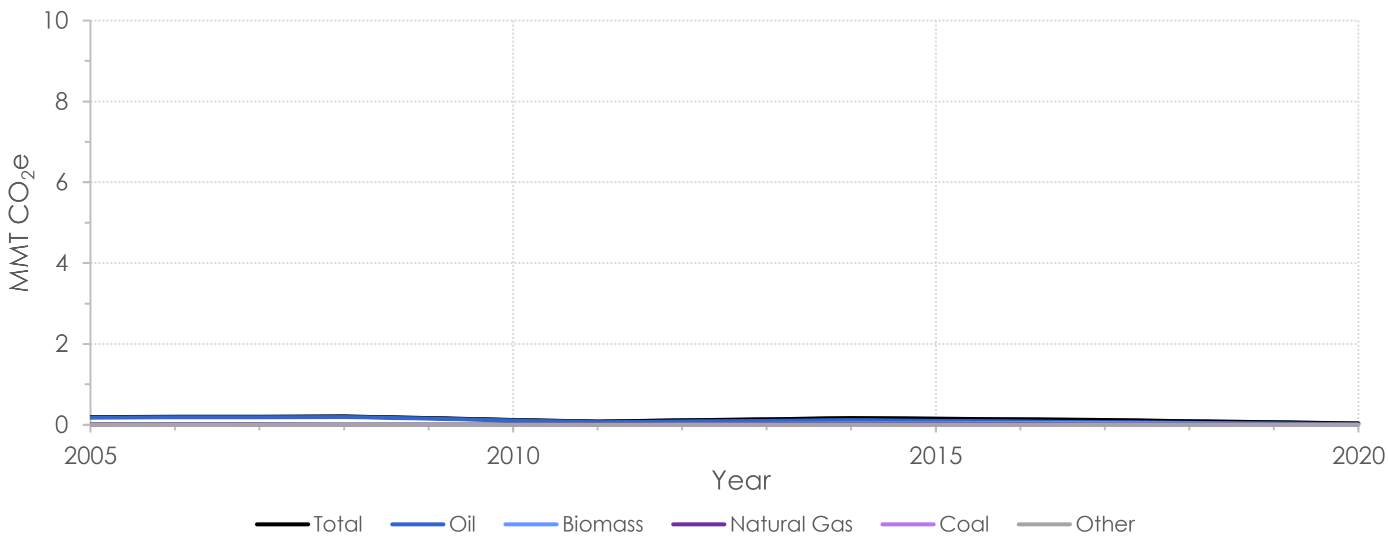


Figure 55. Black Carbon from Industrial Processes ($GWP_{100}$)[53]

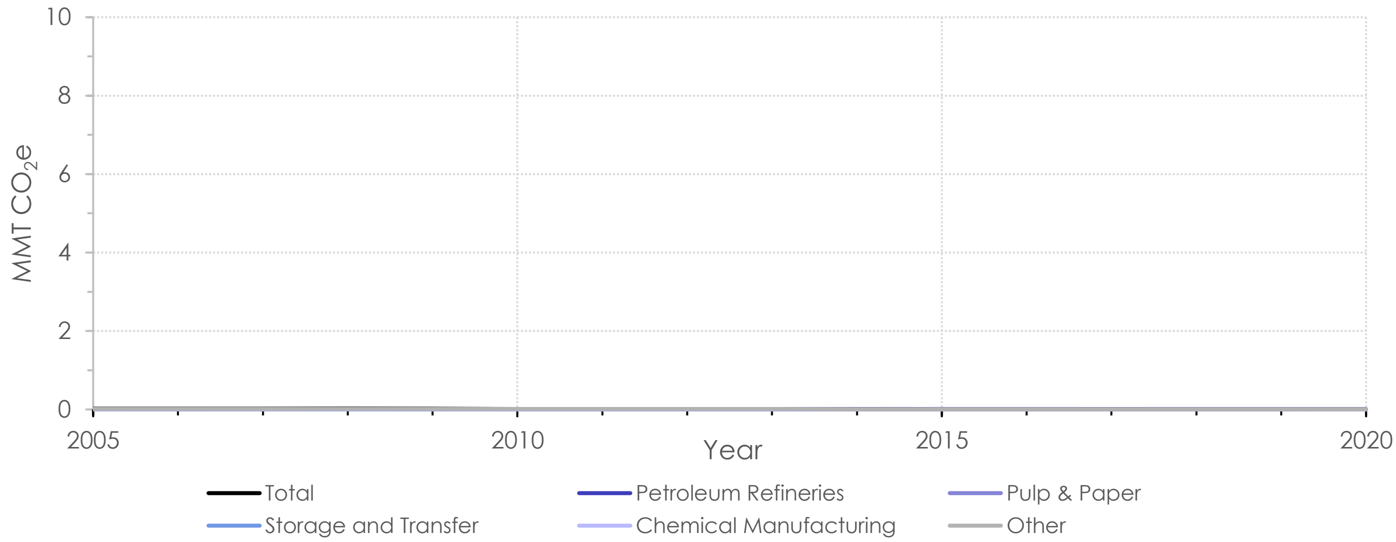
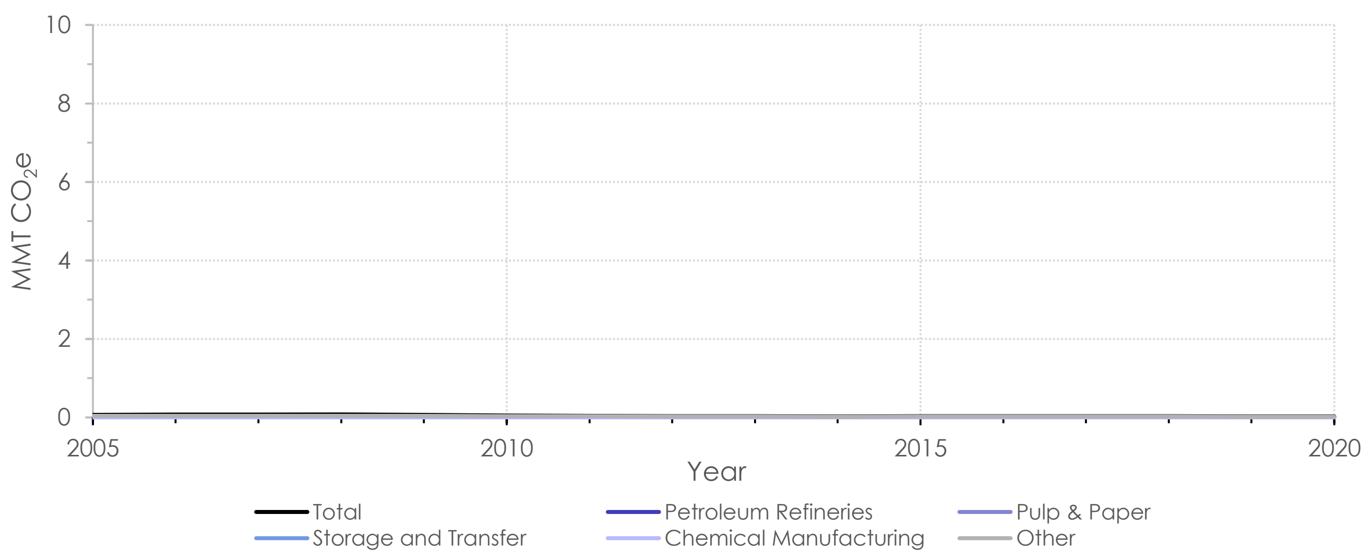



Figure 56. Black Carbon from Industrial Processes ($GWP_{20}$)[54]




### 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

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

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

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 0.01 MMT $CO_2e$ ($GWP_{100}$)/ 0.05 MMT $CO_2e$ ($GWP_{20}$) annually between 2008 and 2020, but with a wide degree of variability from year to year (Figures 57 and 58; Table A-31). Prescribed burns averaged 0.04 MMT $CO_2e$ ($GWP_{100}$)/ 0.14 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.

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

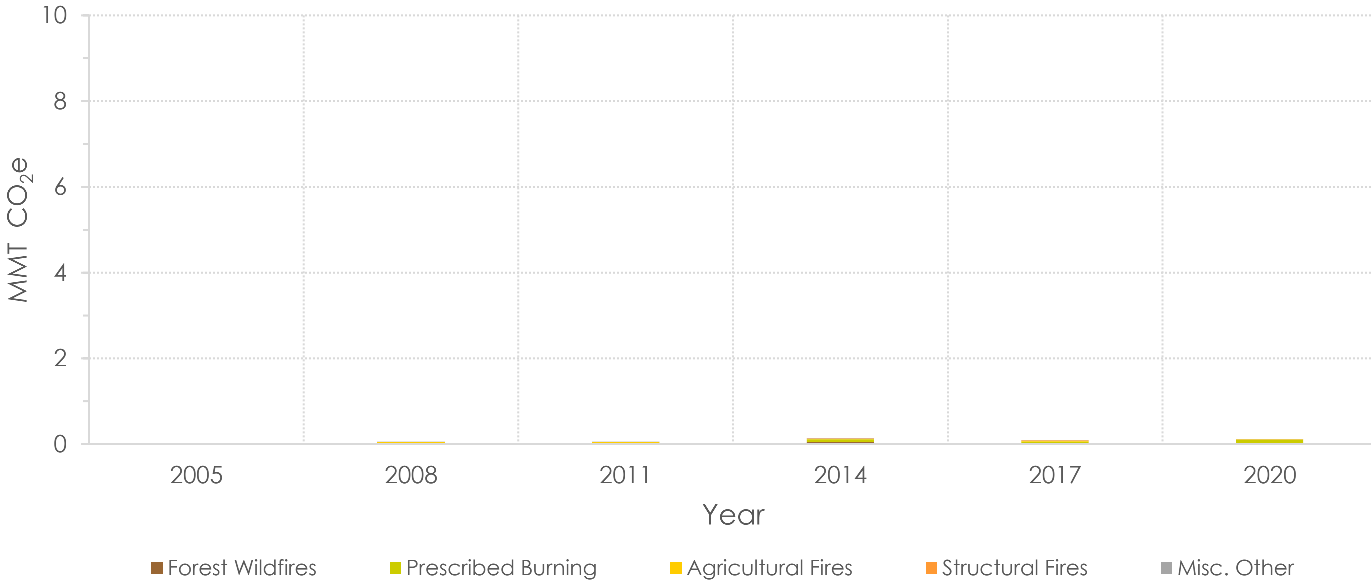
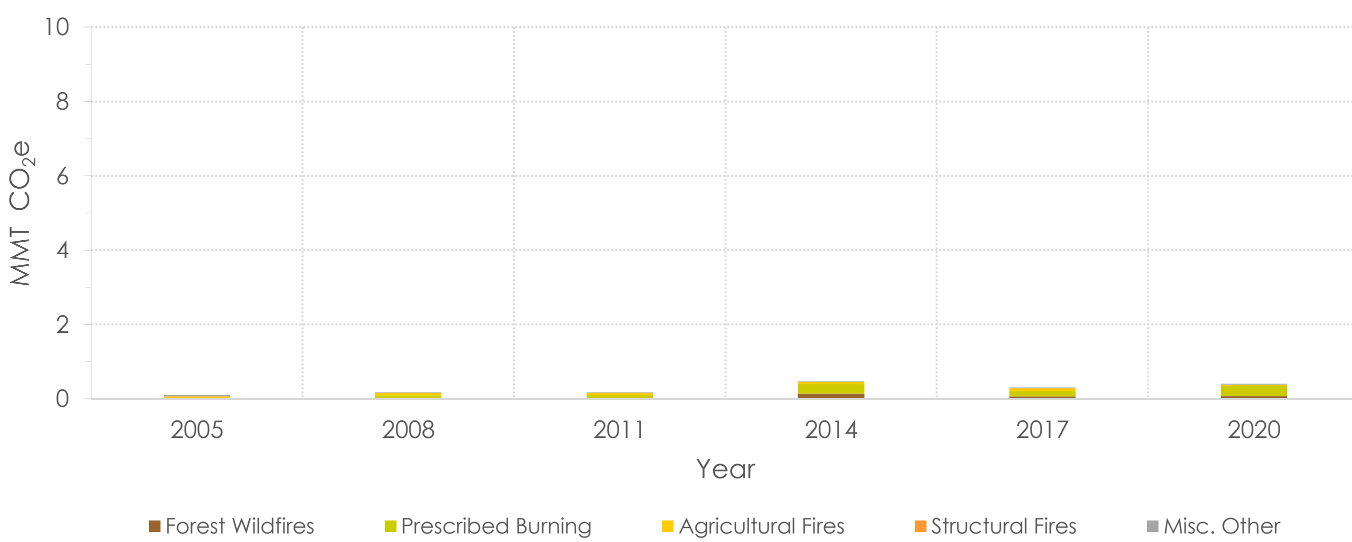



*Figure 58. Wildfires, Prescribed Burns, and Related Sources ($GWP_{20}$)*



# 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 2021 net emissions of 97.6 MMT $CO_2e$ ($GWP_{100}$) were 13% below the 1990 level of 112.6 MMT $CO_2e$.[55] Emissions for 2021 were also 19% below the 2006 level of 121.7 MMT $CO_2e$. Technological advances and shifts to cleaner fuels led to a substantial 38% 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 22%, while onroad black carbon emissions have dropped 86%. 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 by 2030 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 photovoltaics, 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,[56] 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 at the leading edge of an energy and environmental transformation that demonstrates its leadership.

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[55] 2019 emissions based on $GWP_{20}$ were 9% below the 1990 level and 12% below the 2006 level.

