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North Carolina **Greenhouse Gas** Inventory (1990-2030)

January 2019

THE GREAT SEAL OF THE STATE OF NORTH CAROLINA
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North Carolina **Greenhouse Gas** Inventory

(1990 – 2030)

North Carolina Department of Environmental Quality

Division of Air Quality

January 2019

Purpose

This emissions inventory provides a high-level perspective of anthropogenic greenhouse gas (GHG) emissions from various economic sectors in North Carolina. It represents North Carolina's "carbon footprint." The inventory can be used by environmental planners and energy policy makers in our State to understand past, current, and expected future GHG emissions in North Carolina. It can also be used as a baseline to evaluate and develop GHG mitigation options for our State and predict their effect on reducing emissions in future years. This report does not discuss the impact of GHGs on climate.

The GHG inventory utilizes data sets assembled by the U.S. Environmental Protection Agency (EPA), federal agencies, and state agencies. The inventory, along with documentation of the data and methods used to develop the emissions estimates, was provided to stakeholders for review between November 2nd and December 14th of 2018. Stakeholders were asked to suggest or provide more appropriate data sets or methods that may improve North Carolina's estimates. Comments and responses from the public comment period are listed in Appendix D. The GHG inventory is expected to be updated biennially to incorporate advancements in data and methodologies, as appropriate.

Acknowledgements

We are thankful to representatives from New York, California, and the U.S. Climate Alliance for providing guidance throughout the inventory development process. Special appreciations are also extended to the EPA, South Coast Air Quality District, and the Environmental Defense Fund for peer reviewing the draft inventory. We also extend thanks to the following groups who submitted written comments: Cape Fear Public Utility Authority, Clean Air Carolina, Dogwood Alliance, Natural Resources Defense Council, Southern Environmental Law Center, and Sierra Club.

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Acronyms

AEO	Annual Energy Outlook
CAFE	Corporate Average Fuel Economy
C&D	construction and demolition
CCT	Carbon Calculation Tool
CH_4	methane
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CSA	Clean Smokestacks Act
DAQ	Division of Air Quality
DOE	Department of Energy
DOT	Department of Transportation
eGRID	Emissions & Generation Resource Integrated Database
EIA	Energy Information Administration
EPA	Environmental Protection Agency
GHG	greenhouse gases
GSP	gross state product
GWP	global warming potential
FHWA	Federal Highway Administration
FIA	Forest Inventory and Analysis Program
FORCARB2	Forest Carbon Budget Model
HCFC-22	chlorodifluoromethane
HFCs	hydrofluorocarbons
IBEAM-ED	Internet-Based Enterprise Application Management - Emissions Data Module
IPCC	Intergovernmental Panel on Climate Change
kWh	kilowatt-hour
lb	pound
LFGTE	landfill-gas-to-energy
LMOP	Landfill Methane Outreach Project
LNG	liquified natural gas
LPG	liquified petroleum gas
LULUCF	Land Use, Land Use Changes and Forestry
MATS	Mercury and Air Toxics Standard
MMBtu	million British thermal units
MMT	million metric tons
MSW	Municipal Solid Waste
MW	megawatt

MWh	megawatt-hour
NASS	National Agricultural Statistics Service
NC DA&CS	North Carolina Department of Agriculture and Consumer Services
NGCC	natural gas combined cycle
NIFC	National Interagency Fire Center
NHTSA	National Highway Traffic Safety Administration
N_2O	nitrous oxide
OAQPS	Office of Air Quality Planning and Standards
ODS	ozone depleting substance
PFCs	perfluorocarbons
PHMSA	Pipeline and Hazardous Materials Safety Administration
RCI	Residential, Commercial, and Industrial
RE	renewable energy
REPS	Renewable Energy and Energy Efficiency Portfolio Standard
SEDS	State Energy Data System
SERC	Southeastern Electric Reliability Council
SF_6	sulfur hexafluoride
SRVC	Southeastern Electric Reliability Council - Virginia/Carolina Subregion
SIT	State Inventory and Projection Tool
U.S.	United States
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VMT	vehicle miles traveled

1.0 Executive Summary

This report presents North Carolina's greenhouse gas (GHG) inventory, a detailed accounting of GHGs emitted or stored by key source categories from 1990 to 2017. In addition, the inventory projects North Carolina's GHG emissions from 2018 to 2030 based on forecasted changes in fuel use, land use, population, historical trends, and other factors. GHGs are air pollutants as defined by a United States Supreme Court decision and subject to regulation by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act.[1] In the report body, only select years are presented; however, estimated GHG emissions data for all analysis years, from 1990 to 2030, are summarized in Appendix A.

The methods used to prepare the North Carolina inventory are based on those used to prepare the Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016 (U.S. Inventory), annually published by EPA.[2] The U.S. Inventory includes estimates of historic anthropogenic emissions of GHG sources and carbon sinks by source category, economic sector, and GHG pollutant type starting from 1990 for the entire country.[3] It is calculated using methodologies consistent with those recommended in the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines).[4] The use of consistent methodologies ensures that GHG inventories prepared by states and other entities are comparable.

1.1 Greenhouse Gases Included in the Inventory

The North Carolina historic and projected emissions inventory presented here estimates emissions of the six primary GHG pollutants listed below.[5]

- carbon dioxide (CO_2)
- methane (CH_4)
- nitrous oxide (N_2O)
- hydrofluorocarbons (HFCs)
- perfluorocarbons (PFCs)
- sulfur hexafluoride (SF_6)

Emissions of each GHG are reported using the common metric "CO_2 equivalent emissions (CO_2e)." This approach normalizes the emissions of the various GHGs to reflect the global warming potential

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[1] *Massachusetts et al. v. Environmental Protection Agency et al*., U.S. Supreme Court, 549 U.S. 497, April 2, 2007, https://www.supremecourt.gov/opinions/06pdf/05-1120.pdf.

[2] Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016, EPA 430-P-18-001, U.S. Environmental Protection Agency, Washington, D.C., February 6, 2018.

[3] Carbon sinks are natural or artificial reservoirs that accumulate and store a carbon-containing chemical compound (generally CO_2) for an extended period, such as the growth of newly planted trees in a sustainably managed forest.

[4] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change. Hayama, Kanagawa, Japan, 2006, https://www.ipcc-nggip.iges.or.jp/public/2006gl/.

[5] These six compounds are being reported under the U.S. GHG reporting program. For information on each compound, see https://www.epa.gov/ghgemissions/overview-greenhouse-gases.

(GWP) of each compound with CO_2 as a baseline.[6] Using a common metric allows the quantity of each GHG compound emitted to be compared on the same basis. It also allows emissions of each GHG compound to be summed together to show the total impact of GHGs. For instance, it allows CH_4 emitted from landfills to be compared to the aggregate of CO_2, CH_4 and N_2O emitted from power plants. Appendix B contains a discussion of GWPs.

1.2 Emission Sources Included in the Inventory

North Carolina's GHG emissions inventory covers all GHG sources and carbon sink categories that are included in the national inventory prepared by EPA and are representative of activities occurring in our State. This includes emissions from Combustion Processes, Industrial Processes, and Waste Management activities.[7] It also includes fugitive emissions from Natural Gas Transmission and Distribution systems, Agriculture Operations, and from Land Use activities such as fertilization and forest fires. Lastly, the emissions inventory includes estimates of the indirect emissions associated with Imported Electricity consumed in North Carolina but generated outside the State. North Carolina's GHG inventory does not include coal, oil, and gas production, cement manufacture, lime manufacture, ammonia production, nitric acid production, adipic acid production, magnesium production, and the production of the refrigerant chlorodifluoromethane (HCFC-22) because these activities do not occur in the State. With additional refinements in emissions estimation methods, it may be possible for future inventories to include a broader scope of indirect emissions beyond Electricity consumption.[8]

The Land Use, Land Use Changes and Forestry (LULUCF) sector is the net sum of all CH_4 and N_2O emissions to the atmosphere from activities on natural and working lands plus the net change in the carbon stocks for each year. Changes in the growth, decay, storage, and use of the carbon-based stocks on North Carolina's natural and working lands, often referred to as carbon flux, are estimated for both the historic and projected emissions inventory in the LULUCF sector.[9] For all years, North Carolina's forestry management practices result in a net sequestration of carbon and are reported as a carbon sink. (See Section 2.9.)

CO_2 emissions from the combustion of biomass must be treated differently than fossil fuel sources in the inventory. This is because the release of carbon from biomass combustion is accounted for in the LULUCF sector per the IPCC Inventory Guidelines. Therefore, including biomass combustion CO_2 emissions elsewhere (i.e., within each applicable combustion sector) would result in double-counting emissions. For these reasons, biomass combustion emissions are included within the net emissions reported for the LULUCF sector. For transparency, and in keeping with EPA's national GHG

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[6] For more information on global warming potential, see https://www.epa.gov/climateleadership/atmospheric-lifetime-and-global-warming-potential-defined.

[7] Combustion processes include burning of coal, natural gas, fuel oil, biomass, and other fuels for electricity generation, process heat, space and water heating, and onroad and non-road transportation, and other combustion processes in the State.

[8] Indirect emissions are generated in other states from activities associated with goods consumed in North Carolina (see further discussion in Appendix D).

[9] Natural and working lands include public and private forests, cropland, grassland, wetlands and "settlement" lands, where settlement refers to both urban and rural communities.

inventory reporting, North Carolina's inventory presents gross CO_2 emissions from biomass combustion in North Carolina in Appendix C, which provides additional discussion on the treatment of CO_2 emissions from biomass combustion. Note that CH_4 and N_2O gross emissions from biomass combustion are included in the inventory within the relevant consumption sector (e.g., Residential/Commercial/Industrial combustion) since these emissions are not accounted for in the LULUCF sector.

1.3 GHG Emissions Estimation Methods

Both the historic and projected GHG emissions are calculated primarily using the "State Inventory and Projection Tool (SIT)," a spreadsheet-based tool developed by EPA to assist state agencies in preparing state-level GHG inventories and projections.[10] The SIT automates the estimation procedures used by EPA to prepare the national GHG inventory for use in preparing state-level GHG inventories.

The SIT includes default data supplied by EPA for North Carolina and other states. The default data are generally publicly available information from various federal agencies such as the U.S. Department of Energy (DOE), U.S. Department of Agriculture (USDA), Federal Highway Administration (FHWA), U.S. Geological Survey (USGS), U.S. Census Bureau, and EPA. These data are frequently used by state and local agencies to develop air pollutant emissions inventories. A limited number of source categories contained in the SIT (e.g., fertilizer application) utilize data obtained from third party vendors. Where default data were unavailable or considered inferior relative to other information sources, data obtained from state agencies are used in the SIT to provide more accurate emissions estimates for North Carolina. Examples of state-specific refinements include: (1) replacing the default CH_4 emission factor for natural gas compressor stations to reflect the average emissions of North Carolina compressor stations that report to EPA's GHG Reporting Program; (2) adding North Carolina poultry production data obtained from the NC Department of Agriculture and Consumer Services where no default data are included in the SIT Wastewater Module; and (3) using waste in place data from the North Carolina Division of Waste Management. The data sources used to estimate emissions are documented in Section 3.0 of this report.

A discussion of the uncertainty associated with the default data available in the SIT is located in each SIT module under the tab labeled "Uncertainty."[11] A discussion of the uncertainty associated with the data and methodology used outside of the SIT is available upon request.

1.4 Reference Case Projection

The projection of the GHG inventory includes all sectors that were estimated for the historic inventory. The projection represents a single reference case for future GHG emissions. No future year scenarios are included in the projections since potential scenarios have not been quantified at

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[10] State Inventory and Projection Tool, US Environmental Protection Agency, https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool accessed January 3, 2018.

this time. This reference case projection will be used to evaluate the impact of future scenarios with policies, programs, or rules that increase or decrease emissions.

There is uncertainty in this reference case projection due to EPA's potential replacement of several regulations involving GHG emissions including; 1) fossil fuel power plant CO_2 emissions, 2) landfill CH_4 emissions 3) corporate average fuel economy (CAFE) standards for vehicles, and 4) phasedown of HFCs under the Montreal Protocol.[11,12] The reference projection still includes the emissions reductions from these regulations, except for Electricity Generation. The Electricity Generation projection does not include any regulation of CO_2 emissions in the future since this regulation has already been removed from the forecast for this sector. Future inventories will incorporate any final regulatory changes.

As stated above, future decreases in GHGs through various mitigations strategies that may be employed by North Carolina are not included. Mitigation strategies along with their impact to net GHG emissions will be evaluated separately to estimate GHG reduction potential in a future year. Examples of mitigation strategies that may be evaluated include; 1) increase in the use of renewable energy, energy efficiency, and storage, 2) increase in the use of electric vehicles, 3) livestock manure management, and 4) sequestration of carbon by natural and working lands.

1.5 GHG Inventory Results

Table 1-1 summarizes the estimates of North Carolina's historical and projected GHG emissions and carbon sinks from 1990 through 2030.[13] Some important details about the table are listed below.

- Emissions are presented in million metric tons as CO_2 equivalent emissions (MMT CO_2e).
- In keeping with IPCC guidelines, CO_2 emissions from combustion of biomass are included within the calculation of net carbon flux in the LULUCF sector (see Appendix C for further discussion of the treatment of biomass CO_2 emissions).
- The inventory is presented as both gross emissions and net emissions (emissions minus carbon sinks) since targets for GHG emissions reductions are generally expressed as net emissions.
- Emissions reductions are presented for a base year of 2005 as well as 2025, which corresponds with the baseline and projection years specified by the Paris Agreement, an agreement within the United Nations Framework Convention on Climate Change (UNFCCC) dealing with GHG-emissions mitigation, adaptation, and finance.[14]

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[11] The Montreal Protocol's charter is to save the upper atmosphere ozone layer that protects from the sun's ultraviolet rays that cause skin cancer (see U.S. Department of State, "The Montreal Protocol on Substances That Deplete the Ozone Layer," https://www.state.gov/e/oes/eqt/chemicalpollution/83007.htm, accessed May 2018.)
[12] https://www.epa.gov/laws-regulations/epa-deregulatory-actions
[13] The data for all years are presented in Appendix A.
[14] https://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en

Based on the estimated emissions in Table 1-1, North Carolina's gross GHG emissions in 2017 are 150 MMT CO_2e.[15] Accounting for carbon sinks, North Carolina's net GHG emissions in 2017 are estimated at 116 MMT CO_2e and are projected to decrease to 104 MMT CO_2e by 2025. Using a base year of 2005, North Carolina reduced its net GHG emissions by 24% between 2005 and 2017. North Carolina's projected net post-2005 GHG reductions in 2025 are 31%, which is greater than the U.S. commitment to reduce GHG emissions by 26% to 28% by 2025 under the Paris Agreement.[16]

Table 1-1: North Carolina GHG Emissions Inventory by Source Sector (MMT CO_2e)

	Historic					Projected		
	1990	**2005**	**2012**	**2015**	**2017**	**2020**	**2025**	**2030**
Electricity Use	**54.57**	**79.37**	**66.85**	**58.48**	**52.60**	**45.74**	**40.59**	**42.46**
Electric Power Generation	46.28	73.27	55.95	51.10	45.32	38.34	32.99	34.70
Imported Electricity[a]	8.29	6.10	10.90	7.37	7.28	7.39	7.60	7.76
Residential/Commercial/Industrial Combustion[b]	**26.77**	**26.02**	**18.66**	**21.15**	**20.92**	**22.52**	**23.26**	**23.92**
Industrial	17.59	14.21	10.00	9.97	9.93	11.32	12.16	12.62
Commercial	3.79	5.06	4.17	5.76	5.72	5.84	5.76	5.93
Residential	5.39	6.75	4.48	5.43	5.28	5.36	5.35	5.38
Transportation	**40.21**	**55.19**	**46.36**	**49.02**	**48.72**	**45.27**	**41.00**	**39.22**
Gasoline & Diesel Highway	35.13	48.21	41.60	44.00	44.05	40.47	36.02	34.02
Non-Highway	5.08	6.96	4.72	4.98	4.62	4.74	4.91	5.12
Alternative Fuel Vehicles	0.00	0.03	0.04	0.05	0.05	0.06	0.07	0.08
Agriculture	**7.06**	**10.65**	**10.56**	**10.38**	**10.53**	**10.51**	**10.47**	**10.44**
Manure Management	2.59	6.02	5.63	5.90	6.05	6.06	6.09	6.11
Agricultural Soil Management	2.87	2.74	3.18	2.74	2.84	2.82	2.78	2.75
Enteric Fermentation	1.60	1.89	1.74	1.73	1.64	1.63	1.60	1.58
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**6.39**	**8.52**	**9.09**	**8.44**	**8.77**	**9.29**	**10.17**	**11.07**
Municipal Solid Waste	5.47	7.23	7.52	6.82	7.09	7.52	8.26	9.00
Wastewater	0.92	1.29	1.57	1.61	1.68	1.77	1.92	2.06
Industrial Processes	**1.04**	**3.83**	**5.39**	**6.03**	**7.18**	**8.84**	**11.31**	**12.73**
Natural Gas and Oil Systems	**0.86**	**1.17**	**1.28**	**1.32**	**1.35**	**1.40**	**1.47**	**1.55**
Gross Emissions	**136.89**	**184.74**	**158.18**	**154.82**	**150.08**	**143.57**	**138.28**	**141.37**
Net Carbon Sinks – LULUCF[c]	**-35.64**	**-32.66**	**-33.97**	**-34.16**	**-34.03**	**-34.03**	**-34.03**	**-34.03**
Net Emissions	**101.25**	**152.08**	**124.22**	**120.66**	**116.06**	**109.55**	**104.25**	**107.35**
Percent Reduction in Net Emissions from 2005					**24%**		**31%**	

Note: Totals may not equal exact sum of subtotals shown in this table due to independent rounding.
[a] Includes estimates of emissions from Imported Electricity that are generated outside North Carolina.
[b] Represents emissions associated with on-site fuel combustion activities in the Residential, Commercial, and Industrial sectors.
[c] Land Use, Land Use Changes and Forestry.

[15] 2015 is the last year of historic GHG emissions data. 2017 is a short-term projection of GHG emissions and is treated as historical data for this analysis.
[16] Cover Note INDC and Accompanying Information, UNFCCC http://www4.unfccc.int/submissions/INDC/

Listed below are key findings from both the GHG emissions inventory and from the analysis of the data used to develop the emissions for each source sector. Additional detail is provided in Section 2.0 Trends in Greenhouse Gas Emissions. Emissions reductions are generally expressed as the percent change in gross GHG emissions, unless otherwise stated, from the baseline year of 2005 to 2017.

- **North Carolina's Gross and Net Emissions**
  - North Carolina reduced gross GHG emissions by 19% and net GHG emissions by 24% since 2005.
  - During this same time period, North Carolina's population and real Gross State Product (GSP) grew by 18%.
  - By 2025, net GHG emissions are projected to decrease by 31% from the 2005 baseline, indicating North Carolina is forecast to achieve the U.S 2025 reduction target of 26% to 28%.
- **GHG Compounds**
  - Carbon dioxide emissions currently account for approximately 82% of total GHG emissions.
  - The primary source of CO_2 emissions is fossil fuel combustion.
  - GHG emissions from fossil fuel combustion have decreased by 26% since 2005. This is due to both a shift in fuel use, from coal to natural gas, and increased energy efficiency.
  - Methane (CH_4) emissions currently account for approximately 11% of total GHG emissions
  - The primary sources of CH_4 are Waste Management and Agriculture.
  - Emissions from Waste Management and Agriculture have not changed significantly since 2005, even with a growing population and economy.
- **Electricity Sector**
  - Electricity Generation is the largest emissions sector and represents 35% of all GHG emissions.
  - GHG emissions from Electricity Generation have decreased by 34% since 2005.
  - North Carolina's Electricity Generation sector has undergone a transformation since 2009 including;
    1) retirement of over 3,000 megawatts (MW) of coal fired power plants, which is 25% of the NC coal fleet.
    2) increased use of efficient natural gas combined cycle plants
    3) North Carolina legislation to promote renewable energy
  - Solar, hydroelectric and wind power now represent 9% of North Carolina's Electricity Generation.
  - Avoided GHG emissions due to renewable energy power are estimated at 4 MMT CO_2e for 2017.
- **Transportation**
  - Transportation is the second largest emissions sector and represents about 32% of all GHG emissions.
  - Emissions from the Transportation sector have decreased by 12% from 2005 to 2017.
  - Gasoline represents 72% of the energy input into Transportation while diesel represents 21%.
  - Projections for gas and diesel vehicle emissions under the current CAFE and GHG standards suggest a substantial decrease in GHG emissions. However, EPA has proposed to relax the last phase of these standards, suggesting projected emission reductions may be lower than forecast here.
- **Residential Commercial and Industrial**
  - Residential, Commercial and Industrial emissions represent 19% of all GHG emissions.

- Residential sector emissions from total energy use have decreased by 22% since 2005, while North Carolina's population grew by 18% over that time.
- GHG emissions from fuel combustion in the Commercial sector have increased by 13% due to shifts in the economy. This is offset by a 29% decrease in emissions from electricity used by this sector.
- Industrial fuel combustion emissions have decreased by 30% since 2005.
- GHG emissions from Industrial Processes have doubled since 2005.