[56] 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 $CO_2$e, based on GWP$_{100}$[57]*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Transportation** | **33.2** | **47.4** | **47.6** | **49.6** | **47.6** | **42.6** | **42.7** | **43.3** | **41.2** | **41.3** | **41.3** | **40.7** | **42.7** | **40.3** | **40.6** | **38.0** | **34.0** | **37.3** |
| On-Road Gasoline | 26.2 | 34.4 | 34.5 | 35.1 | 34.2 | 33.3 | 32.8 | 32.3 | 31.6 | 31.8 | 32.1 | 31.7 | 32.5 | 31.1 | 30.4 | 29.7 | 24.8 | 27.0 |
| 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 | 6.6 | 7.3 |
| On-Road CNG and Other | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 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 | 1.0 | 1.0 |
| Marine | 1.7 | 3.2 | 3.2 | 4.2 | 4.3 | 1.8 | 1.7 | 1.7 | 1.6 | 1.5 | 0.7 | 0.9 | 1.2 | 1.1 | 1.7 | 0.6 | 1.1 | 1.5 |
| 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 | 0.4 | 0.4 |
| **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** | **23.6** | **23.6** | **26.5** | **25.5** | **23.1** | **24.8** |
| Residential | 15.6 | 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 | 14.1 | 14.9 |
| Commercial | 11.0 | 11.3 | 9.6 | 11.0 | 10.7 | 11.1 | 10.9 | 11.7 | 10.5 | 10.6 | 12.3 | 10.7 | 10.0 | 9.7 | 10.7 | 10.2 | 9.0 | 9.9 |
| Fuel-Based Industrial | 14.7 | 13.5 | 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 | 7.2 | 7.6 |
| **Electricity** | **26.8** | **34.0** | **30.9** | **32.3** | **29.8** | **23.5** | **26.0** | **23.2** | **20.7** | **20.3** | **20.8** | **19.5** | **20.8** | **18.0** | **19.1** | **19.4** | **18.7** | **19.1** |
| 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 | 13.7 | 13.5 |
| 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 | 0.8 | 0.8 |
| Imported Electric | 14.4 | 13.4 | 11.6 | 11.7 | 10.0 | 7.7 | 7.7 | 6.8 | 5.2 | 5.4 | 3.1 | 0.4 | 0.0 | 0.0 | 0.4 | 1.2 | 4.2 | 4.8 |
| Halogenated Gases (excl. SF6) | | 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 | 5.3 | 5.2 |
| SF6 | 0.6 | 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 | 0.1 | 0.1 |
| Non-Fuel Agriculture | 0.7 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 |
| Natural Gas Trans. & Distr. | 3.0 | 2.9 | 3.1 | 3.1 | 3.1 | 3.1 | 3.0 | 3.0 | 2.9 | 2.9 | 2.9 | 2.8 | 2.8 | 2.7 | 2.7 | 2.6 | 2.5 | 2.5 |
| **Landfills** | **9.6** | **4.2** | **4.0** | **3.5** | **4.2** | **4.8** | **5.2** | **4.8** | **3.8** | **4.0** | **4.0** | **4.3** | **4.6** | **5.8** | **6.1** | **6.1** | **6.8** | **6.6** |
| In-State | 5.3 | 1.8 | 1.7 | 1.5 | 1.8 | 2.1 | 2.1 | 1.9 | 1.7 | 1.8 | 2.0 | 2.0 | 2.1 | 2.3 | 2.4 | 2.4 | 2.5 | 2.5 |
| Industrial | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Out-of-State | 3.8 | 2.0 | 1.9 | 1.6 | 2.0 | 2.2 | 2.7 | 2.5 | 1.7 | 1.9 | 1.6 | 2.0 | 2.1 | 3.1 | 3.4 | 3.4 | 3.8 | 3.7 |
| Wastewater Treatment | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| 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 | 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 | 1.0 | 1.0 |
| TOTAL GROSS EMISSIONS | 116.6 | 136.5 | 127.7 | 132.4 | 126.9 | 114.7 | 117.4 | 116.3 | 108.1 | 110.6 | 112.5 | 108.7 | 110.3 | 105.5 | 110.7 | 107.6 | 100.3 | 105.7 |
| 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 | -8.1 | -8.1 |
| TOTAL NET EMISSIONS | **112.6** | **130.5** | **121.7** | **124.8** | **119.3** | **107.1** | **109.8** | **108.7** | **100.5** | **102.5** | **104.4** | **100.6** | **102.2** | **97.4** | **102.6** | **99.5** | **92.2** | **97.6** |

[57] 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 E.

*Table A-2 NJ Black Carbon Emissions, MMT $CO_2e$, based on $GWP_{100}$*[58]

| YEAR | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Black Carbon** | **5.75** | **5.63** | **4.67** | **4.23** | **3.97** | **3.98** | **3.61** | **3.40** | **3.19** | **2.99** | **2.75** | **2.45** | **2.29** | **2.07** | **1.86** | **1.73** |
| **Transportation** | **3.25** | **3.27** | **2.45** | **2.15** | **1.97** | **2.05** | **1.75** | **1.60** | **1.45** | **1.31** | **1.18** | **0.98** | **0.92** | **0.77** | **0.63** | **0.58** |
| 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 | 0.52 | 0.42 | 0.40 |
| Non-Road Transportation | 0.67 | 0.51 | 0.35 | 0.19 | 0.21 | 0.22 | 0.24 | 0.25 | 0.26 | 0.26 | 0.27 | 0.28 | 0.30 | 0.25 | 0.21 | 0.17 |
| Non-Road Mobile Equipment | 1.58 | 1.50 | 1.41 | 1.33 | 1.29 | 1.25 | 1.21 | 1.14 | 1.07 | 1.01 | 0.92 | 0.83 | 0.75 | 0.69 | 0.64 | 0.58 |
| 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 | 0.23 | 0.20 | 0.17 |
| 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 | 0.04 | 0.03 | 0.03 |
| 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 | 0.16 | 0.17 | 0.19 |
| **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** | **0.03** | **0.03** | **0.02** |
| 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 | 0.03 | 0.02 | 0.01 |
| 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 | 0.01 | 0.01 | 0.01 |
| Other, including Wildfires & Agriculture | 0.02 | 0.03 | 0.05 | 0.06 | 0.09 | 0.11 | 0.14 | 0.15 | 0.17 | 0.18 | 0.16 | 0.14 | 0.13 | 0.14 | 0.15 | 0.17 |

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.

[58] 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 E.

*Table A-3. NJ GHG Emissions, MMT $CO_2e$, based on $GWP_{20}$[59]*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Transportation** | 33.3 | 47.5 | 47.9 | 49.7 | 47.7 | 42.7 | 42.8 | 43.4 | 41.3 | 41.4 | 41.4 | 40.8 | 42.9 | 40.5 | 40.7 | 38.1 | 34.1 | 37.4 |
| 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 | 24.9 | 27.0 |
| 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 | 7.0 | 7.2 | 6.3 | 6.6 | 7.3 |
| On-Road CNG and Other | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 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 | 1.0 | 1.0 |
| Marine | 1.7 | 3.2 | 3.2 | 4.2 | 4.3 | 1.8 | 1.7 | 1.7 | 1.6 | 1.5 | 0.7 | 0.9 | 1.2 | 1.1 | 1.7 | 0.6 | 1.1 | 1.5 |
| 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 | 0.4 | 0.4 |
| **Buildings** | 26.6 | 28.3 | 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 | 23.1 | 24.8 |
| Residential | 15.6 | 17.0 | 14.2 | 16.2 | 15.9 | 15.6 | 14.7 | 14.0 | 12.5 | 14.8 | 16.2 | 15.6 | 13.6 | 13.9 | 15.8 | 15.3 | 14.1 | 14.9 |
| 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 | 9.0 | 10.0 |
| 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 | 7.2 | 7.6 |
| **Electricity** | 26.9 | 34.1 | 30.9 | 32.3 | 29.9 | 23.5 | 26.1 | 23.3 | 20.7 | 20.3 | 20.8 | 19.6 | 20.8 | 18.0 | 19.2 | 19.4 | 18.8 | 19.1 |
| In-State Electric | 12.3 | 19.8 | 18.5 | 19.7 | 19.1 | 15.0 | 17.7 | 15.7 | 14.8 | 14.2 | 16.9 | 18.4 | 20.1 | 17.2 | 17.9 | 17.4 | 13.7 | 13.5 |
| 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 | 0.9 | 0.9 |
| Imported Electric | 14.4 | 13.5 | 11.6 | 11.7 | 10.0 | 7.7 | 7.7 | 6.8 | 5.2 | 5.4 | 3.1 | 0.4 | 0.0 | 0.0 | 0.4 | 1.2 | 4.2 | 4.8 |
| Halogenated Gases (excl. SF6) |  | 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 | 12.0 | 11.8 |
| 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 | 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 | 0.7 | 0.6 | 0.6 |
| Natural Gas Trans. & Distr. | 9.0 | 8.7 | 9.4 | 9.4 | 9.3 | 9.2 | 9.0 | 8.9 | 8.8 | 8.7 | 8.7 | 8.5 | 8.3 | 8.2 | 8.0 | 7.7 | 7.6 | 7.5 |
| **Landfills** | 28.7 | 12.7 | 12.1 | 10.5 | 12.5 | 14.3 | 15.7 | 14.4 | 11.5 | 12.1 | 11.9 | 13.0 | 13.7 | 17.5 | 18.3 | 18.4 | 20.3 | 19.7 |
| In-State | 15.9 | 5.5 | 5.2 | 4.5 | 5.4 | 6.4 | 6.4 | 5.6 | 5.2 | 5.3 | 5.9 | 5.9 | 6.3 | 6.9 | 7.1 | 7.2 | 7.6 | 7.5 |
| Industrial | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| Out-of-State | 11.5 | 6.0 | 5.8 | 4.8 | 5.9 | 6.7 | 8.1 | 7.6 | 5.2 | 5.6 | 4.9 | 5.9 | 6.2 | 9.4 | 10.1 | 10.1 | 11.5 | 11.1 |
| Wastewater Treatment | 1.8 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |
| 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 | 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 | 1.0 | 1.0 |
| TOTAL GROSS EMISSIONS | 143.4 | 155.5 | 147.3 | 150.8 | 146.8 | 135.9 | 139.7 | 137.9 | 127.9 | 131.0 | 133.0 | 130.1 | 132.5 | 130.4 | 136.3 | 133.4 | 127.3 | 132.2 |
| 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 | -8.1 | -8.1 |
| TOTAL NET EMISSIONS | **139.4** | **149.5** | **141.3** | **143.2** | **139.2** | **128.3** | **132.1** | **130.3** | **120.3** | **122.9** | **124.9** | **122.0** | **124.4** | **122.3** | **128.2** | **125.3** | **119.2** | **124.1** |

[59] 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 E.

*Table A-4 NJ Black Carbon Emissions, MMT $CO_2e$, based on $GWP_{20}$[60]*

| YEAR | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total Black Carbon** | **20.23** | **19.81** | **16.42** | **14.87** | **13.96** | **14.00** | **12.70** | **11.95** | **11.21** | **10.50** | **9.66** | **8.60** | **8.05** | **7.27** | **6.54** | **6.09** |
| **Transportation** | **11.41** | **11.50** | **8.62** | **7.57** | **6.92** | **7.21** | **6.17** | **5.63** | **5.11** | **4.62** | **4.14** | **3.44** | **3.25** | **2.72** | **2.23** | **2.03** |
| 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 | 1.82 | 1.48 | 1.42 |
| Non-Road Transportation | 2.36 | 1.79 | 1.23 | 0.67 | 0.73 | 0.79 | 0.85 | 0.87 | 0.90 | 0.92 | 0.96 | 1.00 | 1.04 | 0.89 | 0.75 | 0.60 |
| Non-Road Mobile Equipment | 5.57 | 5.27 | 4.97 | 4.67 | 4.53 | 4.39 | 4.25 | 4.01 | 3.77 | 3.54 | 3.23 | 2.93 | 2.63 | 2.44 | 2.25 | 2.06 |
| 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 | 0.82 | 0.71 | 0.59 |
| 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 | 0.14 | 0.12 | 0.11 |
| 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 | 0.55 | 0.61 | 0.66 |
| **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** | **0.12** | **0.09** | **0.06** |
| 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 | 0.09 | 0.06 | 0.04 |
| 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 | 0.03 | 0.03 | 0.02 |
| Other, including Wildfires & Agriculture | 0.07 | 0.12 | 0.17 | 0.22 | 0.31 | 0.40 | 0.50 | 0.54 | 0.58 | 0.62 | 0.56 | 0.50 | 0.44 | 0.49 | 0.54 | 0.59 |

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.

[60] 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 E.

*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 | 2020 | 2021 |
| Gas Passenger Vehicles | 31.5 | 27.8 | 27.1 | 22.6 | 24.5 |
| Diesel Freight & Commercial | 6.7 | 5.5 | 4.8 | 5.3 | 5.8 |
| Gas Freight & Commercial | 2.9 | 2.5 | 2.5 | 2.2 | 2.4 |
| Diesel Passenger Vehicles | 1.0 | 0.8 | 0.8 | 0.7 | 0.8 |
| Diesel Buses | 0.7 | 0.9 | 0.7 | 0.6 | 0.6 |
| Gas Buses | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 |
| CNG Trucks & Buses | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 |
| Motor Homes | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 |

*$GWP_{20}$*

| VEHICLE CATEGORY | YEAR | | | | |
| --- | --- | --- | --- | --- | --- |
| | 2006 | 2018 | 2019 | 2020 | 2021 |
| Gas Passenger Vehicles | 31.8 | 27.9 | 27.2 | 22.6 | 24.6 |
| Diesel Freight & Commercial | 6.7 | 5.5 | 4.8 | 5.3 | 5.8 |
| Gas Freight & Commercial | 2.9 | 2.5 | 2.5 | 2.2 | 2.4 |
| Diesel Passenger Vehicles | 1.0 | 0.8 | 0.8 | 0.7 | 0.8 |
| Diesel Buses | 0.7 | 0.9 | 0.7 | 0.6 | 0.6 |
| Gas Buses | 0.0 | 0.1 | 0.1 | 0.0 | 0.1 |
| CNG Trucks & Buses | 0.0 | 0.2 | 0.2 | 0.2 | 0.2 |
| Motor Homes | 0.1 | 0.1 | 0.0 | 0.0 | 0.1 |

*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 | 2020 | 2021 |
| Gasoline Motorcycle | 0.1479 | 0.1590 | 0.1576 | 0.1338 | 0.1484 |
| Gasoline Passenger Car | 13.4950 | 11.9015 | 11.6792 | 8.6803 | 9.3653 |
| Gasoline Passenger Truck | 17.8863 | 15.6811 | 15.2421 | 13.6834 | 14.9495 |
| Gasoline Light Commercial Truck | 2.3479 | 1.9967 | 1.9497 | 1.7434 | 1.9182 |
| Gasoline Other Buses | 0.0087 | 0.0188 | 0.0142 | 0.0120 | 0.0159 |
| Gasoline Transit Bus | 0.0094 | 0.0488 | 0.0372 | 0.0315 | 0.0355 |
| Gasoline School Bus | 0.0123 | 0.0070 | 0.0050 | 0.0048 | 0.0052 |
| Gasoline Refuse Truck | 0.0062 | 0.0009 | 0.0007 | 0.0003 | 0.0003 |
| Gasoline Single Unit Short-haul Truck | 0.4493 | 0.4113 | 0.3859 | 0.3242 | 0.3559 |
| Gasoline Single Unit Long-haul Truck | 0.0811 | 0.1173 | 0.1097 | 0.0984 | 0.1077 |
| Gasoline Motor Home | 0.0397 | 0.0293 | 0.0276 | 0.0255 | 0.0291 |
| Gasoline Combination Short-haul Truck | 0.0026 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Diesel Passenger Car | 0.0546 | 0.0962 | 0.0925 | 0.0665 | 0.0716 |
| Diesel Passenger Truck | 0.9471 | 0.7048 | 0.7163 | 0.6729 | 0.7750 |
| Diesel Light Commercial Truck | 0.3049 | 0.1603 | 0.1524 | 0.1380 | 0.1517 |
| Diesel Other Buses | 0.1612 | 0.1281 | 0.0942 | 0.0700 | 0.0874 |
| Diesel Transit Bus | 0.2312 | 0.3449 | 0.2554 | 0.2040 | 0.2253 |
| Diesel School Bus | 0.2945 | 0.4286 | 0.3149 | 0.2937 | 0.3169 |
| Diesel Refuse Truck | 0.1320 | 0.1106 | 0.1025 | 0.0951 | 0.1075 |
| Diesel Single Unit Short-haul Truck | 1.4924 | 1.5271 | 1.4090 | 1.1700 | 1.2734 |
| Diesel Single Unit Long-haul Truck | 0.3329 | 0.4253 | 0.3898 | 0.3464 | 0.3748 |
| Diesel Motor Home | 0.0147 | 0.0214 | 0.0205 | 0.0194 | 0.0221 |
| Diesel Combination Short-haul Truck | 1.4403 | 1.0616 | 0.9208 | 1.1240 | 1.2956 |
| Diesel Combination Long-haul Truck | 2.9951 | 2.2150 | 1.8463 | 2.4263 | 2.6148 |
| CNG Other Buses | 0.0175 | 0.0137 | 0.0101 | 0.0075 | 0.0097 |
| CNG Transit Bus | 0.0165 | 0.0384 | 0.0283 | 0.0221 | 0.0251 |
| CNG School Bus | 0.0009 | 0.0056 | 0.0044 | 0.0046 | 0.0054 |
| CNG Refuse Truck | 0.0001 | 0.0132 | 0.0154 | 0.0178 | 0.0232 |
| CNG Single Unit Short-haul Truck | 0.0017 | 0.0249 | 0.0259 | 0.0233 | 0.0277 |
| CNG Single Unit Long-haul Truck | 0.0003 | 0.0079 | 0.0079 | 0.0077 | 0.0091 |
| CNG Motor Home | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| CNG Combination Short-haul Truck | 0.0000 | 0.0217 | 0.0224 | 0.0289 | 0.0385 |
| E-85 Passenger Car | 0.0000 | 0.0080 | 0.0080 | 0.0083 | 0.0063 |
| E-85 Passenger Truck | 0.0000 | 0.0420 | 0.0408 | 0.0502 | 0.0387 |
| E-85 Light Commercial Truck | 0.0000 | 0.0061 | 0.0058 | 0.0070 | 0.0053 |

*$GWP_{20}$*

| FUEL AND VEHICLE TYPE | YEAR | | | | |
|---|---|---|---|---|---|
| | 2006 | 2018 | 2019 | 2020 | 2021 |
| Gasoline Motorcycle | 0.1531 | 0.1618 | 0.1601 | 0.1359 | 0.1513 |
| Gasoline Passenger Car | 13.6184 | 11.9280 | 11.7019 | 8.6981 | 9.3878 |
| Gasoline Passenger Truck | 18.0548 | 15.7141 | 15.2705 | 13.7073 | 14.9806 |
| Gasoline Light Commercial Truck | 2.3719 | 2.0026 | 1.9545 | 1.7476 | 1.9234 |
| Gasoline Other Buses | 0.0087 | 0.0189 | 0.0142 | 0.0120 | 0.0160 |
| Gasoline Transit Bus | 0.0094 | 0.0489 | 0.0373 | 0.0316 | 0.0356 |
| Gasoline School Bus | 0.0125 | 0.0071 | 0.0050 | 0.0048 | 0.0052 |
| Gasoline Refuse Truck | 0.0063 | 0.0009 | 0.0007 | 0.0003 | 0.0003 |
| Gasoline Single Unit Short-haul Truck | 0.4549 | 0.4127 | 0.3871 | 0.3251 | 0.3571 |
| Gasoline Single Unit Long-haul Truck | 0.0818 | 0.1175 | 0.1099 | 0.0985 | 0.1078 |
| Gasoline Motor Home | 0.0403 | 0.0295 | 0.0277 | 0.0256 | 0.0292 |
| Gasoline Combination Short-haul Truck | 0.0027 | 0.0001 | 0.0000 | 0.0000 | 0.0000 |
| Diesel Passenger Car | 0.0546 | 0.0963 | 0.0925 | 0.0665 | 0.0722 |
| Diesel Passenger Truck | 0.9471 | 0.7059 | 0.7174 | 0.6741 | 0.7775 |
| Diesel Light Commercial Truck | 0.3049 | 0.1606 | 0.1527 | 0.1383 | 0.1521 |
| Diesel Other Buses | 0.1612 | 0.1282 | 0.0942 | 0.0701 | 0.0875 |
| Diesel Transit Bus | 0.2312 | 0.3451 | 0.2556 | 0.2041 | 0.2255 |
| Diesel School Bus | 0.2945 | 0.4292 | 0.3153 | 0.2942 | 0.3175 |
| Diesel Refuse Truck | 0.1320 | 0.1107 | 0.1026 | 0.0952 | 0.1076 |
| Diesel Single Unit Short-haul Truck | 1.4924 | 1.5310 | 1.4128 | 1.1736 | 1.2779 |
| Diesel Single Unit Long-haul Truck | 0.3329 | 0.4258 | 0.3902 | 0.3468 | 0.3752 |
| Diesel Motor Home | 0.0147 | 0.0215 | 0.0205 | 0.0194 | 0.0221 |
| Diesel Combination Short-haul Truck | 1.4403 | 1.0627 | 0.9217 | 1.1250 | 1.2969 |
| Diesel Combination Long-haul Truck | 2.9951 | 2.2167 | 1.8477 | 2.4279 | 2.6169 |
| CNG Other Buses | 0.0231 | 0.0187 | 0.0140 | 0.0106 | 0.0148 |
| CNG Transit Bus | 0.0222 | 0.0526 | 0.0391 | 0.0306 | 0.0370 |
| CNG School Bus | 0.0010 | 0.0078 | 0.0061 | 0.0066 | 0.0084 |
| CNG Refuse Truck | 0.0001 | 0.0173 | 0.0203 | 0.0242 | 0.0336 |
| CNG Single Unit Short-haul Truck | 0.0020 | 0.0331 | 0.0347 | 0.0318 | 0.0407 |
| CNG Single Unit Long-haul Truck | 0.0003 | 0.0106 | 0.0107 | 0.0105 | 0.0133 |
| CNG Motor Home | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| CNG Combination Short-haul Truck | 0.0000 | 0.0278 | 0.0288 | 0.0376 | 0.0537 |
| E-85 Passenger Car | 0.0000 | 0.0081 | 0.0080 | 0.0084 | 0.0064 |
| E-85 Passenger Truck | 0.0000 | 0.0422 | 0.0410 | 0.0504 | 0.0388 |
| E-85 Light Commercial Truck | 0.0000 | 0.0061 | 0.0059 | 0.0071 | 0.0053 |

*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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 |
| 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 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Diesel Ships & Non-Recreational Boats | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| Residual Fuel | 1.0 | 1.1 | 1.7 | 1.2 | 1.2 | 1.6 | 1.1 | 0.6 | 0.4 | 0.8 | 2.9 | 1.3 | 2.3 | 0.9 | 1.5 | 2.5 | 2.6 | 3.4 |
| **Total** | **1.7** | **1.7** | **2.4** | **1.9** | **2.0** | **2.3** | **1.8** | **1.4** | **1.1** | **1.6** | **3.7** | **2.1** | **3.1** | **1.7** | **2.2** | **3.2** | **3.2** | **4.2** |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 0.4 | 0.4 | 0.4 | 0.5 | 0.5 | 0.4 | 0.4 |
| 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 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Diesel Ships & Non-Recreational Boats | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| Residual Fuel | 1.0 | 1.1 | 1.7 | 1.3 | 1.2 | 1.6 | 1.1 | 0.6 | 0.4 | 0.8 | 2.9 | 1.3 | 2.3 | 0.9 | 1.5 | 2.5 | 2.6 | 3.5 |
| **Total** | **1.7** | **1.7** | **2.4** | **1.9** | **2.0** | **2.3** | **1.8** | **1.4** | **1.1** | **1.6** | **3.7** | **2.1** | **3.1** | **1.7** | **2.2** | **3.2** | **3.2** | **4.2** |

*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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 0.4 | 0.3 |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 0.4 | 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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 13.7 | 13.5 |
| 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 | 0.8 | 0.8 |
| Imported Electricity | 14.4 | 13.4 | 11.6 | 11.7 | 10.0 | 7.7 | 7.7 | 6.8 | 5.2 | 5.4 | 3.1 | 0.4 | 0.0 | 0.0 | 0.4 | 1.2 | 4.2 | 4.8 |
| **Total** | **26.8** | **34.0** | **30.9** | **32.3** | **29.8** | **23.5** | **26.0** | **23.2** | **20.7** | **20.3** | **20.8** | **19.5** | **20.8** | **18.0** | **19.1** | **19.4** | **18.7** | **19.1** |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In-State Generation | 12.3 | 19.8 | 18.5 | 19.7 | 19.1 | 15.0 | 17.7 | 15.7 | 14.8 | 14.2 | 16.9 | 18.4 | 20.1 | 17.2 | 17.9 | 17.4 | 13.7 | 13.5 |
| 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 | 0.9 | 0.9 |
| Imported Electricity | 14.4 | 13.5 | 11.6 | 11.7 | 10.0 | 7.7 | 7.7 | 6.8 | 5.2 | 5.4 | 3.1 | 0.4 | 0.0 | 0.0 | 0.4 | 1.2 | 4.2 | 4.8 |
| **Total** | **26.9** | **34.1** | **30.9** | **32.3** | **29.9** | **23.5** | **26.1** | **23.3** | **20.7** | **20.3** | **20.8** | **19.6** | **20.8** | **18.0** | **19.2** | **19.4** | **18.8** | **19.1** |

*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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 0.0 | 0.0 |
| Distillate Fuel Oil | 5.9 | 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 | 1.5 | 1.8 |
| Propane | 0.2 | 0.3 | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 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 | 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 | 11.9 | 12.3 | 13.7 | 13.2 | 12.4 | 12.8 |
| **Total** | **15.6** | **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** | **14.1** | **14.9** |

*GWP20*

| | YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 0.0 | 0.0 |
| Distillate Fuel Oil | | 5.9 | 3.8 | 3.1 | 3.2 | 3.4 | 2.9 | 2.3 | 2.0 | 1.8 | 1.9 | 2.1 | 2.1 | 1.4 | 1.4 | 1.8 | 1.8 | 1.5 | 1.8 |
| Propane | | 0.2 | 0.3 | 0.2 | 0.3 | 0.4 | 0.4 | 0.4 | 0.4 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 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 | 0.0 | 0.0 |
| Natural Gas | | 9.3 | 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 | 12.4 | 12.8 |
| **Total** | | **15.6** | **17.0** | **14.2** | **16.2** | **15.9** | **15.6** | **14.7** | **14.0** | **12.5** | **14.8** | **16.2** | **15.6** | **13.6** | **13.9** | **15.8** | **15.3** | **14.1** | **14.9** |

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

*GWP100*

| | YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | | 0.02 | 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 | 0.0 |
| Distillate Fuel Oil | | 3.6 | 1.5 | 0.9 | 1.4 | 1.0 | 1.0 | 0.8 | 1.1 | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.6 | 0.6 | 0.7 | 0.5 | 0.8 |
| 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 | 0.1 | 0.1 |
| Kerosene | | 0.1 | 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 | 0.0 | 0.0 | 0.0 |
| Gasoline | | 0.3 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.05 | 0.8 | 0.8 | 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 | 7.6 | 8.3 |
| 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 | 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** | **10.7** | **10.0** | **9.7** | **10.7** | **10.2** | **9.0** | **9.9** |

*GWP20*

| | YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | | 0.02 | 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 | 0.0 |
| Distillate Fuel Oil | | 3.6 | 1.5 | 0.9 | 1.4 | 1.1 | 1.0 | 0.8 | 1.1 | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.6 | 0.6 | 0.7 | 0.5 | 0.8 |
| 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 | 0.1 | 0.1 |
| Kerosene | | 0.1 | 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 | 0.0 | 0.0 | 0.0 |
| Gasoline | | 0.3 | 0.03 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.05 | 0.8 | 0.8 | 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 | 9.3 | 8.6 | 7.6 | 8.3 |
| 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 | 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** | **9.0** | **10.0** |