➢ **Land use, Land Use Changes and Forestry**

- Forests, natural lands, and agricultural lands sequestered an estimated 34 MMT of CO_2 or 25% of gross GHG emissions estimated in 2017.
- These carbon sinks are primarily due to increases in forest stocks and storage of carbon in wood products, reflecting North Carolina's increasing sustainable management of its forests and their economic uses.

➢ **Landfills**

- Many large landfills in North Carolina are now collecting CH_4 and using the captured biogas as energy, resulting in 561,000 MWh of Electricity Generation and an additional 149,000 million British thermal units (MMBtu) of heat input in 2017.
- There has been a reduction in GHG emissions from this sector since 2005, despite a large growth in population. This is primarily due to the energy recovery from landfill gas.

1.6 Structure of the Report

The remainder of this report is divided into two sections. The first section is an analysis of the key economic sectors and a discussion of the trends in North Carolina's GHG sources and sinks. The second section discusses the methodologies and data sets used to prepare the estimates, including key assumptions and limitations. Appendix A provides a tabulated summary of each year of GHG emissions from 1990 to 2030. Appendix B provides a brief overview of global warming potentials and Appendix C discusses the treatment of CO_2 emissions from biomass combustion. Appendix D summarizes comments received on the draft Inventory report during the public comment period, which was open between November 2nd and December 14th of 2018. This Appendix also provides responses to these comments and a description of the appropriate method used to modify the inventory.

2.0 Trends in Greenhouse Gas Emissions

This section of the report provides summary tables and figures, trend analysis, and detailed information on key source sectors impacting North Carolina's GHG emissions and carbon sinks from 1990 through 2017. This analysis uses 2005 as the baseline year of the inventory to evaluate emissions reductions because it is the most common baseline reporting year currently used. For completeness, long-term trend analysis references back to 1990. The last year of comprehensive historic GHG emissions data in the SIT is 2015. Year 2016 and 2017 represent short-term projections using a mix of historical data and projections (e.g., transportation emissions reflect data availability up through 2016). Projections of GHG emissions from 2016 to 2030 are discussed in Section 2.10.

2.1 North Carolina GHG Trends from 1990 to 2017

Figure 2-1 presents North Carolina's gross GHG emissions from 1990 through 2017 for all source sectors. Emissions of GHGs peaked in 2007 and began to decline rapidly after 2010, primarily due to: (1) shifts in the types of fuel used and (2) decreases in the amount of fuel burned by the Electricity Generation and Use and Transportation sectors. Since the 2005 baseline year, gross GHG emissions have dropped by 19% - from a total of 185 MMT CO_2e in 2005 to 150 MMT CO_2e in 2017.

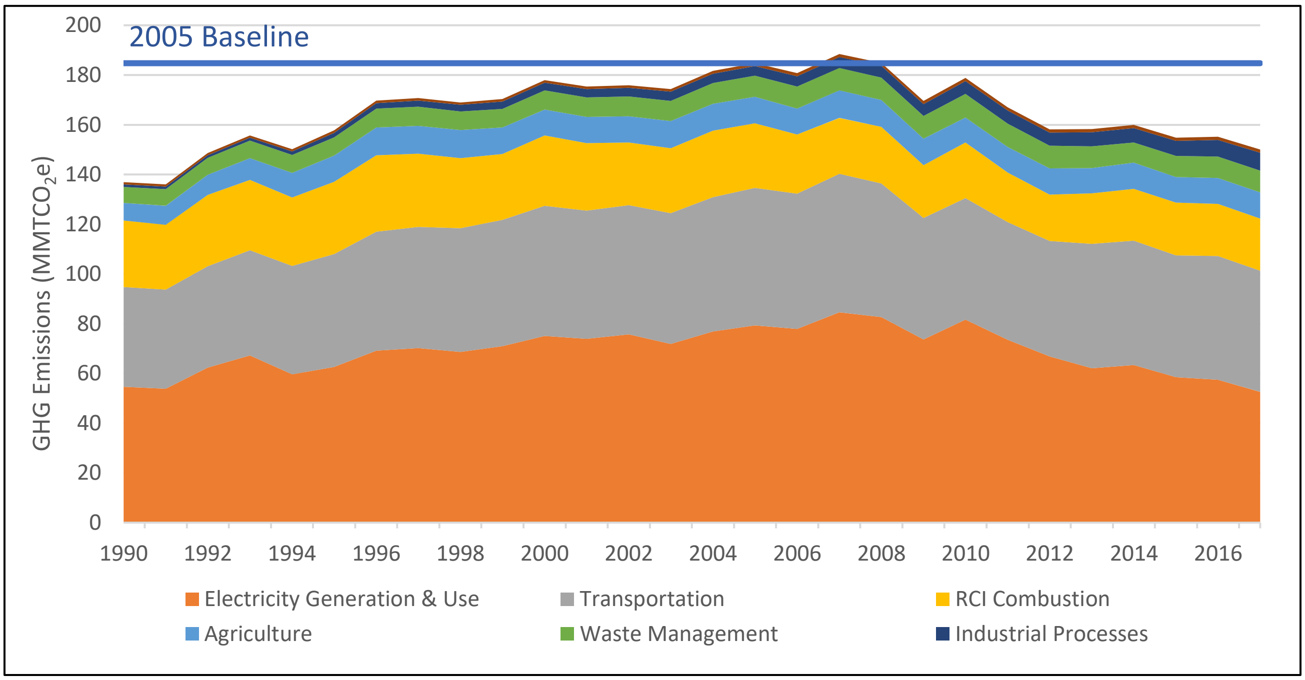

Figure 2-1: North Carolina Gross GHG Emissions Trends, 1990–2017

2.2 Gross GHG Emissions by Source Sector

Figure 2-2 shows the gross GHG emissions contributed by each source sector in 2017. Electricity Generation and Use is the largest source sector at 35% followed by Transportation at 32%, and Residential, Commercial, and Industrial (RCI) Combustion at 14%. Together, combustion activities contribute to over 80% of the total statewide gross emissions.

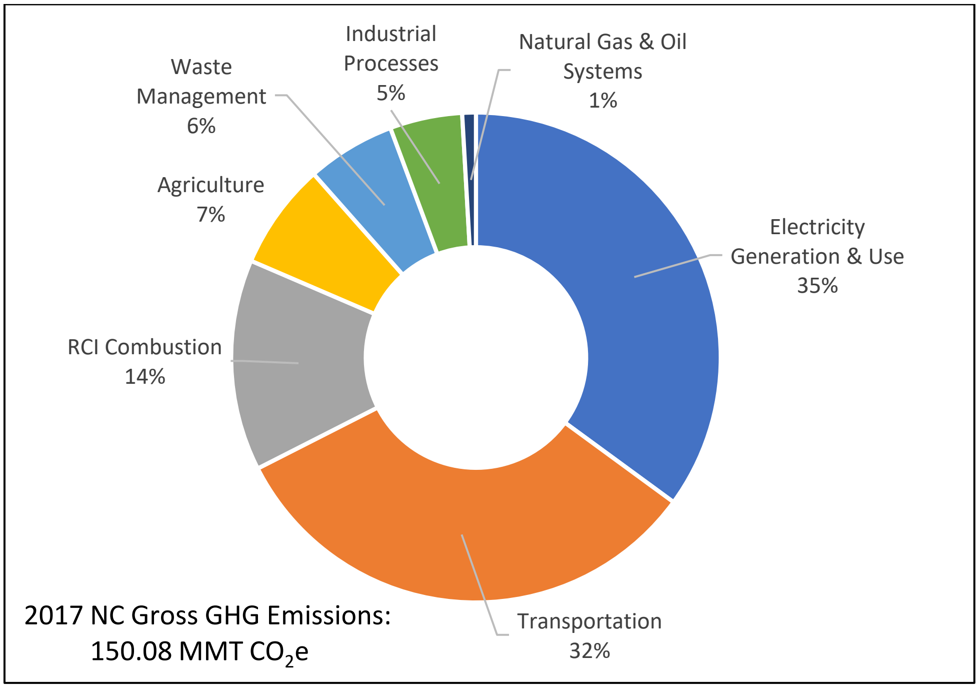

Figure 2-2: Percentage of North Carolina 2017 GHG Emissions by Source Sector

While these three sectors are the largest emitters, they also represent the sectors with the largest reductions in gross GHG emissions achieved between 2005 and 2017, as shown in Table 2-1.

Table 2-1: Change in North Carolina GHG Emissions by Source Sector, 2005-2017

Source Sector	2005 GHG Emissions (MMT CO_2e)	2017 GHG Emissions (MMT CO_2e)	Change in GHG Emissions
Electricity Generation & Use	79.37	52.60	-34%
RCI Combustion	26.02	20.92	-20%
Transportation	55.19	48.72	-12%
Agriculture	10.65	10.53	-1%
Waste Management	8.52	8.77	3%
Industrial Processes	3.83	7.18	88%
Natural Gas Systems	1.17	1.35	16%
Gross Emissions	**184.74**	**150.08**	**-19%**

Note: Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

The emissions reductions achieved in the Electricity Generation and Use and RCI Combustion sectors are primarily the result of switching from coal to natural gas combustion units. The decrease in emissions from the Transportation sector is due to several factors, including federal standards for fuel economy and CO_2 emissions from cars and trucks (see Section 2.8).[17] Emissions from Waste Management, Industrial Processes, and Natural Gas Systems sectors increased from the 2005 baseline. These increases are due to additional natural gas pipelines coming online in North Carolina, increases in population, and an increase in the use of non-ozone depleting substances (ODS) used for refrigeration and cooling.[18]

Figure 2-3 presents the long-term GHG emissions trends separately for each sector from 1990 to 2017. The figure illustrates an increase in emissions from 1990 to 2007 for all sectors except RCI combustion, which shows a steady decline starting in the mid-1990's through roughly 2011. After 2007, there is a large drop in emissions from the Electricity Generation sector that was described above as well as an overall 13% drop in emissions from the Transportation sector. (See Sections 2.6 through 2.8 for a more detailed discussion of these three sectors). The other sectors show upwards trends with slight decreases in recent years except for Agriculture, which stays relatively constant.

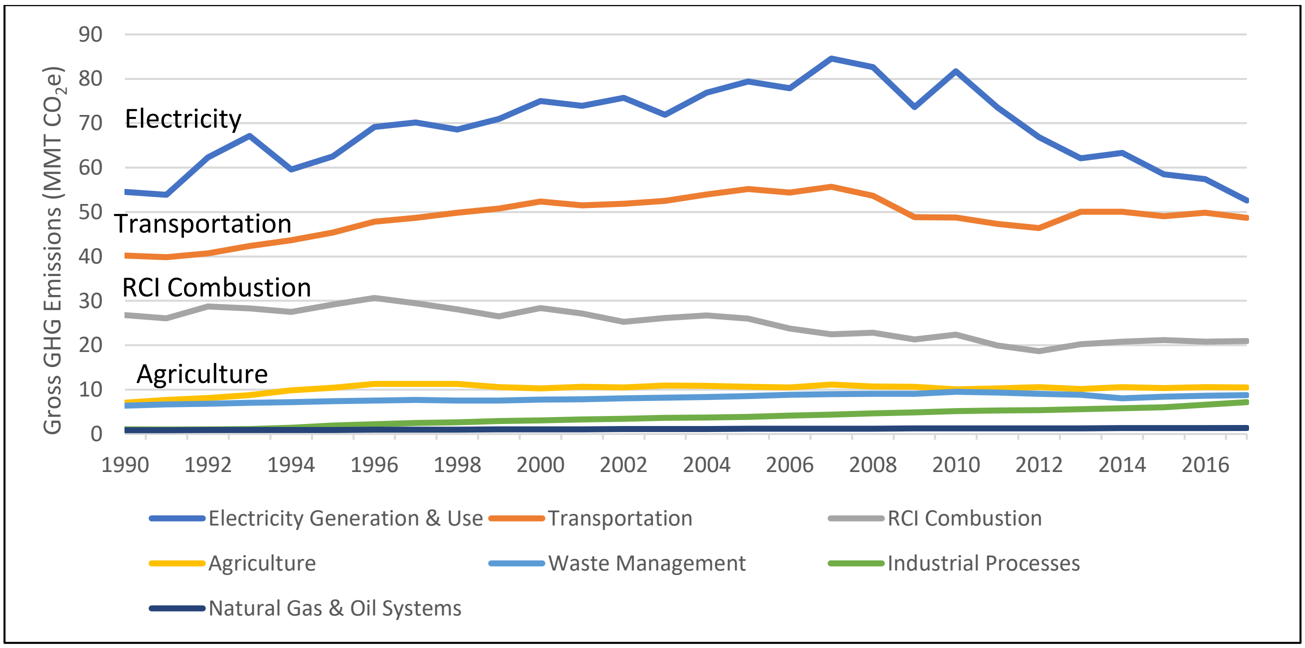

Figure 2-3: North Carolina GHG Emissions Trends by Source Sector, 1990-2017

2.3 Gross GHG Emissions by Gas Type and Fuel Type

The contribution of each gas relative to North Carolina's total GHG emissions in 2017 is presented in Figure 2-4. Carbon dioxide is emitted in much larger amounts than the other GHGs combined.

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[17] https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-greenhouse-gas-ghg-emissions.

[18] HFCs and PFCs are synthetic chemicals produced as alternatives for the ozone-depleting chlorofluorocarbons (CFCs) in response to the phase out of CFCs under the Montreal protocol of 1987. (See https://www.epa.gov/ozone-layer-protection/addressing-ozone-layer-depletion for more information.)

However, the global warming potential for the other GHGs, which incorporates both atmospheric lifetime and ability to trap heat, makes them significant contributors as well. See Appendix B for more information on Global Warming Potentials.

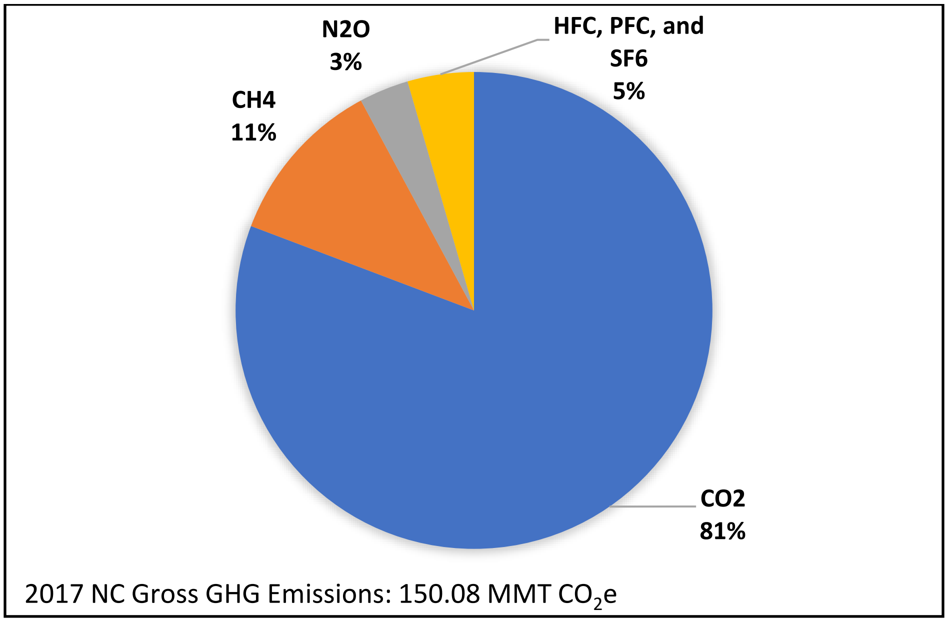

Figure 2-4: Percentage of North Carolina 2017 GHG Emissions by Gas Type

The primary source of CO_2 emissions in North Carolina is the combustion of fossil fuel. This includes fossil fuel combustion in the Electricity Generation, RCI Combustion, and Transportation sectors. Figure 2-5 presents North Carolina's CO_2 emissions from fossil fuel combustion for each fuel type. The figure indicates significant changes in fuel use over time. These changes resulted in a 26% reduction in CO_2 emissions from combustion of all fossil fuels between 2005 and 2017.

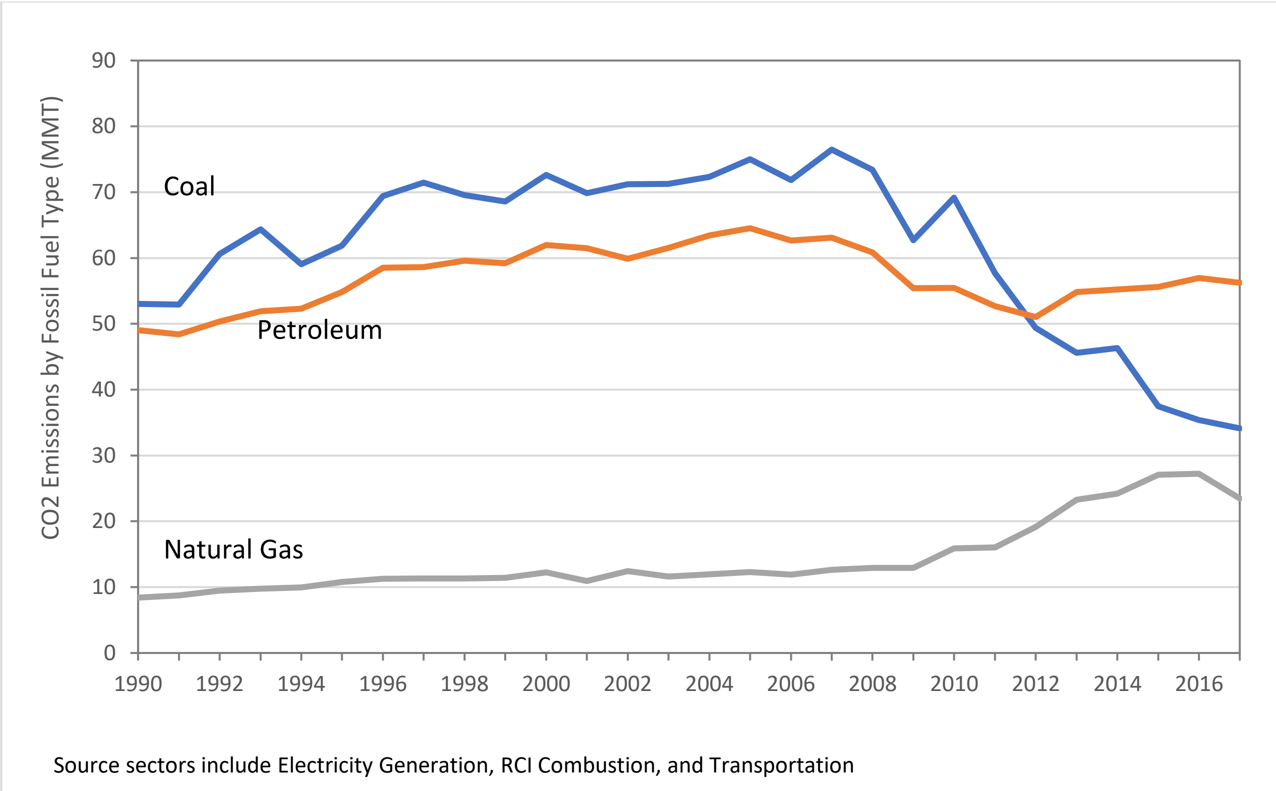

Figure 2-5: North Carolina CO_2 Emissions Trends in Fossil Fuel Combustion, 1990-2017

North Carolina's electricity generators and industries have significantly reduced their use of coal in favor of less expensive natural gas combustion units. Figure 2-5 illustrates this transition from coal to natural gas between 1990 and 2017. Since 2005, emissions from coal combustion have dropped by 55% while emissions from natural gas have almost doubled during this same period. Emissions from petroleum combustion decreased from 2005 to a low in 2012 (21% reduction). Emissions from petroleum combustion have increased in recent years with an overall reduction of 13% between 2005 and 2017.

2.4 Gross GHG Emissions by Population and Gross State Product

It is important to understand the impact of North Carolina's growing population and thriving economy has on GHG emissions over time. From 2005 to 2017, North Carolina's real Gross State Product (GSP) and population both increased by 18%.[19,20] Figure 2-6 compares the 2005-2017 trends in: (1) population and real GSP and (2) gross GHG emissions per capita and per dollar of real GSP.

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[19] North Carolina's Gross State Product (GSP) in 2009 dollars obtained from the North Carolina Office of State Budget and Management.

[20] North Carolina census data provided by North Carolina Office of State Budget and Management in January 2018.