*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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | 0.7 | 0.01 | 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 | 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 | 0.6 | 0.8 |
| Kerosene | 0.1 | 0.6 | 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 | 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 | 0.4 | 0.5 | 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 | 3.2 | 3.3 |
| Petroleum Coke | 3.0 | 3.6 | 3.1 | 3.3 | 3.4 | 3.1 | 2.3 | 3.3 | 2.8 | 2.0 | | | | | | | | |
| 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 | 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 | 1.7 | 1.8 |
| Hydrocarbon Gas Liquids | 0.7 | 0.1 | 0.1 | 0.2 | 0.1 | 0.0 | 1.4 | 1.4 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 |
| **Total** | **14.7** | **13.5** | **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** | **7.2** | **7.6** |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Coal | 0.7 | 0.01 | 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 | 1.5 | 0.8 | 1.0 | 0.9 | 0.8 | 0.8 | 0.7 | 0.9 | 0.8 | 0.7 | 0.9 | 0.9 | 0.9 | 0.7 | 0.7 | 0.7 | 0.6 | 0.8 |
| Kerosene | 0.1 | 0.6 | 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 | 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 | 0.4 | 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 | 3.3 | 3.3 |
| 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 | 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 | 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 | 1.7 | 1.8 |
| Hydrocarbon Gas Liquids | 0.7 | 0.2 | 0.1 | 0.2 | 0.1 | 0.1 | 1.2 | 1.3 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| **Total** | **14.9** | **13.6** | **12.1** | **12.0** | **10.6** | **9.2** | **9.6** | **10.9** | **10.8** | **10.1** | **8.1** | **7.9** | **8.3** | **7.4** | **7.9** | **7.9** | **7.1** | **7.5** |

*Table A-13. HFC emissions by source type and category (GWP100)*

| SOURCE | CATEGORY | YEAR 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 1.80 | 1.78 |
| 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 | 0.08 | 0.08 |
| 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 | 0.05 | 0.05 |
| Stationary Commercial AC > 50 lbs. | AC - Stationary | 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 | 0.27 | 0.28 |
| Stationary Commercial AC <50 lbs. | AC - Stationary | 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 | 0.62 | 0.67 |
| Stationary Residential Heat Pumps | AC - Stationary | 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 | 0.10 | 0.12 |
| Stationary Residential Central AC | AC - Stationary | 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 | 0.45 | 0.49 |
| Stationary Residential Room Unit AC | AC - Stationary | 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 | 0.27 | 0.29 |
| Light-duty MVAC | AC- Mobile | 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 | 0.72 | 0.64 |
| Heavy-duty MVAC | AC- Mobile | 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 | 0.26 | 0.26 |
| Transport Refrigeration | AC- Mobile | 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 | 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 | 0.18 | 0.15 |
| 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 | 0.25 | 0.13 |
| 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 | 0.07 | 0.07 |
| **Total** | | **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** | **5.3** | **5.2** |
| 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 | 1.92 | 1.91 |
| 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 | 1.71 | 1.84 |
| 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 | 1.12 | 1.05 |
| 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 | 0.18 | 0.15 |
| 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 | 0.25 | 0.13 |
| 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 | 0.07 | 0.07 |

*Table A-14. HFC emissions by source type and category (GWP20)*

| SOURCE | CATEGORY | YEAR | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
| 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 | 4.10 | 4.05 |
| 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 | 0.17 | 0.18 |
| 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 | 0.11 | 0.11 |
| Stationary Commercial AC > 50 lbs. | AC - Stationary | 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 | 0.62 | 0.64 |
| Stationary Commercial AC <50 lbs. | AC - Stationary | 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 | 1.41 | 1.52 |
| Stationary Residential Heat Pumps | AC - Stationary | 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 | 0.23 | 0.26 |
| Stationary Residential Central AC | AC - Stationary | 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 | 1.02 | 1.12 |
| Stationary Residential Room Unit AC | AC - Stationary | 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 | 0.62 | 0.66 |
| Light-duty MVAC | AC- Mobile | 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 | 1.64 | 1.47 |
| Heavy-duty MVAC | AC- Mobile | 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 | 0.59 | 0.59 |
| Transport Refrigeration | AC- Mobile | 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 | 0.32 | 0.33 |
| 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 | 0.42 | 0.34 |
| 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 | 0.56 | 0.31 |
| 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 | 0.16 | 0.16 |
| **Total** | | **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** | **12.0** | **11.8** |
| 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 | 4.38 | 4.35 |
| 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 | 3.90 | 4.21 |
| 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 | 2.56 | 2.39 |
| 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 | 0.42 | 0.34 |
| 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 | 0.56 | 0.31 |
| 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 | 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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transmission | 0.15 | 0.25 | 0.28 | 0.28 | 0.28 | 0.25 | 0.25 | 0.22 | 0.22 | 0.22 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| Distribution | 2.84 | 2.65 | 2.86 | 2.85 | 2.82 | 2.80 | 2.76 | 2.74 | 2.71 | 2.68 | 2.66 | 2.61 | 2.55 | 2.50 | 2.42 | 2.36 | 2.32 | 2.27 |
| **Total** | **3.00** | **2.90** | **3.14** | **3.13** | **3.10** | **3.05** | **3.02** | **2.97** | **2.94** | **2.91** | **2.89** | **2.83** | **2.78** | **2.72** | **2.65** | **2.58** | **2.54** | **2.49** |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transmission | 0.46 | 0.75 | 0.84 | 0.84 | 0.84 | 0.75 | 0.75 | 0.67 | 0.67 | 0.67 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 | 0.68 |
| Distribution | 8.53 | 7.94 | 8.57 | 8.55 | 8.47 | 8.40 | 8.29 | 8.23 | 8.14 | 8.05 | 7.99 | 7.82 | 7.66 | 7.49 | 7.27 | 7.07 | 6.95 | 6.80 |
| **Total** | **8.99** | **8.69** | **9.41** | **9.38** | **9.30** | **9.16** | **9.05** | **8.90** | **8.81** | **8.73** | **8.66** | **8.50** | **8.34** | **8.17** | **7.95** | **7.75** | **7.63** | **7.48** |

*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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In-State MSW LF | 5.3 | 1.8 | 1.7 | 1.5 | 1.8 | 2.1 | 2.1 | 1.9 | 1.7 | 1.8 | 2.0 | 2.0 | 2.1 | 2.3 | 2.4 | 2.4 | 2.5 | 2.5 |
| Industrial LF | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| MSW Export | 3.8 | 2.0 | 1.9 | 1.6 | 2.0 | 2.2 | 2.7 | 2.5 | 1.7 | 1.9 | 1.6 | 2.0 | 2.1 | 3.1 | 3.4 | 3.4 | 3.8 | 3.7 |
| **Total** | 9.6 | 4.2 | 4.0 | 3.5 | 4.2 | 4.8 | 5.2 | 4.8 | 3.8 | 4.0 | 4.0 | 4.3 | 4.6 | 5.8 | 6.1 | 6.1 | 6.8 | 6.6 |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In-State MSW LF | 15.9 | 5.5 | 5.2 | 4.5 | 5.4 | 6.4 | 6.4 | 5.6 | 5.2 | 5.3 | 5.9 | 5.9 | 6.3 | 6.9 | 7.1 | 7.2 | 7.6 | 7.5 |
| Industrial LF | 11.5 | 6.0 | 5.8 | 4.8 | 5.9 | 6.7 | 8.1 | 7.6 | 5.2 | 5.6 | 4.9 | 5.9 | 6.2 | 9.4 | 10.1 | 10.1 | 11.5 | 11.1 |
| MSW Export | 1.3 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 |
| **Total** | 28.7 | 12.7 | 12.1 | 10.5 | 12.5 | 14.3 | 15.7 | 14.4 | 11.5 | 12.1 | 11.9 | 13.0 | 13.7 | 17.5 | 18.3 | 18.4 | 20.3 | 19.7 |

*Table A-17. 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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wastewater Treatment | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wastewater Treatment | 1.8 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 | 2.2 |

*Table A-18. 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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-Fuel Agriculture | 0.7 | 0.5 | 0.5 | 0.5 | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 |

*$GWP_{20}$*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 0.7 | 0.6 | 0.6 |

*Table A-19. 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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-Fuel Industrial $CO_2$ | 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 | 0.3 | 0.3 |

*Table A-20. 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 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sulfur Hexafluoride | 0.6 | 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 | 0.1 | 0.1 |

*GWP20*

| YEAR | 1990 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sulfur Hexafluoride | 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 | 0.1 | 0.1 |

*Table A-21. Black carbon emissions by sector (MMT $CO_2e$)*

*GWP100*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Transportation | 3.25 | 3.27 | 2.15 | 1.75 | 1.31 | 0.92 | 0.58 |
| Non-Road Equipment | 1.58 | 1.50 | 1.33 | 1.21 | 1.01 | 0.75 | 0.58 |
| Residential | 0.46 | 0.41 | 0.29 | 0.31 | 0.25 | 0.27 | 0.17 |
| Electric Generation | 0.23 | 0.22 | 0.20 | 0.08 | 0.08 | 0.04 | 0.03 |
| Commercial [1] | 0.13 | 0.13 | 0.12 | 0.08 | 0.11 | 0.14 | 0.19 |
| Industrial [1] | 0.07 | 0.08 | 0.08 | 0.03 | 0.06 | 0.04 | 0.02 |
| Other [2] | 0.02 | 0.03 | 0.06 | 0.14 | 0.18 | 0.13 | 0.17 |
| **Total** | **5.75** | **5.63** | **4.23** | **3.61** | **2.99** | **2.29** | **1.73** |

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

*GWP20*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Transportation | 11.41 | 11.50 | 7.57 | 6.17 | 4.62 | 3.25 | 2.03 |
| Non-Road Equipment | 5.57 | 5.27 | 4.67 | 4.25 | 3.54 | 2.63 | 2.06 |
| Residential | 1.63 | 1.43 | 1.01 | 1.08 | 0.87 | 0.93 | 0.59 |
| Electric Generation | 0.82 | 0.78 | 0.71 | 0.29 | 0.29 | 0.15 | 0.11 |
| Commercial [1] | 0.46 | 0.44 | 0.41 | 0.30 | 0.38 | 0.49 | 0.66 |
| Industrial [1] | 0.26 | 0.27 | 0.29 | 0.12 | 0.19 | 0.15 | 0.06 |
| Other [2] | 0.07 | 0.12 | 0.22 | 0.50 | 0.62 | 0.44 | 0.59 |
| **Total** | **20.23** | **19.81** | **14.87** | **12.70** | **10.50** | **8.05** | **6.09** |

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

*Table A-22. On-road black carbon emissions (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| Diesel Heavy Duty | 2.02 | 2.23 | 1.55 | 1.22 | 0.80 | 0.44 | 0.34 | 0.25 | 0.25 | 0.23 |
| Diesel Light Duty | 0.27 | 0.37 | 0.20 | 0.16 | 0.11 | 0.06 | 0.08 | 0.06 | 0.05 | 0.05 |
| Non-Diesel Heavy Duty | 0.01 | 0.01 | 0.00 | 0.00 | 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 | 0.11 | 0.11 |
| **Total On-Road** | **2.58** | **2.76** | **1.96** | **1.51** | **1.05** | **0.63** | **0.52** | **0.42** | **0.40** | **0.40** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| Diesel Heavy Duty | 7.12 | 7.83 | 5.47 | 4.29 | 2.83 | 1.56 | 1.21 | 0.89 | 0.86 | 0.82 |
| Diesel Light Duty | 0.94 | 1.31 | 0.72 | 0.56 | 0.39 | 0.22 | 0.27 | 0.23 | 0.18 | 0.18 |
| Non-Diesel Heavy Duty | 0.02 | 0.02 | 0.01 | 0.01 | 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 | 0.37 | 0.40 |
| **Total On-Road** | **9.06** | **9.71** | **6.90** | **5.32** | **3.70** | **2.21** | **1.82** | **1.48** | **1.42** | **1.41** |

*Table A-23. Largest Sources of Black Carbon from On-Road Diesel Vehicles (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| Long-Haul Combo | 0.87 | 0.92 | 0.65 | 0.50 | 0.32 | 0.14 | 0.11 | 0.08 | 0.10 | 0.10 |
| Short-Haul Combo | 0.36 | 0.47 | 0.27 | 0.21 | 0.14 | 0.11 | 0.08 | 0.06 | 0.06 | 0.06 |
| Long-Haul Single Unit | 0.10 | 0.09 | 0.08 | 0.06 | 0.05 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| Short Haul Single-Unit | 0.43 | 0.48 | 0.35 | 0.28 | 0.20 | 0.11 | 0.08 | 0.06 | 0.05 | 0.04 |
| Buses | 0.22 | 0.21 | 0.17 | 0.14 | 0.08 | 0.04 | 0.05 | 0.03 | 0.02 | 0.02 |
| Light Duty/Light Commercial | 0.27 | 0.37 | 0.20 | 0.16 | 0.11 | 0.06 | 0.08 | 0.06 | 0.05 | 0.05 |
| Other Diesel | 0.04 | 0.05 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 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** | **0.30** | **0.28** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|---|---|---|---|---|
| Long-Haul Combo | 3.05 | 3.22 | 2.30 | 1.74 | 1.13 | 0.51 | 0.37 | 0.28 | 0.34 | 0.34 |
| Short-Haul Combo | 1.27 | 1.66 | 0.95 | 0.75 | 0.49 | 0.40 | 0.27 | 0.20 | 0.22 | 0.22 |
| Long-Haul Single Unit | 0.36 | 0.33 | 0.28 | 0.23 | 0.16 | 0.06 | 0.05 | 0.04 | 0.02 | 0.02 |
| Short Haul Single-Unit | 1.52 | 1.70 | 1.22 | 0.99 | 0.69 | 0.38 | 0.29 | 0.22 | 0.17 | 0.16 |
| Buses | 0.77 | 0.73 | 0.59 | 0.48 | 0.29 | 0.15 | 0.17 | 0.12 | 0.08 | 0.06 |
| Light Duty/Light Commercial | 0.94 | 1.31 | 0.72 | 0.56 | 0.39 | 0.22 | 0.27 | 0.23 | 0.18 | 0.18 |
| Other Diesel | 0.15 | 0.18 | 0.12 | 0.10 | 0.07 | 0.05 | 0.05 | 0.04 | 0.03 | 0.03 |
| **Total On-Road Diesel** | **8.06** | **9.13** | **6.18** | **4.85** | **3.22** | **1.78** | **1.48** | **1.11** | **1.04** | **1.00** |