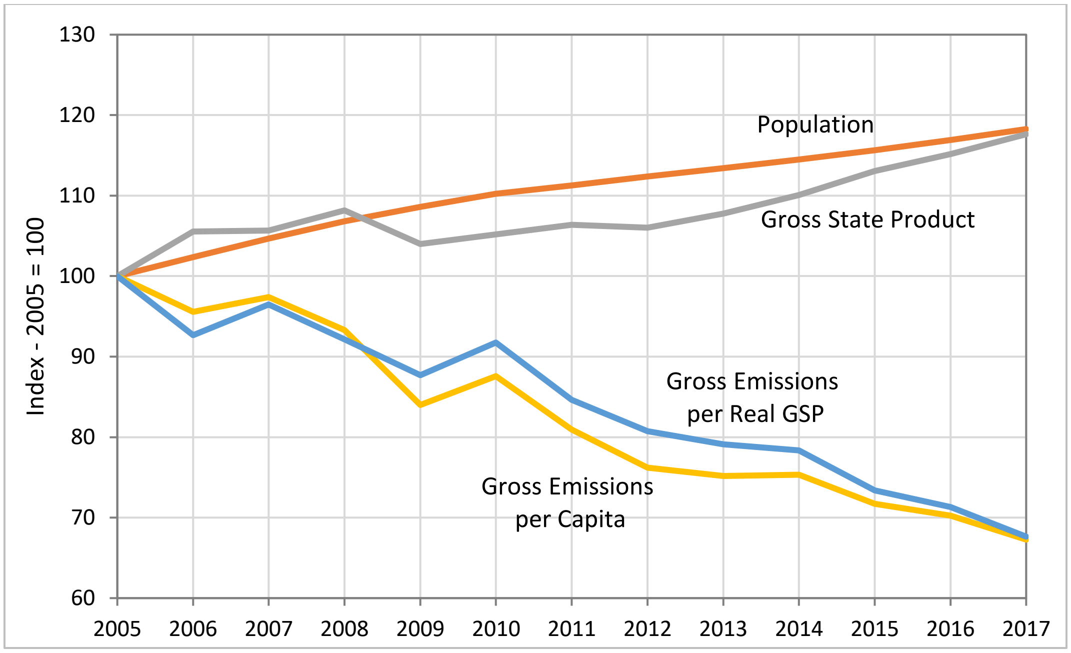

Figure 2-6: North Carolina GHG Emissions Relative to Population and GSP, 2005-2017

As shown in the figure, population increased steadily during this period. GSP increased from 2005 up to 2008, then declined during 2008 and 2009 due to the Great Recession. GSP remains relatively flat until 2012 then climbs again through 2017. Emissions on both a per capita basis and a per real dollar GSP basis decline fairly steadily during this time period, with a brief dip during 2009 due to the economic recession. There is an overall decrease of 32% in both emissions on a per capita basis and a per real dollar GSP relative to 2005 levels, while experiencing an 18 percent increase in both population and GSP. This analysis demonstrates that State policies [e.g. Clean Smokestacks Act (CSA), Renewable Energy and Energy Efficiency Portfolio Standard (REPS)], federal regulations [CAFE and GHG standards, Electricity Generating Unit Mercury and Air Toxics Standards (MATS)] and market forces (e.g., low natural gas and declining solar technology prices) have resulted in a lower-carbon economy in North Carolina.[21,22,23,24]

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[21] Session Law 2002-4, "An Act to Improve Air Quality in the State by Imposing Limits on the Emission of Certain Pollutants from Certain Facilities that Burn Coal to Generate Electricity and to Provide For Recovery by Electric Utilities of the Costs of Achieving Compliance with those Limits", June 20, 2002, https://www.ncleg.net/Sessions/2001/Bills/Senate/PDF/S1078v5.pdf.

[22] Session Law 2007-397, "North Carolina's Renewable Energy and Energy Efficiency Portfolio Standard (REPS), August20, 2007, http://www.ncuc.commerce.state.nc.us/reps/reps.htm.

[23] Corporate Average Fuel Economy, National Highway Traffic Safety Administration, https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.

[24] Mercury and Air Toxics Standards (MATS), U.S. Environmental Protection Agency, https://www.epa.gov/mats/regulatory-actions-final-mercury-and-air-toxics-standards-mats-power-plants.

2.5 Comparison Between North Carolina and National Gross GHG Emissions

This section compares North Carolina's GHG emissions trends to national emissions trends. Note that the national GHG inventory includes source sectors that do not operate in North Carolina. Some of these source sectors are large, such as coal mining, cement production, and iron, steel and coke production. The U.S. data are taken from the Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016.[25]

North Carolina emits approximately 2.3% of the total U.S. gross GHG emissions, based on 2016 emissions data, as shown in Table 2-2. This table also indicates that North Carolina is achieving larger reductions in gross GHG emissions than the country as a whole.

Table 2-2: Comparison of Gross GHG Emssions for North Carolina and U.S., 2005-2016

Region	2005 GHG Emissions (MMT CO_2e)	2016 GHG Emissions (MMT CO_2e)	Percent Reduction 2005 to 2016	North Carolina Percentage of U.S. GHG Emissions in 2016
North Carolina	185	153	17%	2.3%
U.S.	7,320	6,511	11%	

This trend is further illustrated by Figure 2-7, which shows the percent reduction in gross GHGs relative to the 2005 baseline year for both North Carolina and the U.S for each year through 2016. As of 2016, North Carolina had reduced gross GHG emissions by 17% from the baseline year, while the U.S. achieved an 11% reduction from the baseline.

[25] Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016, EPA 430-P-18-001, U.S. Environmental Protection Agency, Washington, D.C., February 6, 2018.

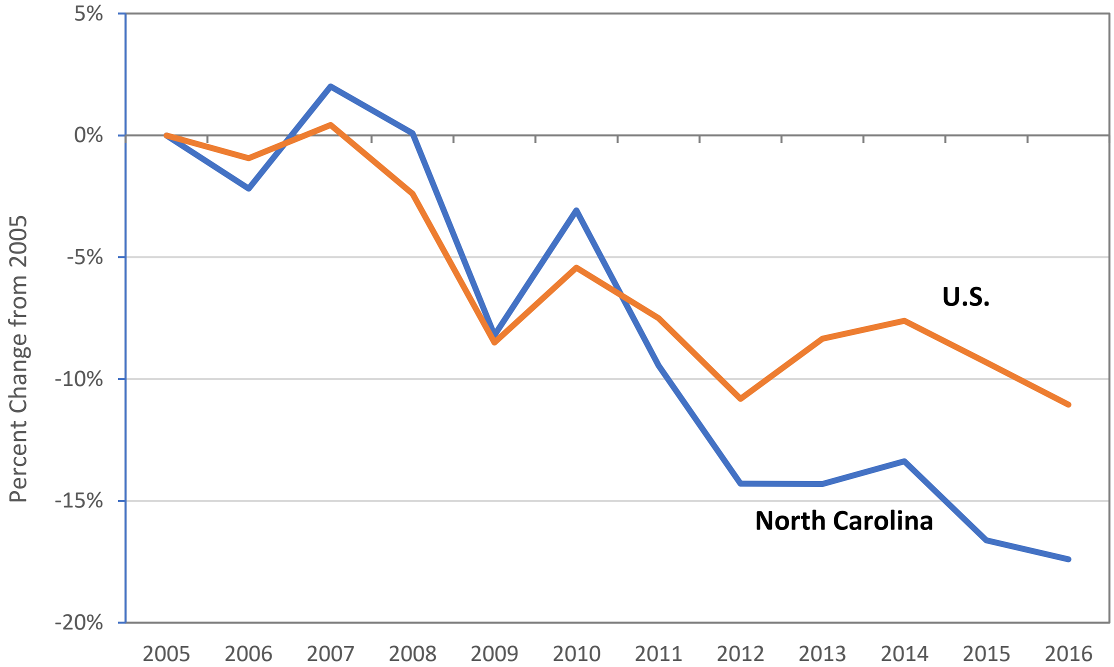

Figure 2-7: Percent Change in Gross GHG Emissions for North Carolina and U.S., 2005-2016

Table 2-3 compares changes in CO_2 emissions due to shifts in fossil fuel combustion for North Carolina and the U.S. Emissions from coal and petroleum combustion in the U.S. have dropped by 38% and 12% between 2005 and 2016, respectively. U.S. emissions from natural gas combustion have increased by 26% during this same period of time. North Carolina has also changed its fossil fuel mix as discussed previously. North Carolina's 2005-2016 CO_2 emissions from coal combustion have dropped by 53%, significantly lower than the U.S. reduction, while emissions from natural gas have more than doubled. The overall changes in fossil fuel combustion result in a 14% reduction in CO_2 emissions for the U.S. and a 21% reduction in emissions for North Carolina.

Table 2-3: CO_2 Emissions by Fossil Fuel Type for North Carolina and U.S., 2005-2016

	North Carolina CO_2 Emissions (MMT)			United States CO_2 Emissions (MMT)		
Fuel Type	**2005**	**2016**	**Percent Change**	**2005**	**2016**	**Percent Change**
Coal	75.0	35.4	-53%	2,112	1,306	-38%
Petroleum	64.5	57.0	-12%	2,468	2,183	-12%
Natural Gas	12.3	27.2	122%	1,167	1,476	26%
Total	151.8	119.6	-21%	5,747	4,966	-14%

The U.S. Energy Information Administration (EIA) estimates energy-related CO_2 emissions for each state.[26] Based on EIA estimates for 2015, North Carolina ranks 14th in the nation for CO_2 emissions as shown in Table 2-4. North Carolina's rankings for CO_2 emissions from each source sector are also shown.

Table 2-4: North Carolina's 2015 State Ranking for Energy-Related Metrics

Metric	Units	Value	Ranking Compared to Other States*
Total Energy Related CO_2 Emissions	MMT CO_2	120.44	14
Electric Power	MMT CO_2	*51.70*	*13*
Industrial	MMT CO_2	*10.15*	*27*
Commercial	MMT CO_2	*5.80*	*14*
Residential	MMT CO_2	*5.29*	*19*
Transportation	MMT CO_2	*47.50*	*12*
Total Energy Consumed per Capita	MMBtu per capita	251	38
Total Energy Expenditures per Capita	$ per capita	3,073	45
Net Electricity Generation	million MWh	128,944	8
Average Residential Retail Price of Electricity	cents/kWh	11	31

*Rank of 1 = highest in U.S.

While North Carolina ranks 14th in the nation for energy-related CO_2 emissions, it ranks 9th for population in 2015.[27] This high population makes North Carolina's energy use per person, 251 MMBtu per capita, lower than the national average of 307 MMBtu per capita.[28] North Carolina is ranked 8th in the nation for generating its own electricity while the CO_2 emissions from this sector are only ranked 13th in the nation. This indicates North Carolina's fossil fuel power plant fleet emits less CO_2 per MWh compared to other high electricity generation states. North Carolina's costs for energy and electricity are also below the national average as shown in Table 2-4 by the rankings for total energy expenditures per capita of 38th and average residential retail price of electricity of 31st in the nation.

2.6 Electricity Generation

Electricity Generation represents the primary GHG emissions sector in North Carolina as shown earlier in Figure 2-2. North Carolina imports an additional 12% of the electricity it consumes from power plants located outside the State.[29] This analysis assumes that all power generated in North

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[26] Energy-related CO_2 emissions refers to emissions released at the location where fossil fuels are combusted.

[27] "North Carolina Becomes Ninth State With 10 Million or More People", Census Bureau Reports, U.S. Census Bureau, https://www.census.gov/newsroom/press-releases/2015/cb15-215.html.

[28] EIA State Rankings: Total Energy Consumed per Capita, 2015 (MMBtu), https://www.eia.gov/state/data.php?sid=NC#EnergyIndicators.

[29] EIA State Energy Data System (SEDS): 1960-2015, https://www.eia.gov/state/seds/seds-data-complete.php?sid=NC#Consumption. The carbon intensity of Imported Electricity is calculated using EPA's estimate of the average carbon intensity of generation in the SRVC region. See Section 3.1.5.

Carolina is used in North Carolina, and the remaining electricity demand is met by imported power. It also accounts for line losses due to transmission and distribution.

2.6.1 Trends in North Carolina's Fossil Fuel Electricity Generation from 2005 to 2017

North Carolina's Electricity Generation sector has undergone drastic changes since 2005. Over 3,000 MW of coal-fired power plants were retired and were replaced with 2,760 MW of natural gas combined cycle (NGCC) power plants between 2010 and 2014. This is primarily due to (1) increased supply of natural gas from shale formations, (2) lower natural gas fuel prices, and (3) increased environmental regulations on coal power plants.[30] Figures 2-8 and 2-9 illustrate the shift from coal to natural gas for Electricity Generation.[31]

Natural gas combustion emitted approximately 40% less CO_2 than coal combustion between 2005 and 2017.[32] In addition, NGCC plants are roughly 20% more efficient at generating electricity than traditional coal plants.[33] Therefore, NGCC power plants emit substantially less CO_2 than coal power plants for the same amount of electricity generation.[34]

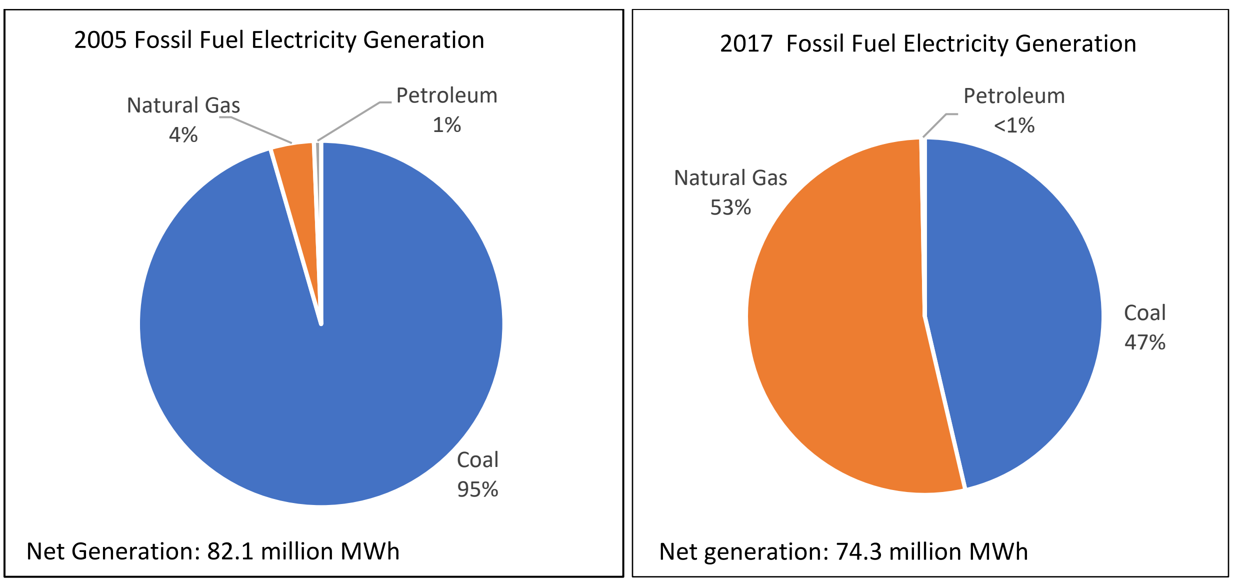

Figure 2-8: Changes in North Carolina Fossil Fuel Electricity Generation, 2005-2017

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[30] Today in Energy, EIA, March 2016, https://www.eia.gov/todayinenergy/detail.php?id=25272.

[31] EIA Form 923 Detailed Data, https://www.eia.gov/electricity/data/eia923/.

[32] On a heat content basis, natural gas combustion emits 40 percent less CO_2 than coal combustion.

[33] Refers to the efficiency of the thermodynamic cycle.

[34] This evaluation does not account for fugitive methane emissions from natural gas piping at natural gas power plants. Emissions from transmission of natural gas to the plant are estimated under the sector Natural Gas and Oil Systems.

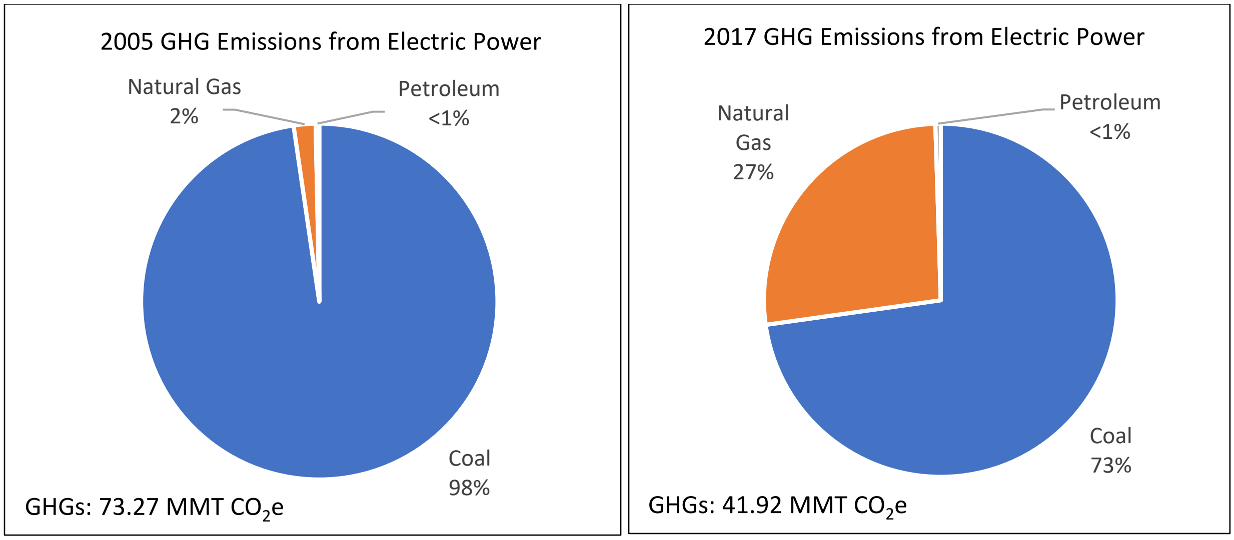

Figure 2-9: Changes in North Carolina GHG Emissions by Fossil Fuel Type, 2005-2017

Figures 2-8 and 2-9 indicate that the 2005 Electricity Generation by each fuel type is proportional to the GHGs emitted by each fuel type. This relationship changes by 2017. Figure 2-8 indicates that coal represented 47% of the fossil fuel used to generate electricity in 2017 while Figure 2-9 indicates it represented 73% of the GHGs emitted. In the same year, large NGCC plants generated 53% of the electricity while these plants emitted only 27% of the total GHG emissions.

Switching to NGCC power plants, which are both more efficient and lower emitting, resulted in an overall 38% reduction of CO_2 emissions from fossil fuel power plants between 2005 and 2017. During this same time period, fossil fuel Electricity Generation in North Carolina decreased by only 9%.

2.6.2 Trends in North Carolina's Renewable Energy Generation

The shift in North Carolina's sources of electric power between 2005 and 2017 are shown in Figure 2-10, using MWhs of electricity generation as a metric. Fossil fuel Electricity Generation has decreased by 9% and nuclear has essentially remained the same. A substantial amount of renewable energy (RE) has come online since 2005: 3,221 MW of solar and 208 MW of wind. This new RE capacity results in an increase in RE Electricity Generation from 4% by hydroelectric in 2005 to 8% by hydroelectric, solar, and wind combined in 2017.

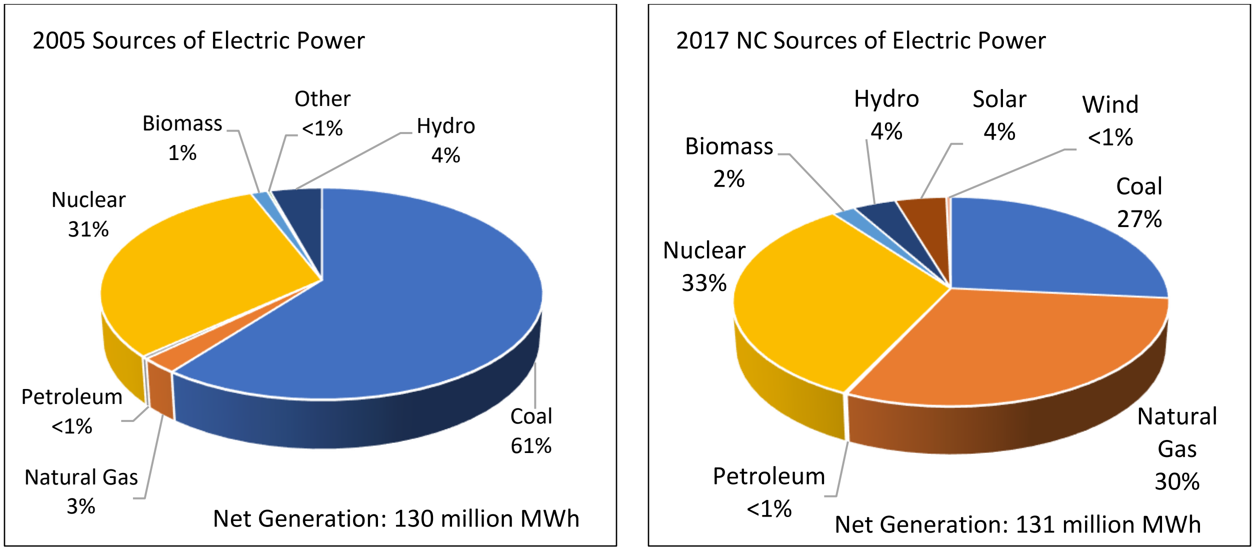

Figure 2-10: Changes in North Carolina Sources of Electricity Generation, 2005-2017

One driver of the increase in RE Electricity Generation is North Carolina's REPS, which became effective in 2007.[35] This law requires North Carolina's investor-owned utilities to obtain 12.5% of electricity demand from a mix of RE, biomass, and energy efficiency by 2021.