*Table A-24. Non-road Transportation Black Carbon Emissions (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Aircraft | 0.052 | 0.039 | 0.014 | 0.031 | 0.036 | 0.033 | 0.028 |
| Commercial Marine Vessels | 0.547 | 0.411 | 0.140 | 0.138 | 0.156 | 0.156 | 0.089 |
| Locomotives | 0.071 | 0.060 | 0.036 | 0.073 | 0.070 | 0.107 | 0.055 |
| **Total Non-Road Transportation** | **0.670** | **0.510** | **0.190** | **0.242** | **0.262** | **0.296** | **0.172** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Aircraft | 0.182 | 0.138 | 0.050 | 0.108 | 0.128 | 0.115 | 0.097 |
| Commercial Marine Vessels | 1.924 | 1.447 | 0.492 | 0.486 | 0.547 | 0.548 | 0.313 |
| Locomotives | 0.250 | 0.209 | 0.127 | 0.256 | 0.246 | 0.377 | 0.193 |
| **Total Non-Road Transportation** | **2.356** | **1.794** | **0.669** | **0.850** | **0.921** | **1.040** | **0.603** |

*Table A-25. Non-Road Equipment Black Carbon Emissions. (MMT CO2e)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Diesel | 1.43 | 1.34 | 1.17 | 1.07 | 0.87 | 0.64 | 0.47 |
| Gasoline | 0.14 | 0.14 | 0.14 | 0.12 | 0.12 | 0.10 | 0.09 |
| Other | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| **Total Non-Road Equipment** | **1.58** | **1.50** | **1.33** | **1.21** | **1.01** | **0.75** | **0.58** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Diesel | 5.02 | 4.72 | 4.11 | 3.77 | 3.07 | 2.24 | 1.67 |
| Gasoline | 0.51 | 0.50 | 0.50 | 0.42 | 0.41 | 0.34 | 0.33 |
| Other | 0.04 | 0.05 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| **Total Non-Road Equipment** | **5.57** | **5.27** | **4.67** | **4.25** | **3.54** | **2.63** | **2.06** |

*Table A-26. Electric Sector Black Carbon Emissions (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Biomass | 0.000 | 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 | 0.002 |
| Natural Gas | 0.035 | 0.036 | 0.039 | 0.028 | 0.035 | 0.029 | 0.020 |
| Oil | 0.042 | 0.034 | 0.017 | 0.041 | 0.034 | 0.009 | 0.005 |
| Other | 0.002 | 0.003 | 0.004 | 0.004 | 0.005 | 0.003 | 0.002 |
| **Total Electric Generation** | **0.234** | **0.223** | **0.202** | **0.081** | **0.082** | **0.044** | **0.030** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Biomass | 0.000 | 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 | 0.007 |
| Natural Gas | 0.122 | 0.127 | 0.136 | 0.098 | 0.122 | 0.101 | 0.072 |
| Oil | 0.149 | 0.119 | 0.060 | 0.145 | 0.121 | 0.033 | 0.019 |
| Other | 0.007 | 0.009 | 0.015 | 0.014 | 0.016 | 0.012 | 0.007 |
| **Total Electric Generation** | **0.821** | **0.784** | **0.709** | **0.286** | **0.289** | **0.154** | **0.106** |

*Table A-27. Residential Black Carbon Emissions (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Natural Gas | 0.003 | 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 | 0.009 |
| Other | 0.000 | 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 | 0.156 |
| **Total Residential** | **0.465** | **0.405** | **0.286** | **0.308** | **0.246** | **0.265** | **0.168** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Natural Gas | 0.009 | 0.009 | 0.009 | 0.009 | 0.010 | 0.009 | 0.009 |
| Oil | 0.108 | 0.094 | 0.064 | 0.053 | 0.046 | 0.029 | 0.031 |
| Other | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Wood | 1.516 | 1.322 | 0.933 | 1.020 | 0.809 | 0.895 | 0.550 |
| **Total Residential** | **1.635** | **1.426** | **1.007** | **1.082** | **0.865** | **0.934** | **0.591** |

*Table A-28. Black carbon emissions from the Commercial Sector, except non-road equipment. (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Commercial Cooking | 0.075 | 0.069 | 0.058 | 0.061 | 0.060 | 0.105 | 0.179 |
| Biomass | 0.000 | 0.000 | 0.000 | 0.002 | 0.010 | 0.011 | 0.003 |
| Coal | 0.000 | 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 | 0.002 |
| Oil | 0.050 | 0.052 | 0.055 | 0.018 | 0.032 | 0.019 | 0.004 |
| Other | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 |
| **Total Commercial** | **0.130** | **0.126** | **0.117** | **0.084** | **0.107** | **0.139** | **0.189** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Commercial Cooking | 0.262 | 0.243 | 0.204 | 0.213 | 0.212 | 0.370 | 0.628 |
| Biomass | 0.000 | 0.000 | 0.000 | 0.006 | 0.036 | 0.040 | 0.010 |
| Coal | 0.001 | 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 | 0.008 |
| Oil | 0.177 | 0.182 | 0.193 | 0.063 | 0.112 | 0.067 | 0.015 |
| Other | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 |
| **Total Commercial** | **0.457** | **0.442** | **0.412** | **0.296** | **0.378** | **0.490** | **0.663** |

*Table A-29. Black carbon from industrial fuel combustion (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Biomass | 0.000 | 0.000 | 0.000 | 0.002 | 0.010 | 0.011 | 0.003 |
| Coal | 0.000 | 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 | 0.002 |
| Oil | 0.050 | 0.052 | 0.055 | 0.018 | 0.032 | 0.019 | 0.004 |
| Other | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 |
| **Total Industrial Fuel Combustion** | **0.055** | **0.057** | **0.059** | **0.024** | **0.047** | **0.034** | **0.010** |

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Biomass | 0.000 | 0.000 | 0.000 | 0.006 | 0.036 | 0.040 | 0.010 |
| Coal | 0.001 | 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 | 0.008 |
| Oil | 0.177 | 0.182 | 0.193 | 0.063 | 0.112 | 0.067 | 0.015 |
| Other | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 |
| **Total Industrial Fuel Combustion** | **0.195** | **0.199** | **0.208** | **0.083** | **0.166** | **0.120** | **0.035** |

*Table A-30. Industrial Process Black Carbon (metric tonnes (MMT $CO_2e$)*

*$GWP_{100}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Cement Mfg. | 0.00001 | 0.00001 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Chemical Mfg. | 0.00092 | 0.00077 | 0.00048 | 0.00080 | 0.00031 | 0.00028 | 0.00025 |
| Ferrous Metals | 0.00068 | 0.00059 | 0.00040 | 0.00013 | 0.00012 | 0.00010 | 0.00009 |
| Mining | 0.00200 | 0.00221 | 0.00262 | 0.00211 | 0.00001 | 0.00001 | 0.00000 |
| Other | 0.00870 | 0.00860 | 0.00840 | 0.00661 | 0.00542 | 0.00630 | 0.00453 |
| Non-ferrous Metals | 0.00020 | 0.00017 | 0.00013 | 0.00009 | 0.00015 | 0.00012 | 0.00010 |
| Oil & Gas Production | 0.00000 | 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 | 0.00122 |
| Pulp & Paper | 0.00132 | 0.00098 | 0.00029 | 0.00009 | 0.00046 | 0.00056 | 0.00016 |
| Storage and Transfer | 0.00050 | 0.00047 | 0.00040 | 0.00032 | 0.00015 | 0.00035 | 0.00058 |
| Industrial Surface Coating & Solvent Use | 0.00029 | 0.00033 | 0.00042 | 0.00013 | 0.00013 | 0.00009 | 0.00008 |
| **Total Industrial Processes** | **0.01955** | **0.02033** | **0.02191** | **0.01137** | **0.00795** | **0.00887** | **0.00702** |

*GWP20*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Cement Mfg. | 0.00005 | 0.00003 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| Chemical Mfg. | 0.00324 | 0.00272 | 0.00169 | 0.00281 | 0.00109 | 0.00097 | 0.00087 |
| Ferrous Metals | 0.00238 | 0.00206 | 0.00142 | 0.00044 | 0.00044 | 0.00035 | 0.00032 |
| Mining | 0.00703 | 0.00776 | 0.00921 | 0.00741 | 0.00004 | 0.00005 | 0.00002 |
| Other | 0.03061 | 0.03025 | 0.02954 | 0.02326 | 0.01904 | 0.02215 | 0.01594 |
| Non-ferrous Metals | 0.00069 | 0.00061 | 0.00045 | 0.00032 | 0.00051 | 0.00041 | 0.00037 |
| Oil & Gas Production | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00001 |
| Petroleum Refineries | 0.01732 | 0.02182 | 0.03082 | 0.00384 | 0.00425 | 0.00373 | 0.00427 |
| Pulp & Paper | 0.00464 | 0.00343 | 0.00101 | 0.00032 | 0.00160 | 0.00196 | 0.00057 |
| Storage and Transfer | 0.00175 | 0.00164 | 0.00142 | 0.00112 | 0.00053 | 0.00124 | 0.00204 |
| Industrial Surface Coating & Solvent Use | 0.00102 | 0.00117 | 0.00148 | 0.00046 | 0.00046 | 0.00032 | 0.00027 |
| **Total Industrial Processes** | **0.06874** | **0.07150** | **0.07704** | **0.04000** | **0.02797** | **0.03118** | **0.02468** |

*Table A-31. Wildfires, Prescribed Burns, and Related Sources (MMT $CO_2e$)*

*GWP100*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Forest Wildfires[1] | 0.000 | 0.009 | 0.028 | 0.007 | 0.138 | 0.061 | 0.075 |
| Prescribed Burning[1] | 0.000 | 0.021 | 0.062 | 0.092 | 0.254 | 0.148 | 0.268 |
| Agricultural Fires | 0.064 | 0.065 | 0.066 | 0.059 | 0.056 | 0.070 | 0.037 |
| Structural Fires | 0.011 | 0.010 | 0.008 | 0.012 | 0.011 | 0.022 | 0.000 |
| Misc. Other | 0.027 | 0.021 | 0.010 | 0.007 | 0.006 | 0.007 | 0.024 |
| **Total** | **0.075** | **0.105** | **0.164** | **0.170** | **0.459** | **0.300** | **0.381** |

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

*$GWP_{20}$*

| Year | 2005 | 2006 | 2008 | 2011 | 2014 | 2017 | 2020 |
|---|---|---|---|---|---|---|---|
| Forest Wildfires[1] | 0.000 | 0.009 | 0.028 | 0.007 | 0.138 | 0.061 | 0.075 |
| Prescribed Burning[1] | 0.000 | 0.021 | 0.062 | 0.092 | 0.254 | 0.148 | 0.268 |
| Agricultural Fires | 0.064 | 0.065 | 0.066 | 0.059 | 0.056 | 0.070 | 0.037 |
| Structural Fires | 0.011 | 0.010 | 0.008 | 0.012 | 0.011 | 0.022 | 0.000 |
| Misc. Other | 0.027 | 0.021 | 0.010 | 0.007 | 0.006 | 0.007 | 0.024 |
| **Total** | **0.075** | **0.105** | **0.164** | **0.170** | **0.459** | **0.300** | **0.381** |

[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 preparation of the inventory (Table B-1) were taken from the IPCC Fifth Assessment Report (AR5),[61] with two exceptions. GWP values for HFCs were taken from the IPCC Fourth Assessment Report (AR4),[62] and GWP values for black carbon were taken from Bond, et al. (2013).[63] Use of $GWP_{100}$ values from AR5 is the standard for conducting national assessments pursuant to international reporting requirements and is consistent with USEPA methodology. As discussed below, HFC emissions were estimated using the US Climate Alliance SLCP Tool, which is based on AR4 GWPs and had not been updated to AR5 at the time of this report's preparation. However, AR5 GWP values for HFCs are generally slightly lower than those from AR4 (on average 18%), and so the emissions estimates presented here should be conservative, that is, they should be slightly greater than estimates based on AR5. The SLCP Tool was preferred over the estimate published in the USEPA state-level inventory[64] because the SLCP Tool provides individual estimates for subcategories such as commercial refrigeration and residential heat pumps, a powerful insight for policy development. This is believed to only have a small impact on emissions calculations. In fact, New Jersey's 2021 HFC emissions estimate of 5.2 MMT $CO_2e$ (based on AR4 $GWP_{100}$) was only 8% greater than USEPA's estimate of 4.8 MMT $CO_2e$ (based on AR5 $GWP_{100}$). This close agreement between the two methodologies supports use of the more detailed profile from the SLCP Tool. With respect to black carbon, Bond, et al. (2013) was chosen for GWP values because it is a comprehensive evaluation and was cited in both IPCC AR5 and AR6.

*Table B-1 Global Warming Potentials*

| Climate Pollutant | $GWP_{100}$ | $GWP_{20}$ | Reference |
|---|---|---|---|
| Carbon Dioxide ($CO_2$) | 1 | 1 | IPCC AR5 Chapter 8, Appendix Table 8.A.1 |
| Methane ($CH_4$) | 28 | 84 | IPCC AR5 Chapter 8, Appendix Table 8.A.1 |
| Nitrous Oxide ($N_2O$) | 265 | 264 | IPCC AR5 Chapter 8, Appendix Table 8.A.1 |
| Sulfur Hexafluoride ($SF_6$) | 23,500 | 17,500 | IPCC AR5 Chapter 8, Appendix Table 8.A.1 |
| 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 these sectors by appropriate emissions factors. Fuel sales data was provided by the US Energy

[61] Table 8.A.1 in Chapter 8 Appendix, IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

[62] Table 2.14 in 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 [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

[63] Bond, T.C., et al., 2013, Bounding the role of black carbon in the climate system: A scientific assessment, J. Geophysical Research: Atmospheres, 118, 5380–5552. This reference is cited in IPCC AR5 and in the subsequent 2021 IPCC *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*.

[64] USEPA, 2023, Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1991-2021. https://www.epa.gov/ghgemissions/state-ghg-emissions-and-removals

Information Agency (USEIA) State Energy Data System[65] (Tables B-2, B-3 and B-4). Emissions factors were from the USEPA.[66] 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.[67] 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 considered in the 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 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 much of 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, and that the material is 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.[68] This is reflected in the emissions record.

*Table B-2. EIA Fuel Consumption Categories for the Residential Sector[69]*

| 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 |

*Table B-3. EIA Fuel Consumption Categories for the Commercial Sector[70]*

| 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 |

[65] https://www.eia.gov/state/seds/
[66] https://www.epa.gov/climateleadership/ghg-emission-factors-hub
[67] IPCC, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Section 8.2.1.
USEPA, 2023. Inventory of U.S. Greenhouse Gas Emissions and Sinks, EPA430-R-23-002, Section 3.10.
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.
[68] USEIA, Technical Notes on the State Energy Data System: Consumption, Section 4, Petroleum, Hydrocarbon Gas Liquids
[69] 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.
[70] 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.

| | |
|---|---|
| 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-4. EIA Fuel Consumption Categories for the Industrial Sector*[71]

| 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 |
| 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 |

## B.3. TRANSPORTATION

### On-Road Transportation

On-road emissions estimates for 2006 and for 2018 through 2021 were found using the third release of the USEPA MOtor Vehicle Emission Simulator transportation emissions model for on-road estimates. MOVES3 produces detailed emissions profiles using 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

[71] 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.

Table 3-13 of the USEPA Inventory of US Greenhouse Gas Emissions and Sinks report.[72] As an example, in 2006, 98.9% of gasoline emissions in the transportation sector were attributed by USEPA to on-road vehicles, with the remainder arising from boats. This fraction (98.9%) was then assumed to equal the fraction of transportation-sector gasoline used in New Jersey for on-road use. A preliminary 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 emissions estimates were then compared with MOVE3 output for the years 2006 and 2018. For 2006, on-road emissions estimate based on fuel sales was 7.9% greater than the MOVES3 estimate, and in 2018, the fuel-based estimate was 5.6% greater than the MOVES3 estimate.[73] To align estimates based on fuel sales with those from MOVES3, these 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 those intervening years. For 1990 and 2005, the adjustment factor for 2006 was applied.

### Aviation

USEIA jet fuel sales data for New Jersey includes some fuel used at New York airports. USEIA acknowledges this limitation and has indicated that their data has not been corrected to account for this. [74] A second challenge 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 considerations lead to greatly overstated emissions estimates when EIA fuel sales data is used. A prior analysis by NJDEP[75] concluded that aviation emissions occurring within the state total approximately 1.0 MMT $CO_2$e annually (based on either $GWP_{100}$ or $GWP_{20}$). This figure is generally consistent with the estimates of 0.81 MMT $CO_2$e for 2017 and 0.55 MMT CO2e for 2020 published by USEPA in the National Emissions Inventories.[76] The NEI estimates were 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. The NEI estimates include 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, 1990-2021 (2023).[77] These fuel quantities were then multiplied by emissions factors for the fuel type to account 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 in the state and then carried away for use elsewhere. Fluctuations in apparent emissions may therefore represent changes in market activity 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

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[72] USEPA, 2023, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021. U.S. Environmental Protection Agency, EPA 430-R-23-002, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021, and associated data file "2023 Energy Tables" at https://www.epa.gov/system/files/other-files/2023-05/Energy.zip

[73] 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.

[74] 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

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

[76] Sum of $CO_2$ emissions for SCC codes 2275050011, 2275050012, 227506001, 2275060012, 2275020000 and 2275001000. Data from the 2017 and 2020 National Emissions Inventories is available at https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei. The 2017 estimate did not include emissions from all individual sources and actual emissions may therefore have been slightly greater than reported.

[77] USEPA, 2023, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021. U.S. Environmental Protection Agency, EPA 430-R-23-002, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021, and associated data file "2023 Energy Tables" at https://www.epa.gov/system/files/other-files/2023-05/Energy.zip

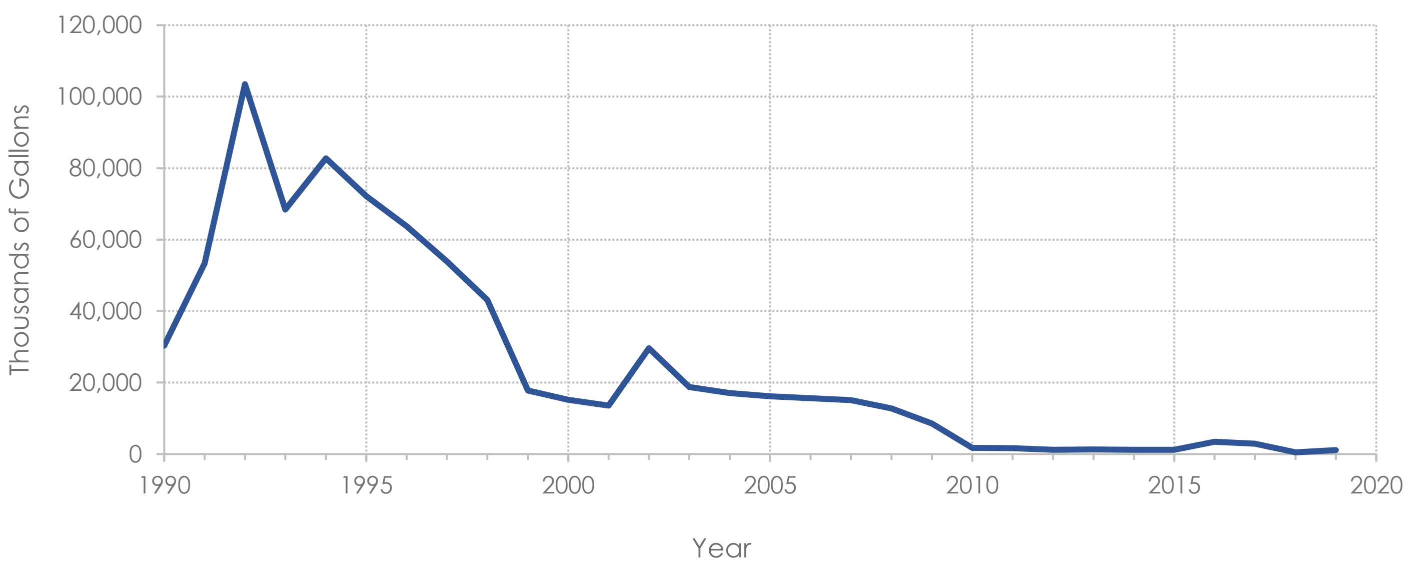
records show that very little distillate fuel is sold inside in the state for rail use.[78] (Figure B-1) Similar effects can be seen in Delaware and Maryland sales records, while Pennsylvania and New York sales often increase when the other states decrease. However, the combined sales quantities across the region[79] 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.[80] This metric responds to overall changes in New Jersey distillate sales across all sectors, including rail, 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%.[81]

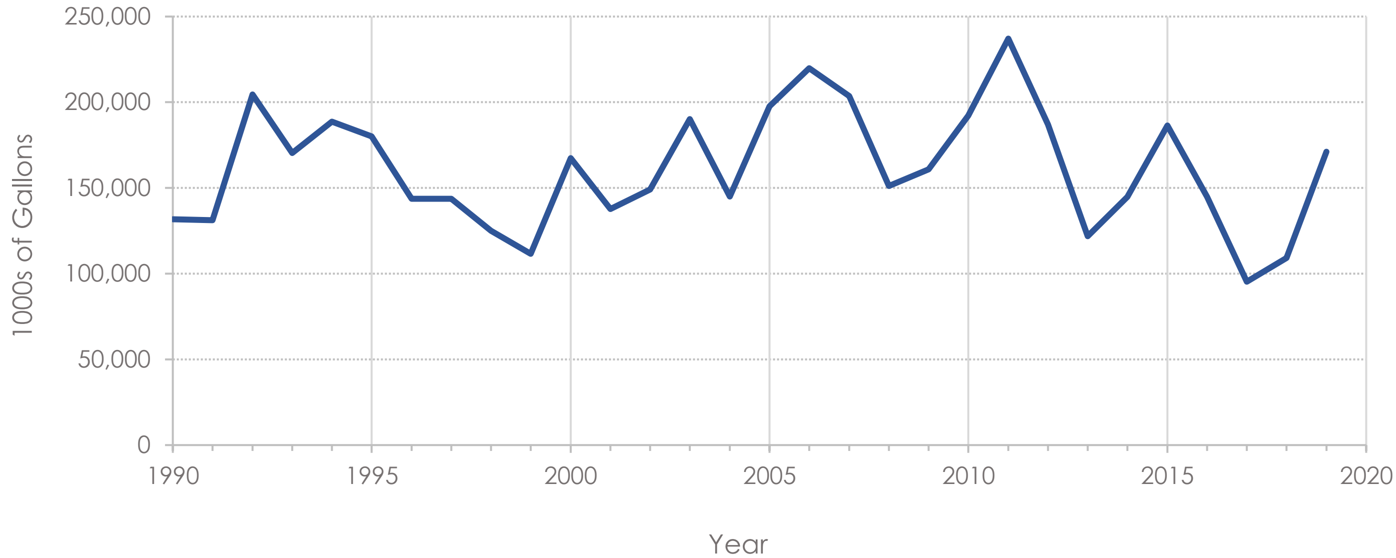
USEIA has suspended publication of the fuel oil sales data used to prepare the emissions estimate for the sector. 2021 emissions were therefore assumed to equal the rail sector emissions for 2020, which is reasonable given the small size and consistency of this sector's emissions over the period of record.

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




[78] 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
[79] USEIA defines the PADD 1B region as NJ, NY, PA, DE, MD and the District of Columbia.
[80] 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.
[81] 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.[82] 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.[83] 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.[84] 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.[85] 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.[86] $CO_2e$ 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 $CO_2$, 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 in-state carbon dioxide and methane mass emissions data submitted to the NJDEP Emissions Statement Database under NAICS code 562213. 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) was excluded based on IPCC guidance. 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 USEIA 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 incinerator 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.

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

[83] 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)"

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

[85] 2006 IPCC Guidelines for GHG Inventories Vol. 2, Energy, pages 1.23 and 1.24. https://www.ipcc-nggip.iges.or.jp/public/2006gl

[86] 2006 IPCC Guidelines for GHG Inventories Vol. 2, Energy, pages 2.16 and 2.17. https://www.ipcc-nggip.iges.or.jp/public/2006gl

### Solar Photovoltaic Capacity and Output

Installed solar capacity was taken from the NJBPU Solar Activity Reports.[87] Solar PV power output was estimated using the NJBPU ten-year average Specific Energy Production (SEP) factor of 1,154 MWh power/MW capacity.[88] Power production other than solar PV was from USEIA generation data.[89]

## B.5. NON-ENERGY EMISSIONS

### Halogenated Gases (excluding sulfur hexafluoride)

HFC 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 those values to individual USCA states, including New Jersey. Reductions due to SNAP and Kigali policy implementation from the USCA tool were then adjusted to align with New Jersey SNAP[90] and federal Kigali implementation dates.

### Non-Fuel Agricultural Emissions

Non-fuel agricultural emissions were found using the USEPA State Inventory Tool's 2023 Carbon Dioxide, Methane and Nitrous Oxide Emissions from Agriculture module.[91] Default inputs were used. Emissions estimates include enteric fermentation, manure management, agricultural soils, urea fertilization, and agricultural residue burning. Due to the unavailability of data for 2021 in the USEPA State Inventory Tool at the time of publication, the value of 2020 was carried over to 2021. Given the consistently small size of this source category, this assumption is considered to have little if any impact on the overall state emissions total.

### Natural Gas Transmission and Distribution

Emissions from natural gas transmission and distribution were found using the USEPA State Inventory Tool's 2023 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.[92] 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 (SIT) 2023 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 annual solid waste survey data published by Biocycle magazine. Quantities for 2005 onward were provided by the NJDEP Bureau of Solid Waste Permitting. Other inputs to the module such as flaring, landfill-gas-to-energy diversion and soil oxidation rates were default values provided in the Tool by USEPA.

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

[88] 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

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

[90] New Jersey SNAP law, P.L. 2019 c. 507.

[91] USEPA State Inventory and Projection Tool, Version 2023.2, June 2023

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

For out-of-state waste disposal, waste disposal quantities for 2005 onward were 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, the ratio of waste disposed of out of state to waste disposed of at in-state landfills was found. Where necessary, adjustments for in-state incineration were made as noted above. 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 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 2023 State Inventory Tool.[93] State population data was adjusted based on US Census data.[94] Otherwise, USEPA default inputs were used for all 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 2023 State Inventory Tool. USEPA default values were used for all calculations. Due to unavailability of 2021 data in the SIT, the 2020 emissions estimate was carried over to 2021. Given the consistency and small size of this source category's emissions, this was judged to have had little if any effect on the state emissions total.

### Emissions Due to Land Clearing

The impacts of land clearing relied on 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: 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, the ratio of the molecular weight of carbon dioxide to the atomic weight of carbon.

### Sulfur Hexafluoride ($SF_6$)

Sulfur hexafluoride emissions were found using the USEPA State Inventory Tool's 2023 Industrial Process module with default inputs. Due to the lack of 2021 data in the SIT at the time of publication, the 2020 value was carried over to 2021. This was considered reasonable due to the small emissions from this source category and the consistency of the historical record.