In order to quantify the impact of new RE generation on the GHG emissions inventory for the Electricity Generation sector, the GHGs that are not emitted as a result of using RE are calculated. These emissions are referred to as "avoided emissions." As shown in Table 2-5, avoided GHG emissions in North Carolina due to RE electric power is estimated to be 4.03 MMT CO_2e in 2017.[36]

Table 2-5: Avoided GHG Emissions Due to Use of Renewable Generation

Parameter	2005	2009	2010	2011	2012	2013	2014	2015	2016	2017
RE Net Generation (thousand MWh)	5,554	5,230	4,828	4,061	3,886	7,283	5,578	6,788	7,890	10,970
Emission Factor (pound/MWh)	1,225.2	1,163.0	1,187.5	1,187.5	1,061.7	1,061.7	986.6	986.6	810.1	810.1
Avoided Emissions (MMT CO_2e) *	3.09	2.76	2.60	2.19	1.87	3.51	2.50	3.04	2.90	4.03

*Calculated using EPA eGRID GHG Emissions Factor for SRVC Subregion and EIA Form 923 Net Generation in MWh.[37]

[35] For more information on the NC REPS, see http://www.ncuc.commerce.state.nc.us/reps/reps.htm.
[36] For this calculation, RE does not include biomass since biomass is not a zero-emitting source (see Appendix C for further discussion).
[37] Emissions & Generation Resource Integrated Database 2014 v2 (eGRID2014), Clean Air Markets Division U.S. Environmental Protection Agency, February 2017, https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid.

2.6.3 Trends in U.S. Electricity Generation

The U.S. Electricity Generation sector has undergone changes similar to North Carolina in both the use of fossil fuels and the increased use of renewable energy. These shifts in generation type vary regionally. For example, the majority of wind power generated in the U.S. is located in the Midwestern States.

The shift in the sources of national electricity generation between 2005 and 2017 are shown in Figure 2-11. Nationally, coal use has decreased from 50% to 30% while natural gas use has increased from 19% to 32%. Petroleum use has decreased to less than 1%. Solar, wind and geothermal energy combined have increased from 1% of total generation in 2005 to 8% of total generation in 2017. Nuclear and hydroelectric generation have remained fairly constant. This shift in sources of electricity generation has resulted in an approximately 24% reduction in national GHG emissions.

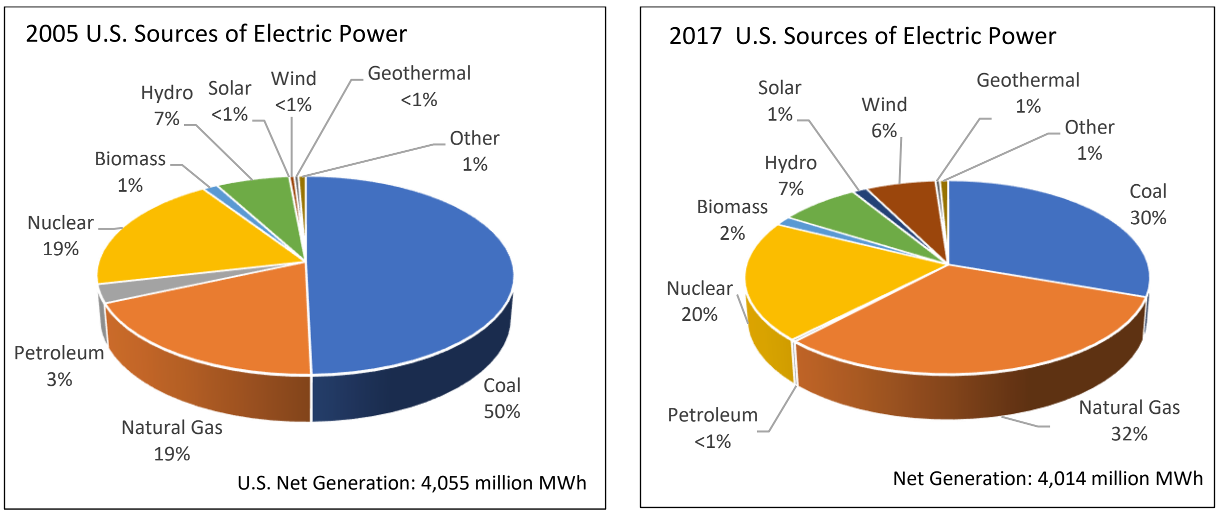

Figure 2-11: Changes in U.S. Sources of Electricity Generation, 2005-2017

2.7 Residential, Commercial and Industrial

Key economic sectors that emit GHGs include the RCI sectors. These sectors produce GHG emissions from (1) on-site fuel combustion and (2) the use of electricity to power homes, businesses, and manufacturing plants.[38] The sum of GHG emissions represents total energy used, and allows policy makers and energy analysts to best evaluate the impacts that these economic sectors have on GHG emissions.

GHG emissions for each RCI sector are presented in Table 2-6. GHG emissions from electricity use contribute significantly to the total GHG emissions for these sectors, especially for the Residential and Commercial sectors.

[38] Note that emissions for Electricity Consumption do not occur at the businesses or homes but occur at power plants supporting the regional electricity grid and are referred to as “indirect emissions”.

Table 2-6: GHG Emissions from Total Energy Use by the RCI Sector (MMT CO_2e)

	1990	2005	2012	2015	2017	Changes from 2005-2017
Industrial Total Energy Use	**36.56**	**36.34**	**26.93**	**24.26**	**20.14**	**-45%**
Fuel Combustion	*17.59*	*17.72*	*12.89*	*12.15*	*9.93*	*-44%*
Electricity Use	*18.97*	*18.62*	*14.04*	*12.10*	*10.21*	*-45%*
Commercial Total Energy Use	**19.27**	**32.37**	**28.45**	**26.84**	**25.07**	**-23%**
Fuel Combustion	*3.79*	*5.06*	*4.17*	*5.76*	*5.72*	*13%*
Electricity Use	*15.48*	*27.31*	*24.28*	*21.07*	*19.36*	*-29%*
Residential Total Energy Use	**25.50**	**40.19**	**33.02**	**30.73**	**28.31**	**-30%**
Fuel Combustion	*5.39*	*6.75*	*4.48*	*5.43*	*5.28*	*-22%*
Electricity Use	*20.11*	*33.44*	*28.54*	*25.30*	*23.03*	*-31%*
Total RCI Fuel Combustion	*26.77*	*29.52*	*21.55*	*23.34*	*20.92*	*-29%*
Total RCI Electricity Use	*54.57*	*79.37*	*66.85*	*58.48*	*52.60*	*-34%*
Total Energy Use	**81.34**	**108.89**	**88.40**	**81.82**	**73.52**	**-32%**

Note: Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

Table 2-6 shows how these sectors' emissions profiles have changed over time. In 1990, Industrial was the largest energy consuming sector and had the highest total energy use GHG emissions. By 2005, the Residential sector became the largest total energy consumer and GHG emitter in North Carolina. It now represents 39% of the emissions from total energy use in these three sectors.

Table 2-6 also includes the percent change in GHG emissions for each sector between 2005 and 2017. GHG emissions from total energy use decreased by 32% for all three sectors combined. This is primarily due to a 45% reduction in emissions from the Industrial sector. This decline in emissions is due to the decrease in North Carolina's manufacturing economy as well as federal clean air act regulations. The table indicates that fuel combustion emissions from the Commercial sector grew by 13% since 2005, while emissions from electricity use in the Commercial sector have decreased by 29%. Residential sector emissions from total energy use have decreased by 30% since 2005, while North Carolina's population grew by 18% over that time.[39] This decline in emissions is the result of the introduction of more energy efficient appliances, lighting, and building codes.[40]

[39] North Carolina census data provided by North Carolina Office of State Budget and Management in January 2018.
[40] North Carolina Energy Conservation Code, North Carolina Department of Insurance, January, 2012, http://www.ncdoi.com/OSFM/Engineering_and_Codes/Default.aspx?field1=State_Building_Codes_USER&user=State_Building_Codes.

2.8 Transportation

Transportation is the second largest GHG-emitting sector in North Carolina, representing approximately 32% of gross GHG emissions as shown in Figure 2-2. Therefore, understanding the factors that drive emissions from this sector is critical for GHG mitigation planning in North Carolina.

Emissions estimated for this sector include both "highway mobile" and "non-highway mobile" sources. Highway mobile sources are transportation vehicles that operate on public roadways, while non-highway mobile sources are vehicles and equipment that perform transportation and other functions in off-road settings. Alternative fuel vehicles are defined separately from other highway mobile sources to identify specific trends in use of non-conventional fuels. Table 2-7 displays some of the specific vehicle and equipment types included in each of these three major sub-sectors.

Table 2-7: Example Vehicle and Equipment Types included in Transportation Sector

Highway Mobile (~90% of sector emissions)	Non-Highway Mobile (~10% of sector emissions)		Alternative Fuel Vehicles (<1% of sector emissions)
Light Duty Vehicles: Passenger Cars Passenger Trucks Heavy Duty Vehicles: Buses Commercial Trucks	Off-road Transportation: Airplanes Trains Marine Vessels Recreational Vehicles	Off-road Equipment: Construction Agriculture Logging Recreation	Compressed Natural Gas Liquefied Petroleum Gas Liquefied Natural Gas Methanol Ethanol

Figure 2-12 presents 1990-2017 GHG emissions from the three Transportation sub-sectors. Emissions from gasoline and diesel-fueled highway vehicles represent approximately 90% of total Transportation sector GHG emissions, with non-highway sources accounting for nearly all the sector's remaining emissions.[41] It is important to note that North Carolina's post-2016 emissions are projected estimates, so the trends for these years should be viewed as preliminary. These projections are discussed in Section 2.10.2.

[41] Emissions of CO_2 from combustion of biomass fuels by alternative fuel vehicles are not included.

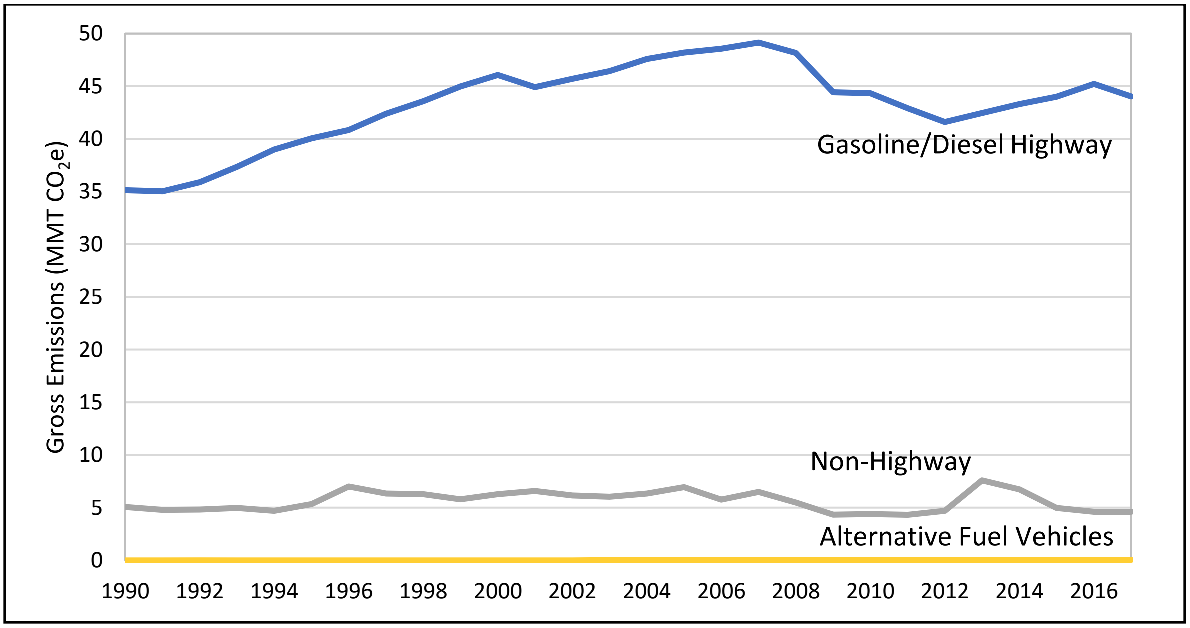

Figure 2-12: Transportation Sector GHG Trends in North Carolina, 1990-2017

Emissions from the Transportation sector are a function of several parameters. The key factors are: (1) population of each vehicle/engine type, (2) vehicle miles traveled/hours of operation, (3) fuel type and consumption, and (4) emissions standards for each fuel/vehicle/engine type. The population of each vehicle type is a function of the number of drivers as well as the type of vehicle/engine registered. Fuel consumption is primarily a function of fuel efficiency and vehicle/engine type. Fuel prices heavily influence the type of vehicle purchased, vehicle miles traveled, and fuel used in a given year. The inventory presented in this document is a "top-down" inventory; therefore, it is difficult to analyze the impact of any one factor on emissions from this sector. The sections below provide high-level conclusions about emissions from the Transportation sector.

As discussed above, Transportation GHG emissions are a function of the use of fuel. This inventory uses EIA state-level fuel use data for the Transportation sector to estimate historic emissions of CO_2.[42] This data set is based on fuel purchases and assumes that the fuel purchased in a state is also consumed in that state. The breakdown of fuels used by the Transportation sector is given in Figure 2-13 for 2016, the last year for which historical fuel consumption data are available. The predominant fuel is gasoline which represents 72% of the energy input into Transportation activity. This is followed by diesel, which represents 20% of the fuel mix. Ethanol now represents 5% of the fuel use in North Carolina; however, only CH_4 and N_2O emissions from ethanol are reflected in gross GHG emissions (discussion of CO_2 emissions from biofuel combustion can be found in Appendix C).

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[42] State Energy Data 2016 Consumption Estimates, Energy Information Administration, June 2018, http://www.eia.gov/state/seds/seds-data-complete.cfm?sid=US#CompleteDataFile.

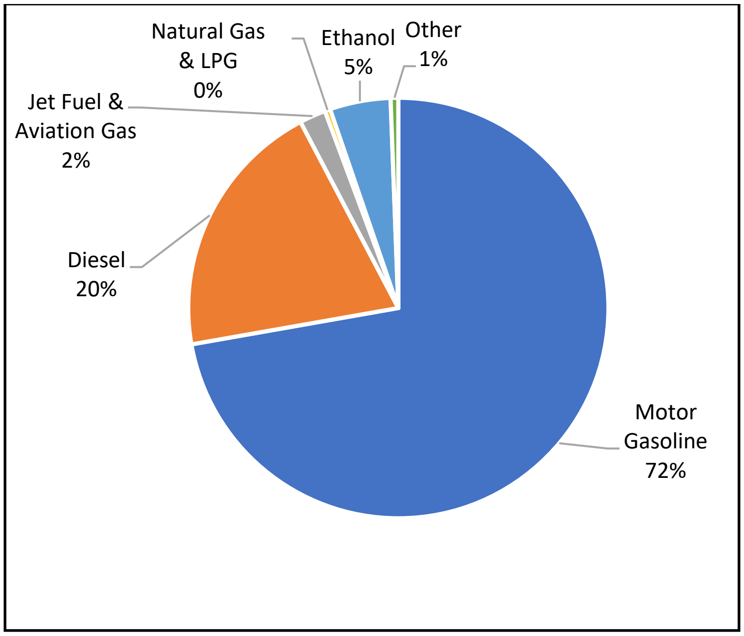

Figure 2-13: 2016 Fossil Fuel Use in the Transportation Sector

Table 2-8 presents the changes in fuel use over time for North Carolina's Transportation sector. It is presented as a function of the heat input rather than gallons to normalize the data on an energy basis. The largest reduction is in the use of jet fuel and aviation gas (a greater than 16,000 billion Btu decrease). The changes in the use of other fuels are due to a combination of factors including vehicle miles traveled, population, and fuel efficiency standards.

Table 2-8: Historic Fuel Use as a Function of Heat Input in Billion Btu

Fuel	1990	2005	2012	2016	Percent Change in Fuel Use 2005-2015
Gasoline	398,897	530,333	504,128	547,545	3%
Diesel	92,060	161,296	134,445	152,045	-6%
Jet Fuel & Aviation Gas*	31,891	42,413	22,936	15,374	-64%
Natural Gas & LPG	7,097	9,267	6,019	3,156	-66%
Ethanol**	0	2,074	32,733	35,439	1,609%
Residual Fuel	3,225	2,649	22	133	-95%
Grand Total	533,170	748,032	700,283	753,692	**1%**

*Jet fuel consists of kerosene and naphtha

**Biogenic CO_2 emissions from the combustion of ethanol are excluded from gross emissions; however, CH_4 and N_2O emissions are included. See Appendix C for more information.

Gasoline and diesel highway vehicle emissions generally increased in the State through 2007, reflecting vehicle miles traveled (VMT) growth stemming from increases in both the driving age population and VMT per driver. Although VMT remained steady between 2007 and 2011, there was some limited growth through 2013, and significant increases were experienced in 2014 and 2015 (shown in Figure 2-14). The combination of high fuel prices and the Great Recession contributed to slow the rate of VMT growth between 2007 and 2011; similarly, lower fuel prices and the economic recovery resulted in the observed VMT increases more recently. Non-highway emissions have remained stable over the time frame. On a percentage basis, emissions from alternative fuel vehicles increased the most over this period. In 1990, these vehicles accounted for only 0.008% of total Transportation emissions; by 2017 their contribution had climbed to 0.11%.

As shown in Figure 2-14, North Carolina's VMT trends are mirrored at the national level. This figure also shows significant decreases in North Carolina's highway vehicle emissions over the 2007-2012 period, followed by small increases since then. Even with these emissions increases, 2016 GHG levels are more than 10% below 2007 peak year values. The fact that Transportation GHG emissions decreased while VMT increased over the 2007-2016 period demonstrates the effect of vehicle fuel efficiency improvements. Figure 2-14 suggests that North Carolina incurred a larger increase in fuel efficiency than the national average. Additional information would need to be identified to determine the cause(s) for this greater increase in fuel efficiency.

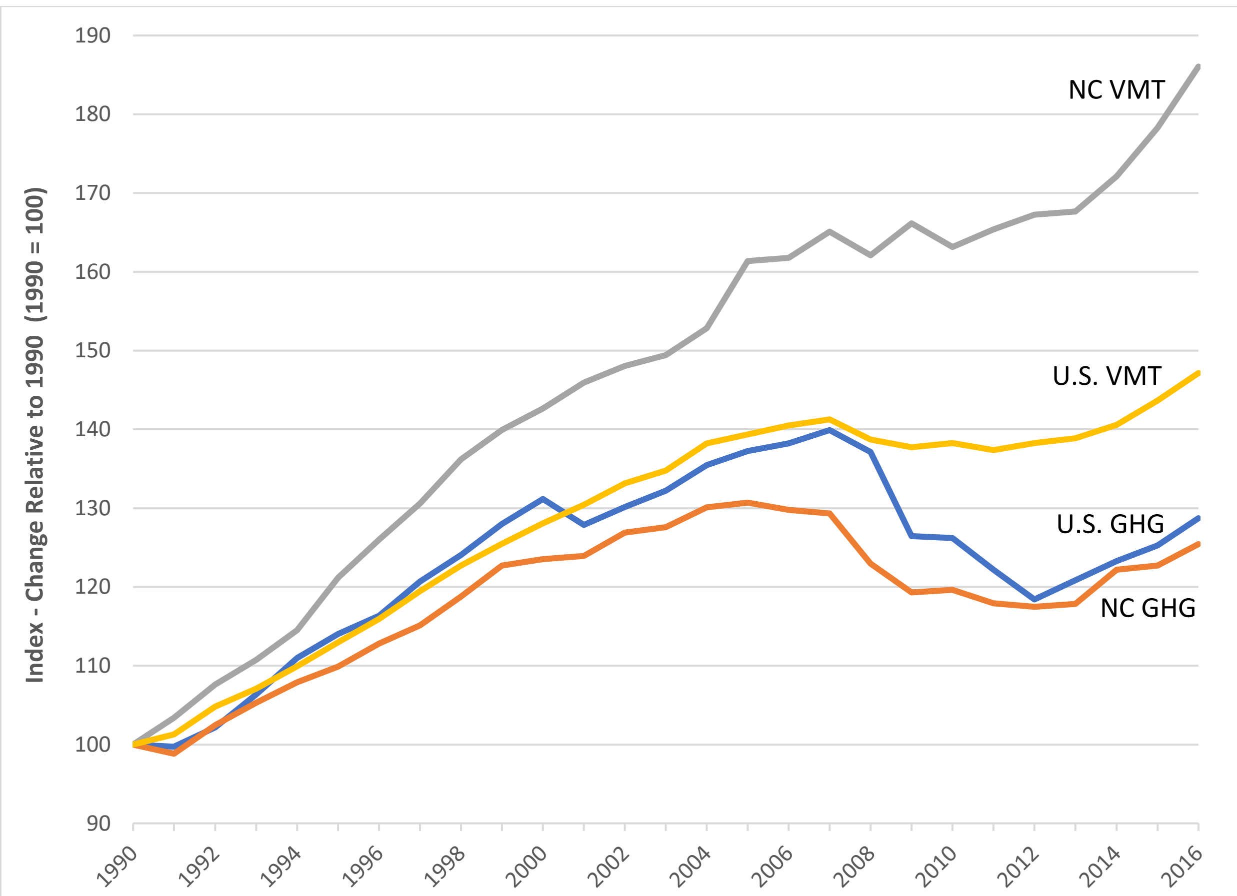

Figure 2-14: Gas/Diesel Vehicle GHG & VMT in U.S. and NC, 1990-2016

Figure 2-15 displays the U.S. and North Carolina gasoline/diesel vehicle emissions on both a per capita and per real GSP basis for 1990-2016. As presented in Figure 2-15, North Carolina's trends are similar to those observed at the national level. However, North Carolina's per capita emissions decrease is notably larger than the national decrease. Further analysis would be needed to explain this phenomenon. In any case, the general similarities between the State and national trends are expected given that fuel price trends are generally similar across the country, and because vehicle fuel efficiency policies are generally set at the national level.[43]