## B.6. CARBON SEQUESTRATION

The natural carbon sequestration estimate 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

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[93] Emissions arising from consumption of fuel at water and wastewater treatment plants is included in the Commercial Sector calculations.
[94] https://www2.census.gov/programs-surveys/popest/tables/2020-2022/state/totals/NST-EST2022-POP.xlsx, with interpolation for 2011-2019

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 tons per acre is based on Lathrop, et al. (2011)[95] 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.[96]

## 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 processes 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.

[95] 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.

[96] [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.

The quantity of $CO_2$e 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,[97] 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 later 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 2020 NEI to NEI $PM_{2.5}$ data[98] for 2005, 2008, 2011, 2014 and 2017. Although the 2014 and 2017 NEIs included black carbon data as originally published, estimates were recalculated here using the most recent speciation factors from USEPA to assure consistency and accuracy. NJDEP also used 2020 NEI $PM_{2.5}$ data to develop black carbon estimates and then compared those estimates to published values in the NEI as a verification of NJDEP methodology.

USEPA's 2020 speciation factor list did not include factors for all source categories in the 2020 NEI, and those factors were estimated by taking the ratio of black carbon and $PM_{2.5}$ values published in the 2020 NEI. Also, certain categories in older releases of the NEI were later reclassified, and in those cases speciation factors from the 2020 NEI for similar sources were applied.

For on-road source categories, NJDEP used the MOVES3 transportation emissions model for years 2006 and 2018 through 2021, the most recent release at the time the calculations were completed. MOVES is the current standard for regulatory submissions to the USEPA, and is the successor to earlier models such as MOBILE and MOVES 2014.[99] For other years, on-road emissions estimates were taken from the USEPA EQUATES program.[100] 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 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).

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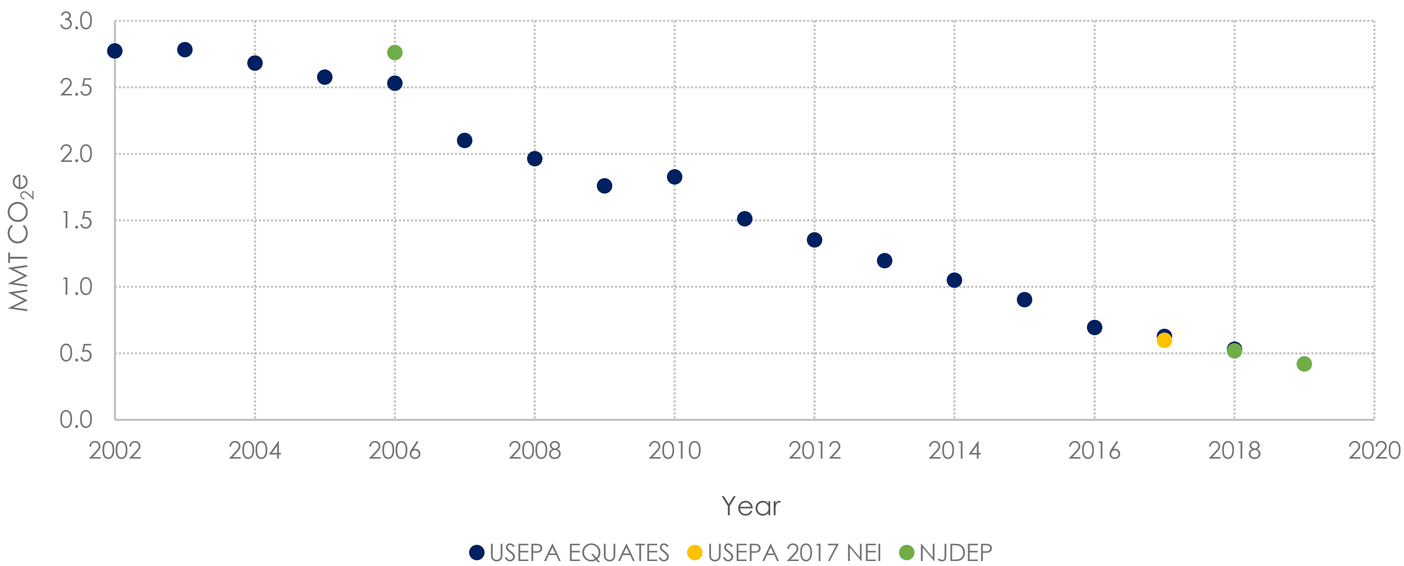
[97] https://www.epa.gov/air-emissions-modeling/speciate-4

[98] 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.

[99] https://www.epa.gov/moves

[100] https://www.epa.gov/cmaq/equates

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

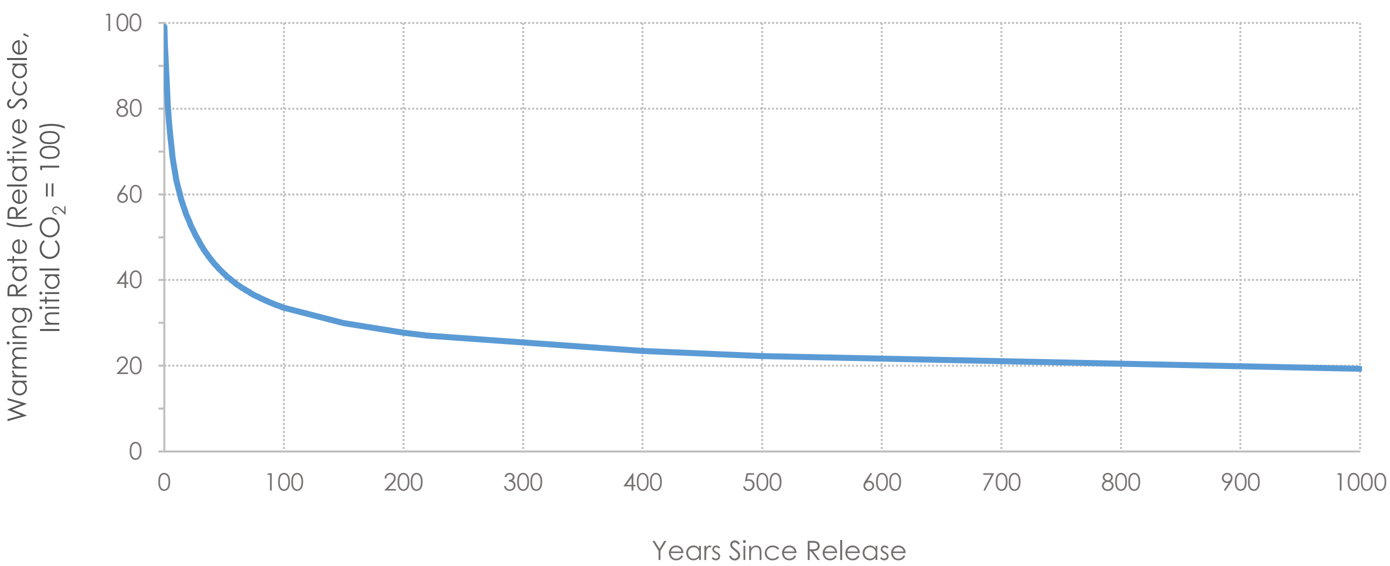


# APPENDIX C. GLOBAL WARMING POTENTIAL

## Climate Pollutants and Their Role in Global Warming

Carbon dioxide ($CO_2$) is by far the dominant gas contributing to climate change in the United States, and is responsible for 79% of the nation's climate impact.[101] In addition to being released in large quantities in the U.S. 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.[102] Over shorter lengths of time, $CO_2$ appears as an almost constant source of warming because the atmospheric concentration declines so slowly. 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 of greatest importance to reduce the amount of global damage.

*Figure C-1. Persistence of Warming Impacts from a Pulse Release of $CO_2$.*[103]




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 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.

One critical difference among GHGs is the time scale of their impact. 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.[104] Such compounds are referred

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[101] USEPA, 2023, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021. U.S. Environmental Protection Agency, EPA 430-R-23-002, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021, Table ES-2.

[102] 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

[103] 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/

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

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 induced by these gases. This stands in contrast to carbon dioxide and LLGHGs, which 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 each pollutant's impact 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,[105] and in accordance with the UN requirement, the USEPA[106] 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 those from around the world. Emissions based on $GWP_{100}$ are found by multiplying the mass of a gas by its $GWP_{100}$ factor to find the equivalent amount of $CO_2$, or $CO_2$e (Figure C-2).

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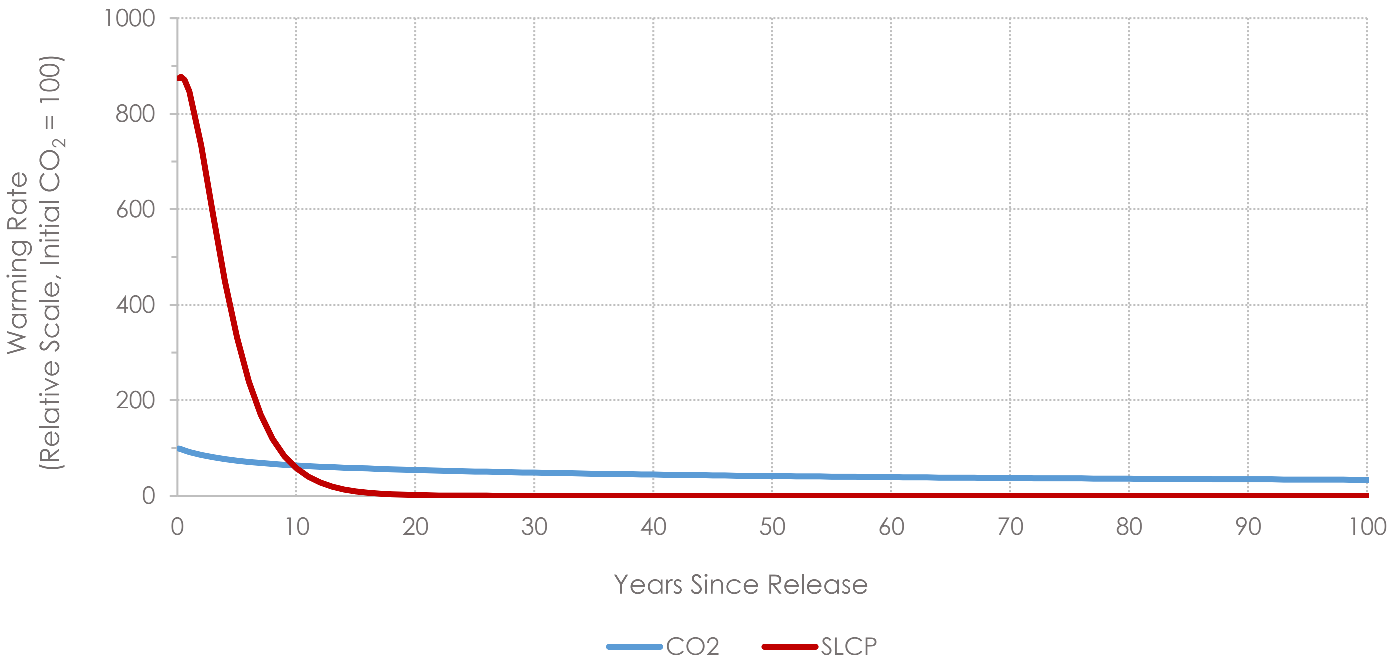
[105] United Nations Framework Convention on Climate Change, 2014. Report of the Conference of the Parties on its Nineteenth Session, held in Warsaw from 11 to 23 November 2013; Addendum, Part two: Action taken by the Conference of the Parties at its nineteenth session. FCCC/CP/2013/10/Add.3. http://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf.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

[106] USEPA, 2023, Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021. U.S. Environmental Protection Agency, EPA 430-R-23-002, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021, page 1-9.

*Figure C-2. Impacts from a short-lived climate pollutant (SLCP) and $CO_2$ using a 100-year time horizon.[107] The areas under the lines represent the total cumulative impact 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 the same.) The ratio of the SLCP impact to the $CO_2$ impact (the GWP) is therefore 1.0.*




Mathematically, the GWP is defined as[108]

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

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

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[107] 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.

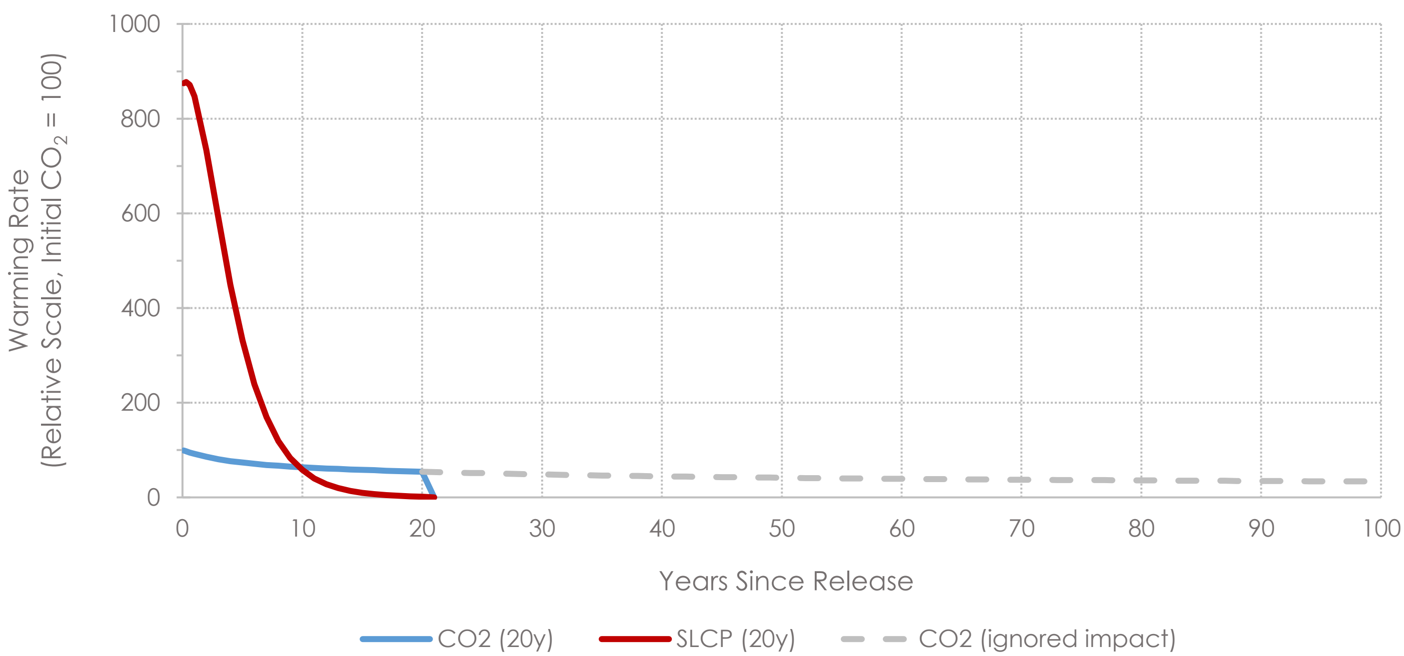
[108] IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, Section 2.10.