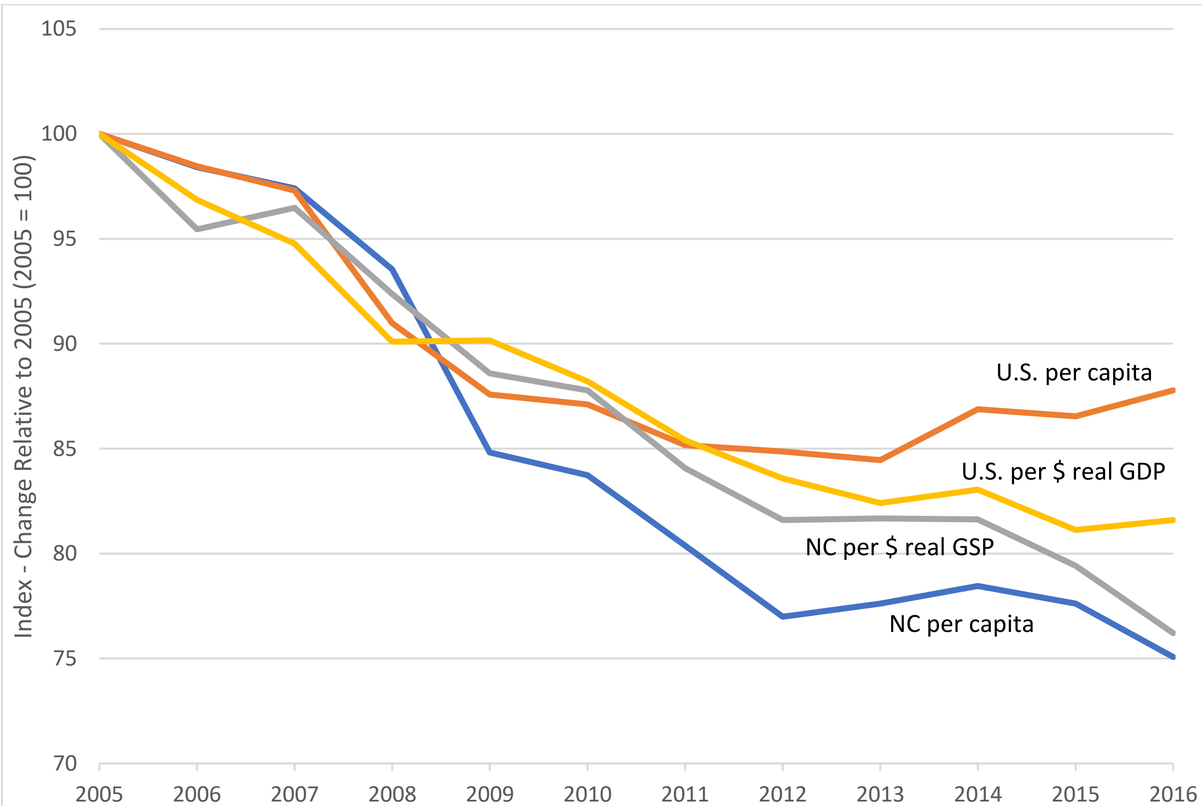

Figure 2-15: Per Capita and Per GSP Gas/Diesel Vehicle GHG Emissions in U.S. and NC

2.9 Land Use, Land Use Changes and Forestry

The Land Use, Land-Use Changes and Forestry (LULUCF) sector accounts for GHG emissions and/or carbon sinks from the following six source/sink subsectors:

Liming of soils	Carbon flux from forest management
Fertilization of settlement soils	Carbon flux from urban and rural settlements
Forest fires	Carbon flux from landfilled yard and food waste

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[43] See Corporate Average Fuel Efficiency (CAFE) discussion here: https://www.transportation.gov/mission/sustainability/corporate-average-fuel-economy-cafe-standards.

Carbon flux refers to the net change in carbon from year to year resulting from activities that emit or store carbon on natural and working lands such as:

- clearing an area of forest to create cropland
- restocking a logged forest
- draining a wetland
- allowing a pasture to revert to grassland
- long-term storage of carbon in wood products like lumber

It is challenging to measure and quantify the mass of carbon associated with various land use activities. The USDA, the U.S. Forest Service (USFS), and other agencies collect representative samples of data for various types of working lands over the course of several years. These data are entered into mathematical models that estimate carbon emissions and storage from various activities.[44] The USFS recently completed its second 5-year cycle of data collection at forests in North Carolina. Forest Service analysts are also using more advanced statistical methods to calculate carbon sequestration by forests. However, there are other categories for which limited data or data of low quality are the only available data at the state level, including harvested wood products and urban forests. Therefore, some Land Use categories have significant uncertainty or were not included in this inventory (e.g., urban trees). In addition, projection data showing future changes in the carbon flux are not currently available at the state level; therefore, carbon sequestration and GHG emissions for future years are kept constant.

This sector has a larger amount of uncertainty associated with it compared to other source sectors in the GHG inventory. As federal agencies, state agencies and nonprofits work to better understand carbon cycles, improve measurement techniques, and develop more robust methods to collect, analyze and model data, there may be additional changes to both the historical and projected emissions and storage from this sector that may impact the net GHG emissions presented in Tables 1-1 and 2-9. North Carolina has convened a panel of experts to improve both the methodology and the data sets currently being used to estimate carbon emissions and storage by natural and working lands.

Table 2-9 presents the carbon sinks and GHG emissions for each activity in North Carolina. Each year, North Carolina sequesters about 33 to 36 MMT of CO_2e. The carbon sinks are primarily due to carbon sequestered in above ground biomass and storage of carbon in wood products. Table 2-9 indicates there has been a 4% increase in the annual carbon sequestered between 2005 and 2017. In 2017, carbon sinks offset North Carolina's GHG emissions by an estimated 34.03 MMT CO_2e, which is about 23% of the State’s gross emissions in that year.

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[44] See Section 3.1.10 for detailed information on the methodology.

Table 2-9: GHG Emissions and Sinks from LULUCF Sector (MMT CO_2e)

Source/Sink	1990	2005	2012	2015	2017	Percent Change 2005-2017
Forest Carbon Flux*	-35.31	-35.17	-38.11	-37.91	-37.77	-7%
Aboveground Biomass	*-19.89*	*-19.04*	*-21.23*	*-21.10*	*-21.01*	
Belowground Biomass	*-4.23*	*-4.00*	*-4.41*	*-4.37*	*-4.34*	
Dead Wood	*-0.20*	*-0.22*	*-0.22*	*-0.22*	*-0.21*	
Litter	*0.70*	*0.61*	*0.50*	*0.52*	*0.53*	
Soil Organic Carbon	*0.60*	*0.44*	*0.20*	*0.21*	*0.22*	
*Wood Products***	*-12.28*	*-12.96*	*-12.96*	*-12.96*	*-12.96*	
Landfill Yard and Food Waste	-0.64	-0.31	-0.35	-0.33	-0.33	
Agricultural Soil Carbon Flux	-0.23	0.75	1.47	1.48	1.48	
Urban Trees**	-	-	-	-	-	
Carbon Sinks	**-36.17**	**-34.73**	**-36.99**	**-36.76**	**-36.62**	**-5%**
Liming of Soils***	0.03	0.00	0.00	0.00	0.00	
Urea Fertilization	0.007	0.011	0.006	0.007	0.007	
Forest Fires	0.40	1.99	2.95	2.52	2.52	
N_2O from Settlement Soils	0.09	0.07	0.07	0.07	0.07	
GHG Emissions	**0.53**	**2.07**	**3.03**	**2.60**	**2.60**	**25%**
Net Carbon Sink	**-35.64**	**-32.66**	**-33.97**	**-34.16**	**-34.03**	**-4%**

* Forest carbon flux is the sum of carbon emitting and carbon sequestering activities listed below in italics.

** Data quality is not sufficient for inclusion in the inventory.

***Data only available for select years

This annual sequestration of carbon reflects North Carolina's sustainable management of its forests and their economic uses. The State's timber inventory has increased by 45% since 1974, and the standing tree inventory increased by 1.7% in 2013. [45]

To illustrate the effects of this activity, Table 2-10 presents both the forest acreage and forest carbon stocks on publicly and privately-owned forests in North Carolina. Forest carbon stocks are the net sum of the carbon from the growth and removal of forest biomass. The data shows that North Carolina's forested land area increased by 2% while carbon stocks increased by 13% in that same time period. This steady increase in North Carolina's forest stock results in CO_2 being removed from the atmosphere and being stored in our forest lands.

[45] North Carolina's Forests and Forest Products Industry by the Numbers, 2013, College of Natural Resources, North Carolina State University, published by the North Carolina Cooperative Extension Service2016, http://www.ncforestry.org/wp-content/uploads/2016/05/NC-Forest-Bulletin_Published.pdf.

Table 2-10: Net Forest Carbon Stocks (MMT carbon) and Forest Area (million acres) from 1990 to 2017

Forest Stocks and Area	1990	1995	2000	2005	2010	2015	2017	Percent Change 1990-2017
Aboveground Biomass	365.3	392.0	417.1	442.7	469.9	498.6	510.1	
Belowground Biomass	72.7	78.4	83.7	89.1	94.8	100.7	103.1	
Dead Wood	65.3	65.6	65.9	66.2	66.5	66.8	66.9	
Litter	45.9	44.9	44.0	43.1	42.3	41.6	41.3	
Soil Organic Carbon	723.3	722.5	721.8	721.2	720.7	720.4	720.3	
Total Forest Carbon Stocks (MMT Carbon)	**1272.5**	**1303.4**	**1332.5**	**1362.2**	**1394.2**	**1428.2**	**1441.8**	**13%**
Total Forest Area (Million Acres)	18.51	18.58	18.64	18.71	18.78	18.84	18.87	**2%**

As stated earlier, this inventory report assumes that beyond 2017, the net carbon sinks for years 2018 through 2030 remain constant. This is a conservative estimate, as there is a large potential for increased carbon sequestration by natural and working lands. Recent work by an expert panel looking specifically at North Carolina's ability to sequester carbon in natural and working lands estimates that North Carolina could sequester an additional 10 to 20 MMT CO_2e through various measures such as reforestation and avoided land conversions.[46] Additionally, future revisions of this inventory will include the growth of commercial and industrial activities related to the harvesting of woody biomass and its impact on North Carolina's forest carbon stock.

2.10 Projections of GHG Emissions to 2030

This section describes the anticipated post-2017 GHG emissions by sector. Figure 2-16 displays North Carolina's gross GHG emissions trends beginning in the 2005 baseline year through 2030 for all source sectors. As indicated by the figure, a continuation of North Carolina's downward trend in historical GHG emissions is projected to continue through 2025. Although increases are projected thereafter, they are modest, and result in year 2030 gross emissions that are about 24% below those of the 2005 baseline year. In addition, recent information on Duke Energy's plans for its coal power plants indicate these increases are not likely to materialize, as discussed further in Section 2.10.1.

[46] State Natural & Working Lands Initiative: North Carolina Opportunity Assessment, U.S. Climate Alliance, July 2018.

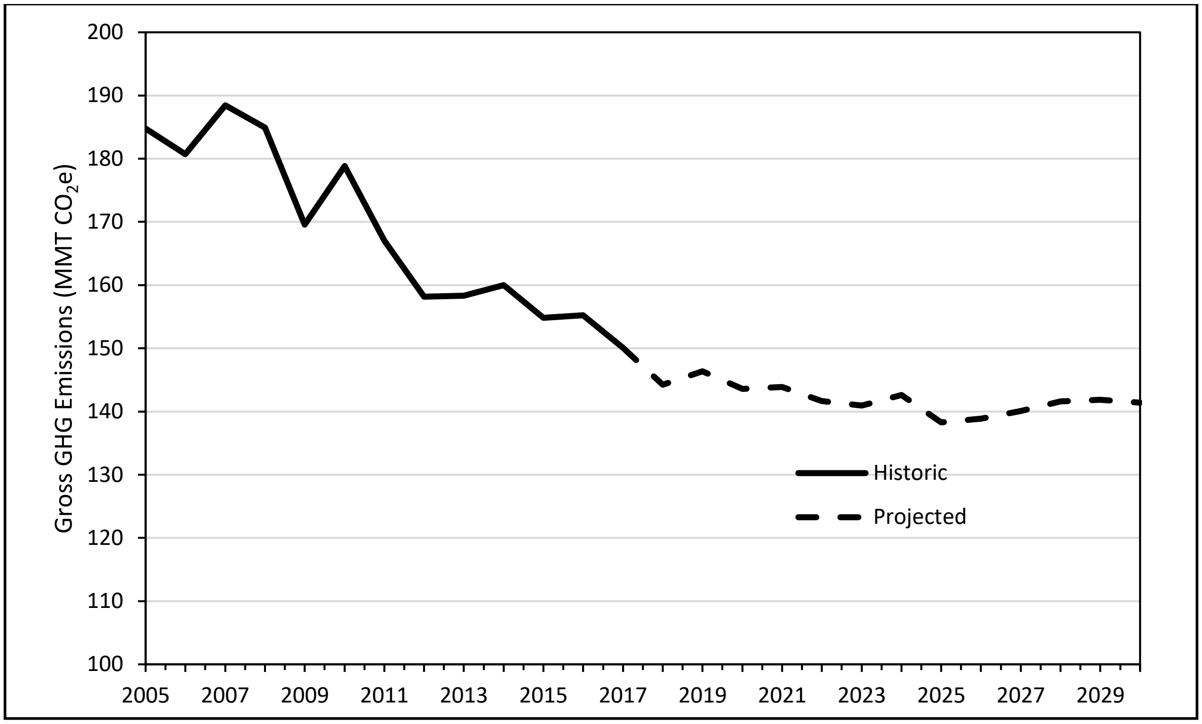

Figure 2-16: Gross GHG Emissions Trends in North Carolina, 2005-2030

Figure 2-17 displays gross GHG emissions trends from 2005 to 2030 by source sector. As indicated by this figure, the Electricity Generation and Use sector and the Transportation sector show substantial decreases over this time-frame. Although most other sectors show relatively stable emission levels, there are relatively large increases over this period in the Industrial Processes sector. The following sections discuss the projected trends for these three sectors.

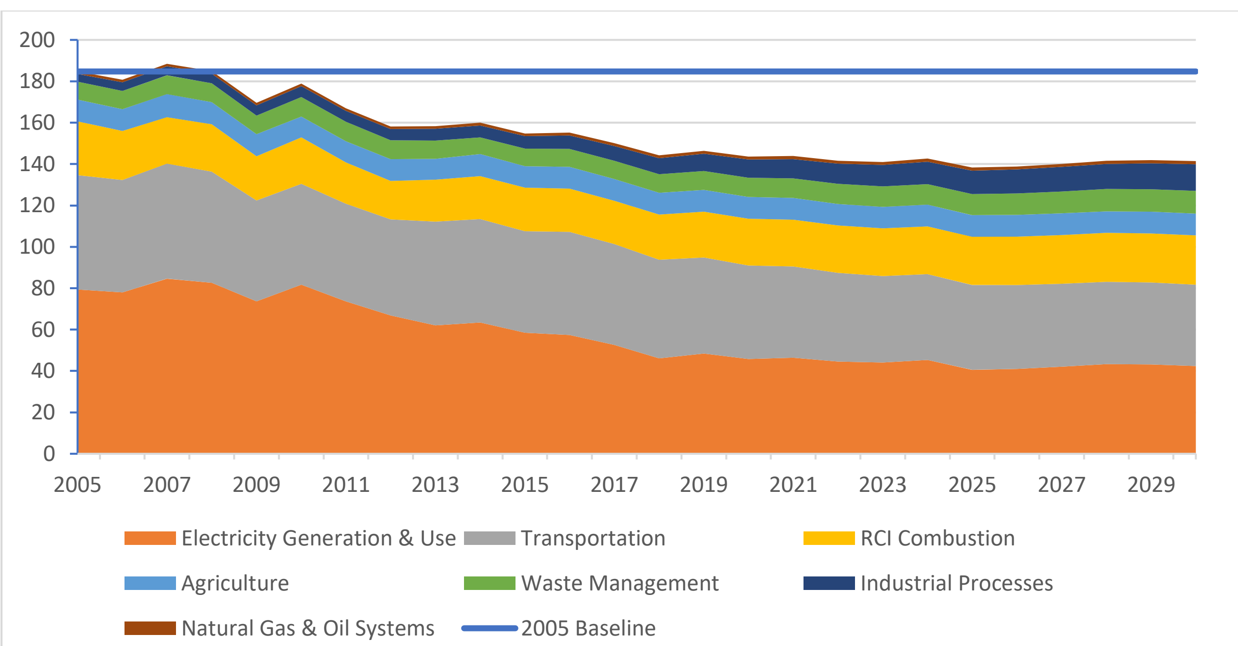

Figure 2-17: Gross GHG Emissions Trends by Source Sector, 2005-2030

2.10.1 Electricity Generation & Use Projections

GHG emissions for this sector are based on a 2017 forecast of fuel use by the electricity generation units that Duke Energy operates in North Carolina.[47] The Duke Energy forecast does not assume any regulation of CO_2 emissions in the future.[48] This projection includes expected operational changes due to the current REPS law, and recently passed law Competitive Energy Solutions for NC; however, additional adjustments may be made as RE implementation options are approved by the North Carolina Utilities Commission (NCUC).[49] An analysis of the data currently available for 2017 indicates the validity of Duke Energy's near-term forecast.[50] Because forecast data are not available for the non-Duke Energy electricity generation units in North Carolina, these units are assumed to maintain their actual 2016 heat input and fuel type profile over the 2017-2030 period. (These units only account for about 10% of total generation in the State.)

Table 2-11 reports 2017-2030 GHG emissions projections by fuel type for select years for the Electricity Generation & Use sector (2005 baseline year emissions are also shown for comparison). The 2020 projection incorporates a new 560 MW NGCC plant that will come online at Duke Energy's Asheville facility to replace the existing 375 MW coal plant. Additional coal generation retirement is forecast to occur in 2024, reducing GHG emissions in 2025 by 27% relative to 2017 levels.

Table 2-11: GHG Emissions Projections for Electricity Generation by Fuel Type (MMT CO_2e)

Fuel Type	2005	2017	2020	2025	2030
Coal	71.57	32.96	17.85	15.28	17.14
Natural Gas	1.45	12.11	19.79	17.38	17.28
Fuel Oil	0.24	0.22	0.67	0.30	0.24
Wood	0.01	0.03	0.03	0.03	0.03
Total	**73.27**	**45.32**	**38.34**	**32.99**	**34.7**
Reduction Relative to 2017			15%	27%	23%
Reduction Relative to 2005		38%	48%	55%	53%

[47] Duke Energy, "DAQ Data Request - April 2017-Short Range.xlsx and "DAQ Data Request-April 2017 - Long Range.xlsx", email transmittal to Ming Xie and Paula Hemmer, North Carolina Division of Air Quality, April 17, 2017.

[48] EPA has proposed repealing the Clean Power Plan (CPP), which regulated CO_2 emissions from existing power plants: "Repeal of Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units," 82 Federal Register (FR) 48035, October 16, 2017. Based on the estimates noted in Table 2-7, North Carolina is below the CPP emissions targets throughout the 2017-2030 period.

[49] House Bill 589, Session Law 2017-192, North Carolina General Assembly, 2017, https://www.ncleg.net/gascripts/BillLookUp/BillLookUp.pl?Session=2017&BillID=h589&submitButton=Go.

[50] CO_2 emissions associated with the Duke Energy 2017 forecast are within one percent of the actual 2017 CO_2 emissions for these units as reported by EPA via the Air Markets Program (https://ampd.epa.gov/ampd/).

As noted in Table 2-11, there is a small increase in GHG emissions forecast to occur between 2025 and 2030. This is due to an 11% projected increase in the use of coal by EGUs as shown in Table 2-12. Both EIA's 2017 Annual Energy Outlook and Duke Energy's 2017 forecast indicate an increase in coal use between 2025 and 2030.[51] However, Duke Energy recently announced plans to reduce the use of coal at their power plants. The plans include: (1) retrofit of over 3,000 MW of coal units to allow co-firing of natural gas in the 2018-2025 time frame, and (2) retirement of 2,900 MW of coal power by 2030. The impact on GHG emissions associated with executing these plans to decrease coal use and increase natural gas use are not included in Tables 2-11 and 2-12 as these operational changes may not materialize. If they do occur, gross GHG emissions in NC are estimated to be further reduced by over 3 MMT CO_2e by 2030. In this case, GHG emissions from the power sector will continue to decrease out to 2030.

Table 2-12: Projected Heat Input for Electricity Generation by Fuel Type

Heat Input (thousand MMBtu)	2017	2020	2025	2030	Percent Change 2025-2030	Percent Change 2017-2030
Coal	355,194	192,341	164,655	184,698	11%	-48%
Natural Gas	228,179	373,068	327,652	325,741	-1%	43%
Distillate Fuel	2,970	8,990	3,985	3,215	-24%	8%
Residual Fuel Oil	13	13	13	13	0%	0%
Wood	14,691	14,691	14,691	14,691	0%	0%
Total Fuel Use	**601,047**	**589,103**	**510,996**	**528,359**	**3%**	**-12%**

Renewable energy generation is expected to continue to increase as a result of both North Carolina's REPS (discussed in Section 2.6) and the recently enacted Competitive Energy Solutions for NC. This law directs Duke Energy to increase renewable energy generation by 2021 as follows; (1) connect 3,500 MW of existing solar (or procure equivalent if it is not connected) and (2) procure an additional 2,660 MW of renewable energy via annual competitive solicitations. This law may increase renewable energy generation by an estimated 10.7 million MWh in each year, which based on a simplified estimation procedure (using the current GHG emission factor for the electricity grid region that includes North Carolina), would result in an additional 1.7 MMT CO_2e of avoided GHG emissions annually.[52,53]

[51] Annual Energy Outlook 2018, U.S. Energy Information System, Department of Energy, February 6, 2018, accessed at https://www.eia.gov/outlooks/aeo/.

[52] Calculated using a capacity factor of 20 % based on EIA Table 6-7.B. Capacity Factors for Utility Scale Generators Not Primarily Using Fossil Fuels, January 2013-February 2018, https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_6_07_b.

[53] Emissions & Generation Resource Integrated Database 2014 v2 (eGRID2014), Clean Air Markets Division U.S. Environmental Protection Agency, February 2017, https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid.

2.10.2 Transportation Projections

Because gasoline and diesel vehicles account for approximately 90% of total Transportation sector emissions, the projected emissions trends for these vehicles are key to understanding overall sector trends. Between 2017 and 2030, North Carolina's GHG emissions from gasoline/diesel vehicles are forecast to decrease by 23% (see Figure 2-18). This projected decline results from the estimated impact of national fuel economy/GHG emissions standards. The highway vehicle GHG projections are derived from CO_2, CH_4, and N_2O emissions estimates for 2011, 2023, and 2028 developed by EPA's Office of Air Quality Planning and Standards (OAQPS), with 2029/2030 values projected using the annual projected percentage change in emissions between 2023 and 2028. The OAQPS modeling relies on VMT projections reflecting forecasts from the 2016 Reference case of the EIA's Annual Energy Outlook (AEO). The VMT projections from AEO 2016 reflect the projected effects of all federal vehicle fuel efficiency/GHG emissions regulations that were promulgated as of the end of February 2016.[54] EPA has proposed the Safer Affordable Fuel Efficient (SAFE) vehicle rule, which would relax these regulations to be less stringent.[55] Therefore, the final SAFE vehicle rule may cause the projected decrease in highway vehicle GHG emissions to not be as pronounced as shown in Figure 2-18.

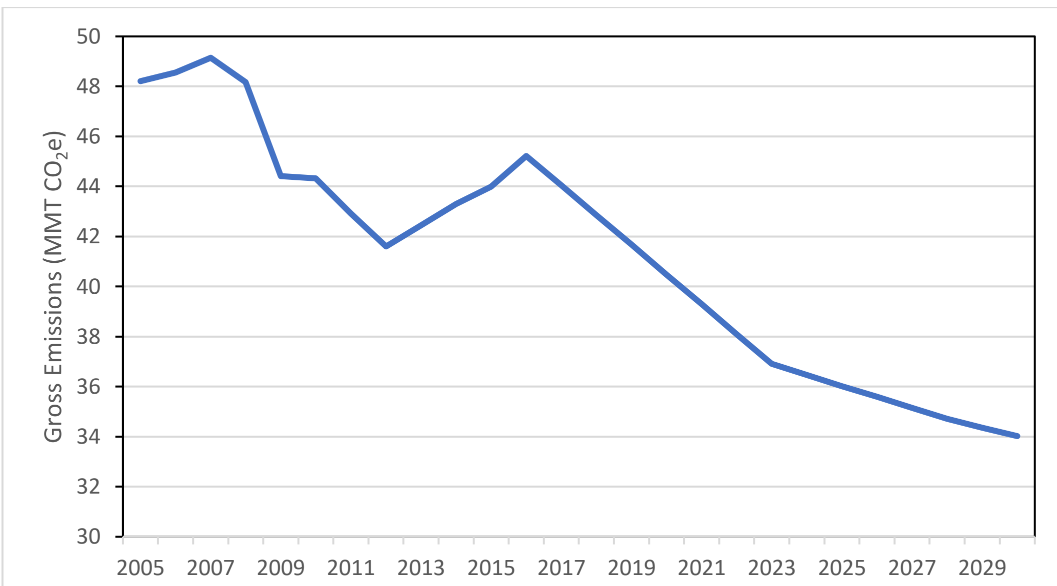

Figure 2-18: Highway Vehicle Emissions Trends in North Carolina, 2005-2030

[54] Includes the Corporate Average Fuel Economy (CAFÉ) and vehicle GHG emissions standards for model year (MY) 2012 to MY 2025 light-duty vehicles. Also includes the fuel consumption and GHG emissions standards for MY 2014 to MY 2018 medium-duty and heavy-duty vehicles.

[55] U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "The Safer Affordable Fuel Efficient (SAFE) Vehicles Proposed Rule for Model Years 2021-2026," 49 CFR 48578, September 26, 2018.

2.10.3 Industrial Processes

Contrary to the trends in the sectors discussed previously, GHG emissions from the Industrial Processes sector are projected to increase substantially from 2017 levels (see Figure 2-19). In 2017, ozone depleting substance (ODS) substitutes accounted for 90 percent of total Industrial Processes sector emissions in North Carolina. HFCs and PFCs are used as alternatives to classes of ODSs that are being phased-out under the Montreal Protocol.[56] Under sections 601 through 607 of the Clean Air Act, EPA issues regulations that phase-out the production and importation of ODS, consistent with the schedules developed under the Montreal Protocol.[57] Although they provide an effective alternative to ODS refrigerants, HFCs and PFCs are also GHGs. EPA's Projections Tool forecasts a continuation of past historic increases in emissions from North Carolina's ODS substitutes. This forecast reflects a national increase of similar magnitude.[58] When compared to 2017 ODS sector emissions, the Tool projects increases of 62 percent and 84 percent in 2025 and 2030 emissions, respectively (these are approximately the same percentage increases projected for the overall Industrial Processes sector).

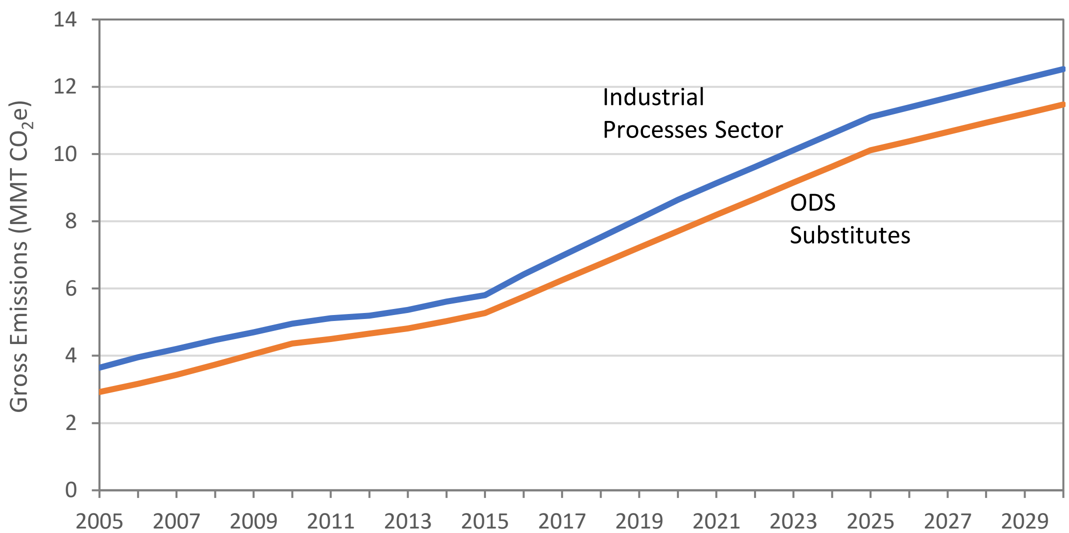

Figure 2-19: Industrial Processes and ODS Substitutes Emissions in North Carolina, 2005-2030

[56] The Montreal Protocol's charter is to save the upper atmosphere ozone layer that protects from the sun's ultraviolet rays that cause skin cancer (see U.S. Department of State, "The Montreal Protocol on Substances That Deplete the Ozone Layer," https://www.state.gov/e/oes/eqt/chemicalpollution/83007.htm, accessed May 2018.)

[57] U.S. Environmental Protection Agency, "What Is the Phaseout of Ozone-Depleting Substances?" accessed from https://www.epa.gov/ods-phaseout/what-phaseout-ozone-depleting-substances, May 2018.

[58] The Tool projects each State's ODS substitute emissions by allocating projected national emissions based on State-level population forecasts.

3.0 Methodology

This section explains the methodologies used to develop North Carolina's historical and projected GHG inventory. Section 3.1 discusses the development of historical GHG emissions from 1990 to 2015 while Section 3.2 discusses the development of projected GHG emissions from 2016 to 2030. Data used in developing the inventory comes from a variety of sources as discussed in the subsections below.

3.1 GHG Emissions Using Available Data (1990-2015)

The historical GHG emissions are calculated to show how emissions in North Carolina have changed from 1990 through 2015, the last year of available historic data for all sectors. This long-term view provides valuable information on the influence of various factors on past GHG emissions.

The GHG emissions are prepared primarily using the "State Inventory and Projection Tool", a spreadsheet-based tool developed by EPA and designed to assist state agencies in preparing state-level GHG inventories and projections.[59] The SIT automates the estimation procedures used by EPA to develop the national GHG inventory to simplify preparing state-specific GHG inventories.

The SIT applies a "top-down approach" to calculate GHG emissions from all relevant anthropogenic source sectors and uses methodologies consistent with those recommended in the 2006 IPCC Guidelines.[60] The use of consistent methodologies ensures that GHG inventories prepared by various entities are comparable.

The SIT is organized into eleven modules for calculating emissions.[61] However, these modules do not correspond to the layout of the sector and source emissions tables presented in Sections 2.0 and 3.0. Instead, they are organized to facilitate the emissions estimation process. Each module has a user's guide that outlines the methodology, and documents the default data sources, emissions factors, references and other pertinent information utilized by the module. There is also a synthesis module which pulls the historic emissions data from each module into a single spreadsheet tool to assist in generating reports and graphics.

The SIT includes default data supplied by EPA. The default data are generally publicly available from various federal agencies such as the Department of Energy (DOE), the U.S. Department of Agriculture (USDA), the Federal Highway Administration (FHWA), U.S. Geological Survey

[59] State Inventory and Projection Tool, US Environmental Protection Agency, https://19january2017snapshot.epa.gov/statelocalclimate/state-inventory-and-projection-tool_.html, accessed January 3, 2018.

[60] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change. Hayama, Kanagawa, Japan, 2006.

[61] North Carolina only utilizes 10 modules since one module estimates emissions from coal production which does not occur in North Carolina.

(USGS), U.S. Census Bureau, and EPA. These data are frequently used by state and local agencies to develop emissions inventories. A limited number of source categories utilize data obtained from third party vendors for estimating emissions. For a select number of source categories, DAQ has replaced the federal default data with data obtained from North Carolina's state agencies to provide more accurate emissions estimates. The methodologies and default and substituted data sources used in each module are presented in Sections 3.1.1 through 3.1.10.

A detailed discussion of the uncertainty associated with the SIT default data used for the historic GHG emission inventory is outlined in each of the SIT modules, which are available for download from the EPA SIT webpage.[62] DAQ deviated from SIT defaults for the Natural Gas and Oil, Electricity Consumption, Agriculture, Municipal Solid Waste, Wastewater, Industrial Processes, and Land Use source sectors. A discussion of the uncertainty associated with the deviations from the default data is available upon request.

3.1.1 CO_2 Emissions from Fossil Fuel Combustion

Description
The Fossil Fuel Combustion Module calculates CO_2 emissions from combustion of fossil fuels including coal, natural gas, and petroleum products. The sectors included in the module are listed below.[63]

Residential	Industrial	Transportation
Commercial	Electric Power	

It also calculates CO_2 that is stored or released through the use of fossil fuels in the production of solvents, asphalt, synthetic rubber, naphtha, lubricant, and other products.

CH_4 and N_2O from fossil fuel combustion are calculated in two separate modules, the Mobile Combustion Module and the CH_4 and N_2O Stationary Combustion Module.

Background and Default Data
The methodology for estimating CO_2 emissions from fossil fuel combustion is provided in the User's Guide for this module as well as instructions and information provided in the spreadsheets for each module.[64]

The default historical fuel consumption data provided in the SIT module for North Carolina are used without any adjustments. This default data is from the DOE Energy Information Administration's

[62] State Inventory and Projection Tool, US Environmental Protection Agency, https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool accessed January 3, 2018.

[63] The Fossil Fuel Combustion Module estimates emissions from international bunker fuel use. These emissions are from international transportation; therefore, they are not included in state inventories.

[64] User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2017-12/documents/co2_from_fossil_fuels_users_guide.pdf.

(EIA) State Energy Data System (SEDS).[65] It consists of the estimated amount of each type of fuel consumed by each sector in each state.

Note the SIT estimates consumption of fuel for non-combustion use in the Industrial sector for each fossil fuel type.

The SEDS gasoline consumption data is adjusted to remove the amount of ethanol in gasoline. Ethanol is a biomass fuel, for which CO_2 emissions are excluded from gross GHG emissions totals (see Appendix C for further discussion of biomass combustion emissions).

Deviations from Defaults

As noted earlier, CO_2 emissions from wood and biofuel combustion are accounted for via changes in LULUCF sector carbon flux, consistent with IPCC reporting guidance. To provide additional transparency, DAQ developed CO_2 emissions estimates for wood, ethanol, and biodiesel consumption in North Carolina; these estimates are reported in Appendix C. North Carolina wood consumption values by year were obtained from the SIT's CH_4 and N_2O Emissions from Stationary Combustion module, and North Carolina annual ethanol consumption data were compiled from the SIT's CO_2 Emissions from Fossil Fuel Consumption module. To address the lack of state-level biodiesel consumption data, DAQ first compiled national annual biodiesel consumption from the EIA data set titled Renewable Energy Consumption: Industrial and Transportation Sectors.[66] To estimate state-level biodiesel consumption, DAQ applied allocation factors to the national consumption values. These factors were derived from state-level adjusted sales of diesel data for on-highway vehicles from the EIA's Petroleum and Other Liquids Database.[67]

Future Refinements

Future refinements for biomass emissions estimates will investigate the availability of data for estimating CO_2 emissions from the combustion of landfill and manure gas, as well as better state-specific data for biodiesel consumption.

3.1.2 CH_4 and N_2O Emissions from Mobile Combustion

Description

The CH_4 and N_2O Emissions from Mobile Combustion Module calculates CH_4 and N_2O emissions from the following mobile sources:

Gasoline Highway	Non-Highway
Diesel Highway	Alternative Fuel Vehicles

CO_2 emissions from the Transportation sector are calculated in the Fossil Fuel Combustion Module discussed in Section 3.1.1. The Mobile Combustion Module provides an alternate

[65] EIA State Energy Data System (SEDS): 1960-2015, https://www.eia.gov/state/seds/seds-data-complete.php?sid=NC#Consumption.
[66] EIA API Query Browser, https://www.eia.gov/opendata/qb.php?sdid=TOTAL.BDACBUS.A
[67] EIA Petroleum & Other Liquids, https://www.eia.gov/dnav/pet/PET_CONS_821DSTA_A_EPD2D_VAH_MGAL_A.htm

method for calculating CO_2 emissions for highway vehicles, however it is not used for this inventory.

Background and Default Data

The methodology for estimating CH_4 and N_2O emissions from mobile combustion is provided in the User's Guide for this module as well as instructions and information provided in the spreadsheets for each module.[68]

For highway/alternative fuel vehicles, CH_4 and N_2O emissions are calculated based on several factors including vehicle miles traveled (VMT), fuel type, engine type and control technology type for the population of vehicles on roads in North Carolina. The default data used to calculate emissions is from the FHWA and EPA.

CH_4 and N_2O emissions from non-highway mobile sources (including aviation, marine, locomotives, tractors, construction equipment, snowmobiles), and other non-highway equipment are derived from fuel consumption data. The default historical fuel consumption data provided in the SIT module for North Carolina are used without any adjustments for non-highway mobile sources.

The Mobile Source Module estimates CH_4 and N_2O emissions for alternative fuel vehicles that use the following fuels: methanol, ethanol, compressed natural gas (CNG), liquefied natural gas (LNG), and liquefied petroleum gas (LPG). The emissions are calculated using default VMT estimates for each alternative fuel vehicle type. The VMT for each state is derived from EPA's national VMT data for each vehicle type and fuel type, and the percentage of alternative fuel vehicles in each state obtained from EIA's Alternative Fuel Vehicle Data.[69]

Deviations from Defaults

No data or estimation methods outside of those provided by the SIT are used.

Future Refinements

There are inconsistencies in the available highway VMT data. Future inventories should investigate these inconsistencies and should reflect more reliable data as it becomes available.

[68] User's Guide for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2017-12/documents/mobile_combustion_users_guide.pdf.

[69] Alternative Fuel Vehicle Data, Fleet and Fuel Data. U.S. Energy Information Administration, accessed at https://www.eia.gov/renewable/afv/users.php?fs=a.

3.1.3 CH_4 and N_2O Emissions from Stationary Combustion

Description

The CH_4 and N_2O Emissions from Stationary Combustion Module calculates CH_4 and N_2O emissions at stationary sources combusting (1) fossil fuels including coal, natural gas, and petroleum products, and (2) wood. The source sectors included in the module are listed below.

Residential	Industrial
Commercial	Electric Power

It also calculates CH_4 and N_2O that are stored or released through the use of fossil fuels in the production of solvents, asphalt, synthetic rubber, naphtha, lubricants, and other products. CO_2 emissions are calculated in the Fossil Fuel Combustion Module as discussed in Section 3.1.1.

Background and Default Data

The methodology for estimating CH_4 and N_2O emissions from fossil fuel and biomass stationary sources is provided in the User's Guide for this module as well as instructions and information provided in the spreadsheets for each module.[70]

The default historical fuel consumption data provided in the SIT module for North Carolina are used without any adjustments. These default data are from the EIA's SEDS.[71] It consists of the estimated amount of each type of fuel consumed by each sector.

Note the SIT estimates consumption of fuel for non-combustion use in the Industrial sector for each fossil fuel type.

Deviations from Defaults

No data or estimation methods outside of those provided by the SIT are utilized in calculations.

Future Refinements

No future refinements have been identified at this time.

3.1.4 Natural Gas and Oil

Description

The Natural Gas and Oil Module calculates CH_4 (and their CO_2-equivalent) emissions from Natural Gas and Oil systems. The subsectors included in the module are listed below.

Natural Gas Production	Natural Gas Distribution
Natural Gas Transmission	Petroleum Production, Refining, and Transportation

[70] User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2017-04/documents/stationary_combustion_users_guide.pdf

[71] EIA State Energy Data System (SEDS): 1960-2015, https://www.eia.gov/state/seds/seds-data-complete.php?sid=NC#Consumption.

GHG emissions from the combustion of natural gas and oil are calculated in the Fossil Fuel Combustion Module as discussed in Section 3.1.1.

Background and Defaults
The methodology for estimating GHG emissions from Natural Gas and Oil systems is summarized in the User's Guide for the module, as well as information provided in the module's spreadsheets.[72] Default activity data are generally not provided in the Natural Gas and Oil Module of the SIT. The focus of running this module for North Carolina is on the Natural Gas Transmission and Distribution sectors because the State does not currently produce or refine any oil or natural gas. CH_4 emissions factors in the module for Natural Gas Transmission and Distribution are taken from a study conducted by the Gas Research Institute and EPA. [73]

Deviations from Defaults
The CH_4 emission factor for natural gas transmission compressor stations was revised from the module's default value of 983.66 metric tons (MT) per compressor station to 500 MT/station. This updated value reflects the approximate median value calculated from CH_4 emissions reported by NC compressor stations to EPA's GHG reporting program for the years available (2011-2016). The 2010-2016 natural gas transmission mileage data input to the module is taken from a North Carolina query performed on the webpage of DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA).[74] Natural gas distribution pipeline miles in North Carolina by material and number of services data for select years (1990-1995, 2000, 2005, 2010, 2013, 2015, 2016) are taken from PHMSA files.[75] Values for other years are estimated via interpolation.