[$C_r(t)$] 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.[109] 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.*




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

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. 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.[110] The UNFCCC and IPCC do not establish reporting requirements for SLCPs other than those based on 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 develop better ways to characterize their impacts. The starting point for this reassessment has been the recognition that 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 very 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, referred to as steady state, where new additions of the gas are balanced by removals. Once the concentration is at steady state, the gas will exert a nearly constant 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 the step-pulse comparison method.

One metric cited by the IPCC for creating such as comparison is the Combined Global Temperature Potential,[111] or CGTP, having units of kg/(kg/yr), or $yr^{-1}$

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

For example, the 50-year CGTP for methane is 2,823 $yr^{-1}$. 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 2,823 kg over that same time period. The 100-year CGTP for methane is 3,531 $yr^{-1}$, indicating that a 1 kg/yr release that lasts 100 years would have an impact equivalent to a one-time $CO_2$ release of 3,531 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 $CO_2e$, the $CO_2e$ value is divided by the GWP factor used in the original calculation to find the mass. 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.[112] NJDEP will continue to track IPCC and UNFCCC recommendations in regards to emissions metrics and inventory accounting.

[110] IPCC, 2021: Climate Change 2021: The Physical Science Basis, Section 7.6.
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. Ch. 2.

[111] IPCC, 2021: Climate Change 2021: The Physical Science Basis, Section 7.6; Table 7.SM.7.

[112] Lynch, John; Cain, Michelle; Pierrehumbert, Raymond; and Allen, Myles. Demonstrating GWP*: a means of reporting warming-equivalent emissions that captures the contrasting impacts of short- and long-lived climate pollutants. Environmental Research Letters, Volume 15, Number 4, 044023, 2020.

# APPENDIX D. COMPARISON OF NEW JERSEY EMISSIONS ESTIMATES WITH THE U.S. EPA EMISSIONS AND SINKS BY STATE REPORT

New Jersey's estimated 2021 net emissions from in-state sources, including removals due to sequestration, agree to within 2% of the value published in USEPA's state-level Emissions and Sinks Report. Specifically, New Jersey found net in-state emissions totaled 89.1 MMT $CO_2e$ while EPA calculated a total of 91.1 MMT $CO_2e$.[113] New Jersey also calculates emissions due to electricity imported from out of state and from solid waste disposed of out-of-state, but these were not included in the EPA total cited above. . A side-by-side comparison is presented in Table D-1, and shown graphically in Figure D-1.

The differences that exist can largely be traced to differences in the methods used, as discussed by USEPA in Section 1.1 of their Methodology Report.[114] For example, USEPA relies on fuel sales data to estimate emissions from commercial aircraft, but flights arriving and departing from New Jersey generally spend little time in New Jersey airspace. Their approach attributes all emissions from a flight departing from New Jersey as if they all occurred within the State. New Jersey instead considers emissions associated with landing and takeoff as occurring in the State, which is an approach similar to that used by USEPA in the National Emissions Inventory.[115]

New Jersey also relies on emissions reports submitted directly to the State by electric generating facilities and solid waste incinerators in the State, while USEPA relies on federally-reported data. Even so, New Jersey and USEPA estimates for the electricity sector agree within 1%.

Methods used to evaluate hydrofluorocarbon emissions are conceptually similar but differ in their execution. USEPA uses an in-house model called the Vintaging Model while New Jersey relies on an analysis by the California Air Resource Board (CARB) based on their closely-related F-Gas model. The California model is actually derived from the USEPA model. However, the California estimates break out specific subcategories of emissions, for example those from motor vehicle air conditioning and commercial refrigeration. This insight assists New Jersey in developing policies to address climate change. New Jersey's estimates are also based on an earlier set of global warming potentials (GWP), from the IPCC Fourth Assessment Report (AR4), due to limitations in the existing data. GWP values from AR4 are slightly higher than those in the Fifth Assessment Report (AR5) used by USEPA, but the newest release of GWP values, from the Sixth Assessment Report,[116] are closer to those in AR4. Overall, the slightly lower estimate of HFC emissions published by USEPA is consistent with the use of the different GWP values.

At a more fundamental level, USEPA's goal was to apportion IPCC-reported national emissions to the individual states. In contrast, New Jersey's inventory report is crafted differently in order to provide policymakers with the data necessary to identify the most effective pathways towards carbon reduction. So, for example, New Jersey includes out-of-state emissions where state-level policies can have an impact (specifically, electricity and solid waste). In some cases, USEPA methods are very similar to what New Jersey used, as in estimating on-road transportation emissions with the MOVES3 model. In other cases, USEPA used geographic proxies such as population size and production capacity that differ from New Jersey's approach but which allowed calculation of state-level estimates that add up to the IPCC-recognized national total.

[113] USEPA Inventory of U.S. Greenhouse Gas Emission and Sinks by State, 1990-2021,. August 2023, https://www.epa.gov/system/files/other-files/2023-02/State-Level-GHG-data.zip EPA estimates are based on the IPCC 5th Assessment Report, 100-year GWP values( https://www.ipcc.ch/report/ar5/wg1/). USEPA only publishes estimates based on $GWP_{100}$ and no comparison was made using $GWP_{20}$.

[114] Methodology Report for Inventory of U.S> Greenhouse Gas Emission and Sinks by State: 1990-2021, EPA-430-R-23-003, August 2023, https://www.epa.gov/system/files/documents/2023-09/Methodology-Report-Full.pdf.

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

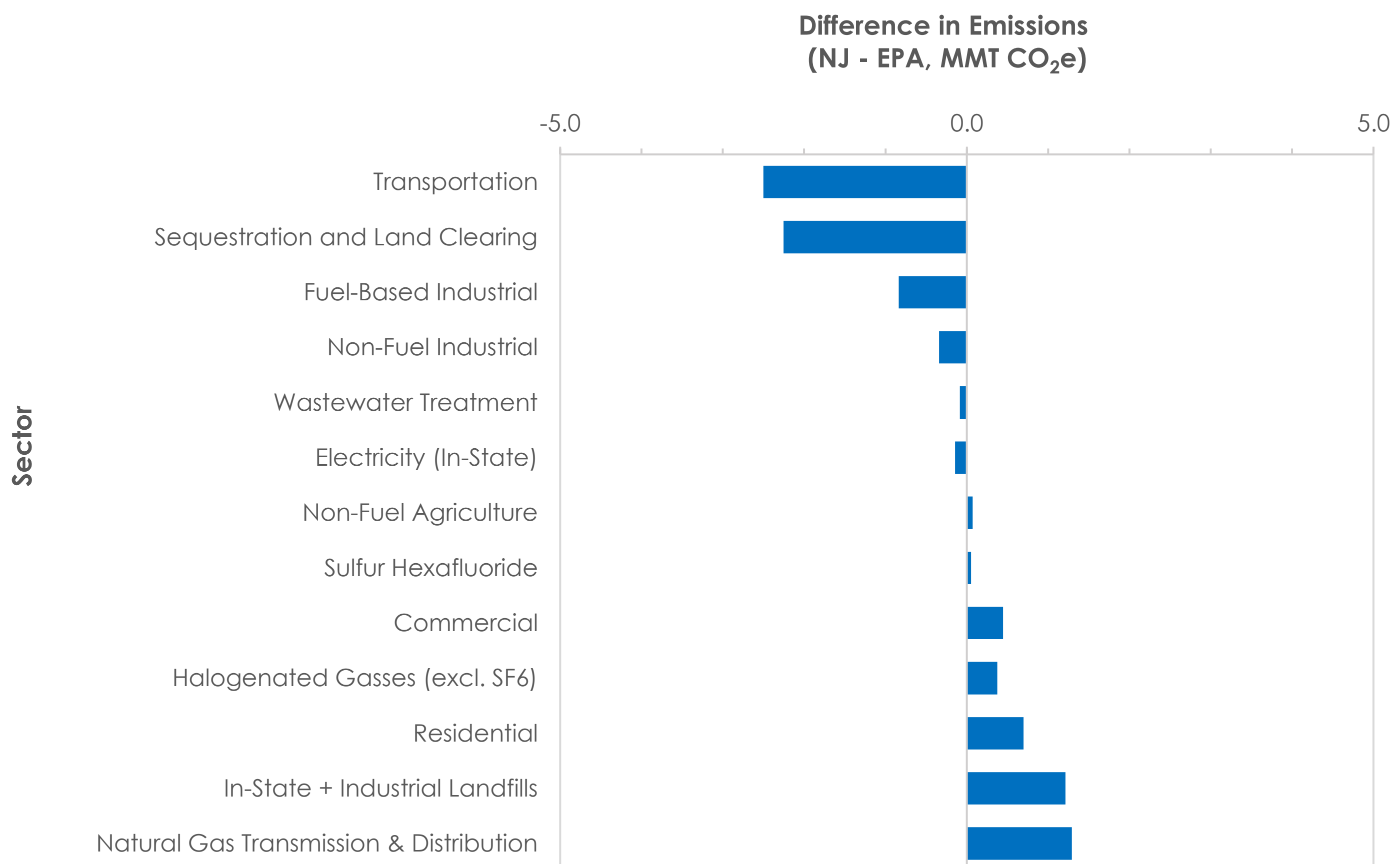
[116] https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport_small.pdf

*Table D-1. Comparison of USEPA and New Jersey Emissions Estimates for 2021.*

| Sector | GHG Emissions Estimates EPA (MMT $CO_2e$) | NJDEP (MMT $CO_2e$) | Notes |
|---|---|---|---|
| Residential | 14.2 | 14.9 | Estimates agree within 5%. |
| Commercial | 9.5 | 9.9 | Estimates agree within 5%. |
| Industrial - Fuel | 8.4 | 7.6 | Estimates agree within 10%. |
| Industrial - Non-Fuel | 0.6 | 0.3 | Estimates agree within 53%. The small quantities involved lead to a large percentage difference. |
| Transportation | 39.8 | 37.3 | Estimates agree within 6%. |
| Electricity - EGU | 13.5 | 13.5 | Estimates agree within 1%. |
| Electricity - MSW | 0.9 | 0.8 | Estimates agree within 6%. |
| Electricity - Imported | N/A | 4.8 | Emissions from imported electricity were not evaluated by USEPA. New Jersey includes estimated emissions from imported electricity under statutory mandate. |
| Halogenated Gases | 4.8 | 5.2 | Estimates agree within 8%. New Jersey used IPCC AR4 GWP values and data derived from California F-Gas model; USEPA uses IPCC AR5 and their Vintaging model. The difference in estimates is consistent with slightly lower GWP values in AR5. |
| Sulfur Hexafluoride (SF6) | 0.02 | 0.08 | Estimates agree within 208%. The small quantities involved lead to a large percentage difference. |
| Non-Fuel Ag | 0.4 | 0.4 | Estimates agree within 19%. |
| Natural Gas Transmission and Distribution | 1.2 | 2.5 | Estimates agree within 19%. To develop state-level estimates for transmission and storage, USEPA apportioned the total national transmission and storage segment emissions to each state based on the fraction of national transmission pipeline mileage occurring in each state. NJ used the USEPA 2023 State Inventory Tool and pipeline data from USDOT Pipeline and Hazardous Materials Safety Administration that is specific to New Jersey. |
| Landfill - In-State, incl Industrial | 1.7 | 2.9 | Estimates agree within 73%. EPA took national totals and distributed them among the states to assure the individual state totals added to the national total. NJ used the USEPA 2023 State Inventory Tool and state-specific solid waste disposal records gathered by NJDEP waste management programs. |
| Landfill - out of state | N/A | 3.7 | Emissions from out-of-state solid waste disposal were not evaluated by USEPA. New Jersey includes estimated emissions from exported waste under statutory mandate. |
| Wastewater Treatment | 1.0 | 0.9 | Estimates agree within 9%. |

| Sector | GHG Emissions Estimates EPA ($MMT\ CO_2e$) | NJDEP ($MMT\ CO_2e$) | Notes |
|---|---|---|---|
| Sequestration & Land Clearing | -4.8 | -7.1 | Estimates agree within 47%. USEPA includes adjustments for harvested wood products and aquaculture, while NJ uses land use change data. Difference also arise from other methodological distinctions and the high levels of uncertainty when estimating land-based processes. |
| Total Net Emissions | 91.1 | 97.6 | Including NJ Out-of-State Estimates. |
| **Total Net In-State Emissions** | **91.1** | **89.1** | **Estimates agree within 2%.** |

*Figure D-1. Comparison of USEPA and New Jersey Emissions Estimates by Sector for 2021.*



# APPENDIX E. DETAILED BLACK CARBON EMISSIONS ESTIMATES

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

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

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

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

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

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

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

Appendix E tables can be downloaded from

https://dep.nj.gov/wp-content/uploads/ghg/2024-nj-ghg-inventory-report-appendix-e-black-carbon-data.xlsx.