According to the North Carolina Utilities Commission there are four LNG liquefaction and storage facilities and 16 natural gas compressor stations currently operating in NC.[76] Due to a lack of historical data, these values are used for 1990-2015. There are no natural gas venting and

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[72] "User's Guide for Estimating Carbon Dioxide and Methane Emissions from Natural Gas and Oil Systems Using the State Inventory Tool," prepared by ICF for the State Energy and Environment Program and U.S. Environmental Protections Agency, October 2017, available from https://www.epa.gov/sites/production/files/2017-12/documents/natural_gas_and_oil_users_guide.pdf.

[73] Methane Emissions from the Natural Gas Industry, Gas Research Institute and U.S. Environmental Protection Agency, EPA-600/R96-080a and GRI-94/0257, June 1996, https://www.epa.gov/sites/production/files/2016-08/documents/1_executiveummary.pdf.

[74] PHMSA, "2010+ Pipeline Miles and Facilities," available from https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-mileage-and-facilities, accessed April 2018.

[75] PHMSA, "Gas Distribution, Gas Gathering, Gas Transmission, Hazardous Liquids, Liquefied Natural Gas (LNG), and Underground Natural Gas Storage (UNGS) Annual Report Data, accessed from https://www.phmsa.dot.gov/data-and-statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-annual-data

[76] Bill Gilmore, North Carolina Utilities Commission, "Natural Gas Facilities in North Carolina," email transmittal to Andy Bollman, NC Division of Air Quality, January 23, 2018.

flaring operations associated with natural gas production in NC from 1990-2015 based on EIA information.[77]

Future Refinements

In future revisions to the inventory for this sector, it would be possible to update the CH_4 emission factor for natural gas transmission compressor stations to reflect the latest North Carolina data in EPA's GHG reporting program. As discussed further in Appendix D, the availability of more detailed information would facilitate the estimation of indirect emissions for this sector (i.e., emissions from production/transportation of natural gas/oil in other States that is consumed in North Carolina) in future versions of this inventory. In addition, EPA recently updated the emissions estimation methods for Natural Gas Systems in support of its national GHG inventory. There may be the potential to adopt or modify the updated national emissions estimation methodology for use in improving upon the SIT-based approach to estimating North Carolina emissions. At a minimum, it would be helpful to perform a comparison of the current methodology's emissions estimates to estimates developed in a manner consistent with EPA's national emissions to identify any particular areas of uncertainty. This comparison could help define priorities for future work (one such approach could be to allocate the national emissions to North Carolina using state-level natural gas consumption data or data for similar proxy variable of natural gas distribution/transmission activity).

3.1.5 Electricity Consumption and Imported Electricity Use

Total electricity consumption refers to the amount of electricity used by the State to power homes, businesses, manufacturing plants and the electric train system. In most years, North Carolina imports a fraction of the total power it uses from neighboring states that make up the electric power grid in the Southeastern Electric Reliability Council - Virginia/Carolina Subregion (SRVC) Region. This section first discusses estimating the GHG emissions from the total electricity used in the State using the EPA's SIT, and then describes how GHG emissions for imported electricity are estimated.

Description - Total Electricity Consumption

The SIT Electricity Consumption module estimates GHG emissions resulting from the total consumption of electricity in a given state. Electricity consumption is not equal to the amount of power generated in a given state since power can be imported or exported across state lines. For this reason, GHG inventories estimate emissions as a function of the total retail sales of electrical power in a given state in megawatt-hours (MWh).

Quantifying emissions for each user sector and equipment category, such as residential lighting and commercial cooling, provides detailed information for analysts to determine how to reduce

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[77] EIA, "Natural Gas Gross Withdrawals and Production," available from: https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_VGV_mmcf_a.htm, accessed February 2018.

electricity consumption at the point of use. The reduction in electricity use results in decreased emissions from electricity generation, either within or outside of the State.

Electricity consumption is estimated for each user sector and equipment type listed in Table 3-1.

Table 3-1: Equipment Used to Estimate Electricity Consumption by Use Sector

Residential	Commercial	Industrial		Transportation
Space Heating	Space Heating	Indirect Use - Boiler Fuel	**Direct Uses-Nonprocess**	Light Rail
Air-conditioning	Cooling	Conventional Boiler Use	Facility HVAC	
Water Heating	Ventilation	CHP and/or Cogeneration	Facility Lighting	
Refrigeration	Water Heating	**Direct Uses-Process**	Other Facility Support	
Other Appliances	Lighting	Process Heating	Onsite Transportation	
Other Lighting	Cooking	Cooling & Refrigeration	Other Nonprocess Use	
	Refrigeration	Machine Drive		
	Office Equipment	Electro-Chemical Process		
	Computers	Other Process Use		
	Other			

It is not possible to track the specific power plants that supply power to the residences, businesses and industries in North Carolina because power is supplied to the SRVC regional electricity grid by multiple power plants located both inside and outside of North Carolina at any given time. Therefore, the SIT methodology calculates GHG emissions using average emissions factors developed by EPA for each regional electricity grid system. This is discussed in more detail in the following section.

Background and Defaults - Total Electricity Consumption

The methodology for estimating GHG emissions from electricity consumption is provided by the User's Guide for this module as well as instructions and information provided in the spreadsheets for each module.[78]

The default historical electricity consumption data provided in the SIT module for North Carolina are used without any adjustments. The User's Guide documents all data sources used to estimate emissions. The default data comes from a number of sources as discussed below.

There are four steps to estimating indirect emissions from electricity consumption. A brief outline is given below with more details provided in the module's User Guide.

1. Total consumption of electricity for each user sector (Residential, Commercial, Industrial and Transportation) is obtained from the DOE through the EIA's SEDS, which is published annually.
2. EPA estimates consumption by each type of equipment given in the table above as a percentage of the total consumption in a user sector. These percentages are developed by

[78] User's Guide for Estimating Indirect Carbon Dioxide Equivalent Emissions from Electricity Consumption Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2017-12/documents/electricity_consumption_module_users_guide.pdf

EPA through a variety of data sources including EIA's periodic energy surveys conducted on Residential, Commercial, and Industrial users.

3. EPA estimates the percentage of electricity loss due to long-distance transmission of the electricity across regional power lines.
4. EPA applies average GHG emissions factors developed for North Carolina's regional power grid, the SRVC. These emissions factors are developed for each regional grid by EPA on a periodic basis using EPA's Emissions & Generation Resource Integrated Database (eGRID).[79] EPA does not estimate emissions factors for each year. If an emissions factor is not available for a given year, the most recent year's emissions factor is used.

Deviations from Default - Total Electricity Consumption

No data outside of those provided by the SIT are utilized in calculations for emissions from total electricity consumption in North Carolina.

Future Refinements - Total Electricity Consumption

Electricity consumption for each equipment type could be developed using estimates that are specific to North Carolina rather than the default electricity consumption percentages published by EIA. Many North Carolina homes and businesses have installed and/or adopted energy efficient/demand-side management equipment and policies due to State laws and policies. This would require significant effort and may require assistance from entities outside the Department of Environmental Quality such as the North Carolina Utilities Commission.

Description - Imported Electricity Use

Imported electricity is the amount of electrical power that North Carolina imports from power plants that are located outside the State via the regional electricity grid system discussed above. The difference between the total electricity consumed in North Carolina and the total electricity generated by power plants located in North Carolina is assumed to be the amount of imported electricity.

Since this power is coming from the regional electricity grid, the average emissions factors developed by EPA for the regional grid that contains North Carolina are used to estimate GHG emissions due to imported electricity use. Note these emissions do not occur in North Carolina, but are emitted due to electricity consumption in North Carolina. Therefore, these emissions are part of the carbon footprint for North Carolina.

Background and Defaults - Imported Electricity Use

The EIA SEDS reports the amount of electricity imported into each state under "net interstate flow" in thousand MWh.[80] North Carolina's net interstate flow was used to estimate the GHG emissions from electricity imported into North Carolina.

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[79] Emissions & Generation Resource Integrated Database 2014 v2 (eGRID2014), Clean Air Markets Division U.S. Environmental Protection Agency, February 2017. More information on eGRID can be found at https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid.

[80] State Energy Data System (SEDS): 1960-2015 (complete), EIA, data set downloaded from https://www.eia.gov/state/seds/seds-data-complete.php?sid=US#Consumption.

The average GHG emissions factors developed by EPA for North Carolina's regional power grid (SRVC) that are discussed above are used to calculate emissions. EPA does not estimate emissions factors for each year. If an emissions factor is not available for a given year, the most recent year's emissions factor is used.

The total GHG emissions are reported as imported electricity under the electricity generation & use source sector.

The imported electricity emissions are then split into the Residential, Commercial, and Industrial sectors by calculating the percentage of EIA's total retail electricity sales for each sector in each year using the data from Step 2 in the Total Electricity Consumption section. The imported electricity emissions data for each subsector (Residential, Commercial, and Industrial) are used to calculate total energy use for each subsector. (See Section 2.7)

Deviations from Default – Imported Electricity

Not applicable.

Future Refinements – Imported Electricity

No refinements have been identified.

3.1.6 Agriculture

Description

The Agriculture Module calculates CH_4 and N_2O emissions from agricultural operations. The subsectors included in the module are listed below.

Enteric Fermentation	Rice Cultivation	Agricultural Soils
Manure Management	Agricultural Residue Burning	

Background and Defaults

The methodology for estimating CH_4 and N_2O emissions from the Agriculture sector is described within the User's Guide for this module as well as instructions and information provided in the spreadsheets for each subsector of the module.[81] The default historical activity data provided in the SIT module for North Carolina are used without adjustments for the agricultural residue burning, agricultural soils – plant residues and legumes; and agricultural soils – plant fertilizer subsectors. Default animal population and crop production data in the module are from the USDA's National Agriculture Statistics Service (NASS). Because there is no rice production in North Carolina, it is not necessary to perform calculations for the rice cultivation subsector. Default fertilizer use data are from the Association of American Plant Food Control Officials and The Fertilizer Institute. It should be noted that the module applies a national adjustment factor to reconcile differences between

[81] "User's Guide for Estimating Methane and Nitrous Oxide Emissions from Agriculture Using the State Inventory Tool," prepared by ICF for the State Energy and Environment Program and U.S. Environmental Protections Agency, October 2017, available from https://www.epa.gov/sites/production/files/2017-12/documents/ag_module_users_guide.pdf.

methodologies for estimating N_2O from agricultural soils between the SIT and EPA's national inventory.

Deviations from Defaults
The default USDA data in the module are revised for the following livestock categories to reflect the most recent set of available livestock inventory estimates: dairy cattle; sheep; goats; broilers; turkeys; and swine. These data are from online queries of USDA datasets (note that USDA compiles these data sets in cooperation with the North Carolina Department of Agriculture and Consumer Services).[82] These livestock data are used to calculate emissions for the following sub-sectors: enteric fermentation, manure management, and agricultural soils, animals & runoff.

Future Refinements
The agricultural soils – plant residues and legumes subsector does not include default production data for the following crop types: alfalfa, corn for grain, all wheat, barley, sorghum for grain, oats, rye, millet, rice, soybeans, peanuts, dry edible beans, dry edible peas, Austrian winter peas, lentils, wrinkled seed peas, red clover, white clover, birdsfoot trefoil, arrowleaf clover, and crimson clover. Also, the agricultural soils – plant fertilizer subsector does not provide default data for the following organic types of fertilizers: compost, dried blood, dried manure, activated sewage sludge, other sewage sludge, and tankage. Further research can be conducted to determine if it may be possible to supplement the default crop production and fertilizer use data with data for additional types of crops and fertilizers.

3.1.7 Municipal Solid Waste

Description
The Municipal Solid Waste module of the SIT calculates CH_4 emissions from landfilling Municipal Solid Waste (MSW) and CO_2 and N_2O from the combustion of MSW. Some landfills have added gas-collection systems to collect and burn landfill gas for electricity production and other energy uses (landfill-gas-to-energy projects or LFGTE). Other landfills flare the landfill gas which converts the CH_4 portion to CO_2.

CO_2 emitted directly from landfills as biogas and CO_2 emitted from CH_4 combustion at the flares are not counted as an anthropogenic GHG emissions in this inventory.

Background and Defaults
There are two sectors in this module, landfills and combustion, and the emissions calculation methodology is different for each sector. The methodology for estimating GHG emissions from Municipal Solid Waste is provided in the User's Guide for this module as well as instructions and information provided in the spreadsheets for each module.[83]

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[82] U.S. Department of Agriculture, "National Agricultural Statistics Service, Quick Stats," North Carolina data obtained March 2018 via online query of data from https://quickstats.nass.usda.gov/.

[83] User's Guide for Estimating Emissions from Municipal Solid Waste Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2017-12/documents/solid_waste_users_guide.pdf

The default values are used for landfill flaring which comes from EPA's Landfill Methane Outreach Project (LMOP) database.[84] Default population data from the US Census is included for the landfill gas emissions calculation.

The CH_4 emissions from industrial landfills in the SIT are assumed to be seven percent of the MSW landfill emissions. No additional information has been found so the default value has been used.

Default fractions for plastics, synthetic rubber, and synthetic fiber combustion are also used.

Deviations from Defaults
For the landfill sector, total landfill disposal data from 1990 to 2015 have been obtained from the North Carolina Division of Waste Management.[85] These data are published in an annual report based on fiscal year, which is from July 1 through June 30 of the following year, and contain construction and demolition (C&D) debris. Since the SIT is based on calendar year rather than this fiscal year, the disposal value is apportioned to the two partial calendar years represented by the fiscal year (half of the value is assigned to each year) then the two values from different fiscal years are summed to get the total for a calendar year. The C&D debris has been apportioned in the same manner and subtracted from the disposal value.

Information regarding LFGTE projects has been extracted from EPA's LMOP database to estimate landfill gas annual flow and years of use.[86]

Future Refinements
Further research into landfill flaring, CH_4 emissions from industrial landfills, and factors for the combustion of plastics, synthetic rubber and synthetic fibers would enhance the accuracy of the emission estimations. For consistency with other modules, State population data could be used instead of the default population values.

3.1.8 Wastewater

Description
The Wastewater module of the SIT calculates CH_4 and N_2O emissions from the treatment of Industrial and Municipal Wastewater. The tool is separated into Municipal Wastewater and Industrial Wastewater sections. The Municipal Wastewater section calculates direct N_2O and N_2O from biosolids, and CH_4 emissions. The Industrial section calculates CH_4 emissions from the fruit and vegetable, red meat, poultry, and pulp and paper industries.

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[84] Landfill Technical Data, Landfill and Landfill Gas Energy Project Database, Landfill Methane Outreach Program (LMOP), US. Environmental Protection Agency, accessed at https://www.epa.gov/lmop/landfill-technical-data.
[85] Solid Waste Management Annual Reports, North Carolina Division of Solid Waste, accessed at https://deq.nc.gov/about/divisions/waste-management/sw/data/annual-reports.
[86] Landfill Gas Energy Project Data, Landfill and Landfill Gas Energy Project Database, Landfill Methane Outreach Program (LMOP), US. Environmental Protection Agency, accessed at https://www.epa.gov/lmop/landfill-gas-energy-project-data.

Background and Defaults
The calculation methodology in the Wastewater module is complex and varies within the two sections. The methodology for estimating GHG emissions from Wastewater is provided by the User's Guide for this module as well as instructions and information provided on the spreadsheets for each module.[87]

The source for Municipal Wastewater default values for CH_4 emissions is reported as state and local public works agencies. Due to the limited time allowed for compiling this report, the default data has been used for the Municipal Wastewater section of this tool.

The Industrial section of this module provides default data for red meat industry but not for the poultry, pulp and paper, or fruit and vegetable industries. The default red meat data is obtained from the USDA, National Agriculture Statistics Service.[88]

Deviations from Defaults
No source of wastewater activity data for the fruits and vegetables industry could be found in the time allowed for this report.

Wastewater emissions data for the pulp and paper industry are estimated from emissions related data reported to NC DAQ's Internet-Based Enterprise Application Management - Emissions Data (IBEAM-ED) module data by permitted pulp and paper facilities. Emissions are estimated for this sector from 2003 to 2016.

Production data needed to calculate wastewater emissions for the poultry sector has been obtained from NC Department of Agriculture and Consumer Services (NC DA&CS).[89]

Future Refinements
State-specific red meat production data and fruit and vegetable production data would enhance the emission estimates for this module.

For consistency with other modules, State population data could be used instead of the default population values.

3.1.9 Industrial Processes

Description
The Industrial Processes module of the SIT calculates GHG emissions as follows:

- CO_2 emissions from cement production, lime manufacture, limestone and dolomite use, soda ash manufacture and consumption, iron and steel production, and ammonia manufacture
- N_2O emissions from nitric acid production and adipic acid production

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[87] User's Guide for Estimating Emissions from Wastewater Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2017-12/documents/wastewater_users_guide.pdf

[88] Quick Stats, National Agricultural Statistics Service, USDA, accessed at https://quickstats.nass.usda.gov/.

[89] Kris Krueger, NC Department of Agriculture and Consumer Services, "Poultry Databases", email transmittal to Tammy Manning, NC Division of Air Quality, January 12, 2018.

- HFC, PFC and SF_6 from aluminum production, HCFC-22 production, consumption of substitutes for ODS, semiconductor manufacture, electric power transmission and distribution, and magnesium production and processing

Background and Defaults

The methodology in the Industrial Processes module varies by sector so each sector is discussed separately with specific examples in the user manual. The methodology for estimating GHG emissions from Industrial Processes is provided in the User's Guide for this module as well as instructions and information provided in the spreadsheets for each module.[90]

North Carolina does not have the following Industrial Processes operating in the State; cement manufacture, lime manufacture, ammonia production, nitric acid production, adipic acid production, magnesium production and HCFC-22 production.

Two sectors in this module, (1) consumption of ODS substitutes and (2) semiconductor manufacture, do not rely on state-level data for emissions estimate. For consumption of ODS substitutes, estimates of the national emissions from this sector are distributed to each state based on the state's percentage of the total population. National emissions from the semiconductor manufacturing sector are distributed to North Carolina based on the ratio of the monetary value of North Carolina semiconductor shipments to the value of the national semiconductor shipments.[91] The results of the module's GHG estimates for semiconductors was compared to the GHG emissions reported by permitted semiconductor manufacturers in North Carolina and the two data sets are comparable.

Deviations from Defaults

Iron and Steel Production is the only sector in the Industrial Processes module where defaults are not used. The default values for this sector are based on national averages and appeared to overestimate emissions. Therefore, production or activity data from NC DAQ's IBEAM-ED module data for three permitted facilities are combined and converted to metric tons. These values are entered into the SIT for calendar years 2001 to 2015.

Phosphoric acid production is not included in the SIT Industrial Processes module; however, North Carolina emissions data are reported for this process to EPA's GHG Reporting Program. Because North Carolina has one phosphoric acid production facility that reports their CO_2 emissions to EPA, we have added these emissions to the Industrial Process sector in this report. For calendar years 2010 through 2016, phosphoric acid production CO_2 emissions obtained from GHG Reporting Program are reported in this inventory. Calendar years 2002-2009 emissions are estimated using data reported to the NC Division of Air Quality, current carbon weight percent values obtained from the facility and the calculation equation Z-1A in Part 98 Subpart Z of the Federal Mandatory GHG Reporting Rule. Based on USGS Mineral Yearbook information, the first year of wet process phosphoric acid production at the North

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[90] User's Guide for Estimating Emissions from Industrial Processes Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2018-03/documents/industrial_processes_users_guide_508.pdf

[91] U.S. Census Bureau Economic Census for Semiconductors (2012), U.S. Census Bureau, Washington, DC., 2012

Carolina facility appears to be 1994. No throughput data or weight percent of carbon are readily available for calendar years 1994 through 2001; therefore, the 2002 CO_2 emission value is reported for 1994 through 2001 as a best estimate.

Future Refinements

For the two sectors that use national emissions, Consumption of ODS substitutes and Semiconductor Manufacturing, the SIT default population values for North Carolina from 1990 to 2015 are used since these tables are protected and could not be accessed. For consistency with other modules, the State population data could be used for the allocation process instead of the default population values.

The ODS substitutes sector is the largest contributor to PFC, HFC, and SF_6 emissions for North Carolina. A more in-depth review of the calculation methodology for this sector may be warranted since the projected values for this sector are significantly larger than previously forecast.

3.1.10 Land Use, Land Use Changes and Forestry

Description

The Land Use, Land-Use Changes and Forestry (LULUCF) module calculates emissions and/or sequestration of CO_2, CH_4, and N_2O from the following eight source/sink subsectors:

Liming of soils	Carbon flux from forest management
Fertilization of soils	Carbon flux from agricultural soil
N_2O from settlement soils	Carbon storage in urban trees, and
Forest fires	Carbon storage in landfilled yard and food waste

There are additional subsectors within this source/sink sector that are not accounted for in the SIT including conversion of land to settlement and both wetlands and conversion of wetlands. A detailed crosswalk between the SIT and the EPA GHG Inventory needs to be developed to understand what LULUCF sources/sinks may not be included in the SIT.

Background and Defaults

The methodology for estimating CO_2, CH_4, and N_2O emissions from LULUCF is provided in the User's Guide for this module as well as instructions and information provided in the spreadsheets for each module.[92] The methodology for estimating emissions/carbon sinks varies considerably for each of the above categories of sources/sinks. Carbon flux estimates are based on changes in use from year to year rather than activities in a given year.

The default historical LULUCF data provided in the SIT module for North Carolina is used for the majority of categories except as noted below. Note that the module does not provide all of the default data necessary for estimating emissions/sinks for all subsectors. Data for liming of

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[92] User's Guide for Estimating Emissions and Sinks from Land Use, Land-Use Changes, and Forestry Using the State Inventory Tool, Prepared for State Energy and Environment Program, US. Environmental Protections Agency, Prepared by ICF, October 2017. https://www.epa.gov/sites/production/files/2017-12/documents/land-use_change_and_forestry_users_guide.pdf.

soils is only available for 1990-1993 and for 2008 from the USGS. No other data sources were found for application of lime to soils. Therefore, emissions are not estimated for some years. Default data for forest fires is not available in the SIT therefore these data were obtained from federal and state sources (see discussion in the following section).

The module provides default data for changes in urban tree stocks. However, for North Carolina, the default data assumes one value for the percent of urban area with tree canopy for all years, 51 percent. Therefore, as the urban area grows, the percent of urban tree canopy grows at a steady rate with no apparent accounting for the loss of vegetation from the expansion of urban settlements. North Carolina urban areas have doubled since 1990, resulting in a doubling of the sequestration of carbon by urban tree stocks. Due to this doubling of the urban tree stocks from 1990-2015, with no accounting for decreases in vegetation due to urbanization, the default data and methodology for urban tree canopy was not included in the carbon flux evaluation.

The table below summarizes the approaches used for the various subsectors of LULUCF.

Table 3-2: Summary of Methods and Data Used to Estimate LULUCF Emissions and Sinks

Subsector of LULUCF	**Approach**	**Data Source**
Liming of soils	SIT Default	Data for liming of soils is only available for 1990, 1992, 1993 and for 2008 from the USGS
Fertilization by urea	SIT Default	Annual data from proprietary source
Synthetic fertilization of settlement soils	SIT Default	Annual data from proprietary source
Forest fires	SIT method with alternate data	Data obtained from NC and federal databases
Carbon flux from forest management	Alternate data and method	Carbon flux data obtained from USDA FIA
Harvested wood products	SIT Default	Annual data developed from estimates for 1987, 1992 and 1997
Carbon flux from agricultural soil	SIT Default	Data available in SIT based on US GHG Inventory
Carbon storage in landfilled yard and food waste	SIT Default	Estimates available in SIT based on population
Carbon storage in urban trees, and	Not Estimated	Data is not sufficient in quality in SIT

<u>Deviations from Defaults</u>

The USDA Forest Inventory and Analysis (FIA) recently completed the second cycle of the 5-year forest survey for North Carolina. This 10-year data set and newer, more robust, statistical modeling of forest carbon allowed for significantly improved estimates of carbon flux for North Carolina compared with the SIT default data and methods. Therefore, these data were used to represent carbon flux from forest management. See Chapter 6 of the EPA U.S. GHG Inventory for a more complete discussion on the methods and data sources.[93]

Data for wildfires and prescribed burning is not included in the SIT Module. The National Interagency Fire Center (NIFC) publishes historic data on the number of acres burned at forests in each state for the years 2002 to 2015.[94] Data on acres burned for earlier years is not available from NIFC. The North Carolina Division of Forestry publishes historic data on the number of acres burned at State- and privately-owned forests from 1928 through 2015.[95] Therefore, these data were used for years 1990 through 2001. The LULUCF module is then used to estimate GHG emissions for wildfires and prescribed burning.

Data Reasonableness for Forest Carbon Flux

The process for estimating forest carbon flux is complicated. It primarily relies on survey data collected by the USFS and the USFS Carbon Calculation Tool (CCT). The CCT is a computer application that reads publicly available forest inventory data collected by the USFS FIA and generates state-level annualized estimates of carbon stocks on forest land based on USFS Forest Carbon Budget Model (FORCARB2) estimators.[96,97]

To provide a means of ground-truthing the FIA forest carbon flux data, the results of the forest management carbon flux calculation due to Land Use Changes in Above Ground Biomass in year 2013 is compared to (1) the equivalent amount of carbon that would need to be sequestered by young trees and (2) the total acres of forest required to grow the young trees. Table 3-3 presents the results of the calculations. In 2013, the USFS estimates approximately 5.77 million metric tons of CO_2 was sequestered in above ground biomass. The calculations show that approximately 844,580 acres of young trees must be planted in North Carolina forests during 2013 to sequester that amount of carbon. This represents approximately 4% of the forest and timberland area in North Carolina and only 2% of the area of the State. Therefore, the estimate for net carbon sequestration of above ground biomass is only a small percentage of the total acreage of North Carolina's forest lands.

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[93] Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2016, EPA 430-P-18-001, U.S. Environmental Protection Agency, Washington, D.C., February 6, 2018.

[94] Historical year-end fire statistics by state compiled from National Interagency Coordination Center fire records, National Interagency Fire Center, accessed at https://www.nifc.gov/fireInfo/fireInfo_statistics.html.

[95] Number of Wildfires on State- or Privately-Owned Land Per Year in North Carolina, 1928-2015, accessed at http://www.ncforestservice.gov/fire_control/pdf/firesperyear.pdf.

[96] Smith, James E.; Heath, Linda S.; Nichols, Michael C., US Forest Carbon Calculation Tool: Forest-Land Carbon Stocks and Net Annual Stock Change, Report NRS-13, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station, 2007, accessed at https://www.nrs.fs.fed.us/pubs/2394.

[97] Smith, James E.; Heath, Linda S.; Nichols, Michael C., Mills, John R., FORCARB2: An Updated Version of the U.S. Forest Carbon Budget Model, Report NRS-67, Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station, 2009, accessed at https://www.nrs.fs.fed.us/pubs/gtr/gtr_nrs67.pdf.

Table 3-3: Check of CO_2 Sequestration - Land Use Changes in Above Ground Biomass

Parameter	Value	Units
Area of North Carolina	34,444,020	acres
2013 NC Area of Forests & Timberland	18,610,700	acres
CO_2 absorbed per young tree	26	lb/tree
Average number of trees per acre	700	tree/acre
lb CO_2 absorbed by young tree	18200	lb/acre
Conversion	0.0004536	metric ton /lb
CO_2 absorbed by young trees per acre	8.2554	metric ton/acre

2013 Change in above ground biomass carbon	**-5,771,685**	**metric ton of carbon**
Estimated acres of young trees growing	**844,580**	**acres**
Area of young trees vs Area of NC Forests	4%	
Area of young trees vs Area of State	2%	

Future Refinements

This module uses data and quantification methods from several different sources. An in-depth analysis of the data and method is beyond the scope of this initial inventory. It is challenging to measure and quantify the mass of carbon associated with each Land Use activity. The following known issues exist for this sector:

- Urban tree data are not of sufficient quality to include in the inventory
- Data for liming of soils are only available for a select year from a third party vendor, and
- Projection data for forestry management are only available at the national level

To address these and other issues, North Carolina has convened a panel of experts to assist in improving both the methodology and the data sets used to estimate emissions and sinks from LULC. Future emissions inventories are expected to use the methods and data sets recommended by this panel.

3.2 Projected GHG Emissions (2016-2030)

Description

Because of delays in preparing and releasing historical data by various government agencies, 2015 is generally the last year for which historical data are used in estimating North Carolina's GHG emissions. This section summarizes the methods and data sources that are used to project the 2015 emissions from 2016 through 2030. These projections represent a characterization of future emissions based on information available at the time of this study and only reflect the effects of "on-the-books" measures to limit GHG emissions where information is available to characterize their effects.

Background and Defaults

Emissions forecasts are developed using the Projections Tool module within EPA's SIT. The Projections Tool has 18 sub-modules for estimating source sector emissions using different default data and forecasting techniques for each sector. The methodologies incorporated into the Projections Tool are summarized in the User's Guide for this module, as well as instructions and information provided in the spreadsheets for each module subsector.[98]

This module forecasts emissions for each source sector using one of the following approaches.

(1) Projections of emissions activity such as fuel use or number of livestock or surrogates for such activity (e.g., human population used to forecast use of ODS substitutes).
(2) Extrapolation of historical trends in emissions or emissions activity.

The following table summarizes the default projection methodology for each source sector.

Table 3-4: Projection Methods for Each Source Sector

Forecast Based on Projections Data	Forecast Based on Historical Trend
Electric Generation and Consumption*	Agricultural Soils
RCI Combustion*	Agricultural Residue Burning
Transportation/Mobile Source Combustion	Waste Combustion
OSD Substitutes; Electric Power Systems	Industrial Processes (except subsectors at left)
Solid Waste Management	Wastewater
Livestock	
Natural Gas Systems	

*Excludes wood. Wood consumption is based on the historical trend in fuel consumption.

For sectors that forecast emissions based on projections data, the tool relies on projections of activity data (or surrogate activity data) obtained from similar federal and State resources as those used in calculating historical emissions.

Note that the Projections Tool does not have a sub-module for the LULUCF sector, therefore, the 2015 year estimates for GHG emissions and carbon sinks are carried forward to each forecast year.

Deviations from Defaults

In some cases, different projections methods/data are used to estimate emissions than the default methods/data provided in EPA's Projections Tool. These revisions reflect the use of more current data or North Carolina-specific data than provided by the Tool. The revisions to the Tool defaults are summarized in Table 3-5. In addition to the revisions listed in this table, the Tool default population and gross state product projections are replaced with projections from the North Carolina Office of State Budget and Management.[99]

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[98] "User's Guide for States Using the Greenhouse Gas Projection Tool," prepared by ICF for the State Energy and Environment Program and U.S. Environmental Protections Agency, October 2017, available for download from https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool.

[99] Carrie Hollis, North Carolina Office of State Budget and Management, "RE: State economic data," transmitted to Andy Bollman, North Carolina Division of Air Quality, March 2, 2018.

Table 3-5: Summary of Revisions to EPA Projections Tool Defaults

Sector	Revised Projections Approach(es)	Rationale for Use
Electric Generation and Imported Electricity Use	*Electricity Generation* For 2016, historical fuel use in MMBtu obtained from EIA's Form 923 data is used.[100] For 2017 through 2030, three different data sets are used. 1) Duke Energy January 2018 forecast of fuel use in MMBtu is used for Duke Energy power plants from 2017-2028.[101] 2) AEO 2018 forecast for Southeast electric power sector consumption of coal, distillate oil and natural gas is used to develop growth factors to apply to Duke 2028 forecast to estimate fuel consumption for 2029 and 2030.[102] 2) All other power plants use the 2014-2016 average fuel use in MMBtu from EIA Form 923 data. This average value is carried forward from 2017 through 2030. *Imported Electricity Use* a. For 2016-2030, AEO 2018 projections for retail electricity consumption are used. b. The percent of imported electricity for all projection years is assumed to be the average of the percent imported for 2013-2015 (11.98%) based on SEDS data.[103] c. The imported electricity use for a given year is calculated as the projected retail electricity use multiplied by the percent imported. d. The 2016 eGRID GHG emissions factor (0.9866 lb CO_2e/kWh) and percent grid loss (4.97%) published by EPA are used to calculate GHG emissions.[104]	Historic fuel use data is preferable to a projection. Duke Energy's forecast is preferred because it is developed using Duke Energy's proprietary data. The historic average fuel use is used since these sources represent a small percentage of emissions from this sector and forecasted use of these smaller sources is not reliable. Imported electricity emissions were calculated using the 2013-2015 average percent imported. This value was held constant for the projection since there are many uncertainties in estimating imported electricity. The 2016 values for the electricity grid emissions factors and transmission losses are used for all years of the projection since no other data are available.

[100] 2016 Form 923 Detailed Data, U.S. Energy Information Administration, accessed at https://www.eia.gov/electricity/data/eia923/.
[101] Duke Energy, "January 2018 FOF Report for 2018-2022.xls" and "2017 IRP No CO_2 Data for NCDAQ_2023-2030.xls", e-mail transmittal to Ming Xie, North Carolina Division of Air Quality, February 2, 2018.
[102] Annual Energy Outlook 2018, U.S. Energy Information System, Department of Energy, February 6, 2018, accessed at https://www.eia.gov/outlooks/aeo/.
[103] EIA State Energy Data System (SEDS): 1960-2015, accessed at https://www.eia.gov/state/seds/seds-data-complete.php?sid=NC#Consumption.
[104] Emissions & Generation Resource Integrated Database 2014 v2 (eGRID2014), Clean Air Markets Division U.S. Environmental Protection Agency, February 2017, https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid.

Sector	Revised Projections Approach(es)	Rationale for Use
RCI Combustion	Incorporate AEO projections for South Atlantic region from latest (2018) AEO	More current than default Tool (reflects 2017 AEO)
Transportation/Mobile Source Combustion	*Gas/Diesel Vehicles* - growth factors derived from emissions output from EPA MOVES model runs for North Carolina (interpolated values from available output for 2011, 2023, and 2028) *Alternative Fuel Vehicles* - extrapolate 2016-2030 trend back to 2015 using the FORECAST function and then applied growth factors from the resulting 2015-2030 series to the 2015 emissions value *Aircraft* - FAA's Terminal Area Forecast, Summary Report growth factors derived from total Itinerant operations in NC by year. *Remaining Subsectors* - growth rates from extrapolated 2000-2015 fuel consumption values	More sophisticated modeling approach that uses official EPA onroad mobile source emissions estimation model To address Tool's suspect large change between 2015 and 2016 Latest official projections of North Carolina emissions activity Default projections result in some anomalous emissions estimates
Industrial Processes	*ODS substitutes* and *Electric Power Transmission & Distribution Systems* – apply growth rates from national projections in Tool to 2015 NC emissions *Aluminum Production* - set emissions to zero in years 2016 thru 2018 (Tool projects zero in all years after 2018) *Phosphoric acid production* is not included in the SIT Industrial Processes module; however, North Carolina emissions data are reported for this process to EPA's GHG Reporting Program. The 2016 CO_2e value is carried forward every year to 2030	Default projections result in some anomalous emissions estimates Aluminum facility has been permanently closed and no longer has air permit Reported GHG emissions from phosphoric acid production are relatively constant from 2002 through 2016, so the 2016 value is held constant for projected years.
Livestock	Replace default emissions factors with 2015 year values from Agriculture Module Replace default livestock counts with extrapolated counts developed from State historical trend for each livestock category (count of goats and horses both held constant)	Emissions factors outdated in Tool Default projections result in some anomalous estimates
Natural Gas Systems	Extrapolation of 2005-2015 historical emissions	Use of entire 1990-2015 results in suspect 2016 value (inflection point

Sector	Revised Projections Approach(es)	Rationale for Use
		between 2004 and 2005 emissions, so extrapolation starts with 2005)
Agricultural Residue Burning	Apply growth rates by pollutant from national projections to the 2015 emission values for NC	Default projections result in some anomalous emissions estimates
Solid Waste	Apply post-2015 growth rates from the Tool to the 2015 SIT Waste Module emissions values	Projections Tool generates much lower historical emissions estimates than the Waste Module

Future Refinements

Most broadly, additional research may identify improved forecast data/methods for sectors for which projections are based on historical trends. It is also important to keep current with the regulatory landscape and determine when the existing projections no longer reflect current standards. For example, the onroad vehicle emissions projections model the effects of full implementation of vehicle CAFE/GHG emissions standards promulgated by EPA and NHTSA.[105] However, EPA and NHTSA has signaled their intention to revise future year GHG/fuel efficiency standards for light-duty vehicles.[106] In addition, projections for a few subsectors are based on EPA national forecasts from several years ago (e.g., the projections for Electric Power and Transmission Systems are from a December 2012 report).[107] With further effort, it may be possible to identify a more current source of national GHG projections for some source sectors. Finally, it is good practice to review the accuracy of these projections as historic data become available, and to incorporate any lessons learned in preparing future GHG forecasts.

Uncertainty

In keeping with our approach of using the SIT for developing historical emissions estimates, DAQ relied on the SIT's Projection Tool to forecast emissions over the 2016-2030 period. In cases where more state-specific and/or recent data were identified than provided in the tool, DAQ replaced default values with these more representative data.

There is associated uncertainty with the forecast capability of the tool, lack of transparency in the methodologies contained in the projection tool, outdated default data, and inherent uncertainty of GHG policy changes. DAQ emphasizes our commitment to review the validity of the GHG projections methods used in this effort when undertaking future GHG inventory efforts. A more in-depth discussion of the uncertainty associated with the emissions projections contained in this report is available upon request.

[105] Corporate Average Fuel Economy, National Highway Traffic Safety Administration, https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.

[106] U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "The Safer Affordable Fuel Efficient (SAFE) Vehicles Proposed Rule for Model Years 2021-2026," 49 CFR 48578, September 26, 2018.

[107] U.S. Environmental Protection Agency, Office of Atmospheric Programs, Climate Change Division, "Global Anthropogenic Non- CO_2 Greenhouse Gas Emissions: 1990 – 2030," EPA 430-R-12-006, revised December 2012.

Appendix A. North Carolina GHG Emissions for All Years

Table A-1: North Carolina Historic GHG Emissions Inventory (1990-2002) in MMT CO_2e

Source Sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Electricity Use	**54.57**	**53.86**	**62.35**	**67.19**	**59.59**	**62.56**	**69.17**	**70.20**	**68.59**	**70.99**	**75.01**	**73.91**	**75.70**
Electric Power Generation	46.28	47.04	54.08	58.67	53.41	56.43	64.27	66.87	66.08	65.42	69.55	66.93	69.40
Imported Electricity[a]	8.29	6.82	8.27	8.52	6.18	6.13	4.90	3.33	2.50	5.57	5.46	6.98	6.31
Residential/Commercial/Industrial[b]	**26.77**	**26.06**	**28.72**	**28.32**	**27.52**	**29.13**	**30.64**	**29.43**	**28.11**	**26.51**	**28.37**	**27.14**	**25.30**
Industrial	17.59	16.95	18.71	17.84	17.05	18.22	18.21	17.91	16.91	15.89	16.45	15.67	14.79
Commercial	3.79	3.60	3.84	4.00	4.36	4.17	4.71	4.50	4.38	4.12	4.61	4.55	4.06
Residential	5.39	5.51	6.17	6.48	6.11	6.74	7.72	7.02	6.81	6.49	7.30	6.92	6.45
Transportation	**40.21**	**39.84**	**40.71**	**42.33**	**43.68**	**45.40**	**47.87**	**48.73**	**49.87**	**50.77**	**52.37**	**51.52**	**51.90**
Gasoline & Diesel Highway	35.13	35.03	35.90	37.36	38.98	40.06	40.86	42.39	43.58	44.97	46.07	44.91	45.72
Non-Highway	5.08	4.80	4.81	4.97	4.69	5.34	7.00	6.33	6.28	5.80	6.30	6.59	6.17
Alternative Fuel Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
Agriculture	**7.06**	**7.67**	**8.13**	**8.75**	**9.86**	**10.44**	**11.28**	**11.26**	**11.28**	**10.59**	**10.31**	**10.61**	**10.47**
Manure Management	2.59	2.94	3.35	3.87	4.68	5.22	5.71	5.79	6.11	5.80	5.60	6.02	5.98
Agricultural Soil Management	2.87	3.03	2.97	3.00	3.18	3.11	3.37	3.29	3.19	2.78	2.77	2.62	2.52
Enteric Fermentation	1.60	1.70	1.81	1.89	2.00	2.11	2.21	2.18	1.98	2.01	1.94	1.98	1.97
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**6.39**	**6.67**	**6.80**	**7.02**	**7.17**	**7.36**	**7.55**	**7.67**	**7.54**	**7.51**	**7.73**	**7.85**	**8.04**
Municipal Solid Waste	5.47	5.74	5.84	6.02	6.15	6.31	6.48	6.58	6.45	6.39	6.55	6.67	6.81
Wastewater	0.92	0.93	0.96	1.00	1.02	1.05	1.07	1.09	1.09	1.12	1.18	1.18	1.22
Industrial Processes	**1.04**	**1.02**	**1.06**	**1.16**	**1.43**	**1.88**	**2.21**	**2.46**	**2.61**	**2.91**	**3.09**	**3.26**	**3.43**
ODS Substitutes	0.01	0.01	0.05	0.16	0.37	0.85	1.18	1.51	1.72	1.96	2.21	2.41	2.56
Iron & Steel Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.07
Electricity Transmission & Distribution	0.77	0.74	0.75	0.75	0.69	0.65	0.59	0.54	0.46	0.47	0.44	0.42	0.39
Semiconductor Manufacturing	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.05	0.06	0.06	0.05	0.07
Soda Ash	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.07	0.08	0.08	0.08
Limestone and Dolomite Use	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.01	0.01	0.04	0.01	0.02	0.02
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aluminum Production	0.18	0.18	0.17	0.16	0.14	0.14	0.15	0.15	0.16	0.16	0.15	0.11	0.12
Phosphoric Acid Production	0.00	0.00	0.00	0.00	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Natural Gas and Oil Systems	**0.86**	**0.86**	**0.88**	**0.91**	**0.92**	**0.94**	**0.96**	**0.98**	**1.01**	**1.03**	**1.05**	**1.07**	**1.10**
Distribution	0.48	0.48	0.50	0.53	0.54	0.56	0.58	0.60	0.63	0.65	0.67	0.69	0.72
Transmission	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Gross Emissions	**136.89**	**135.98**	**148.66**	**155.67**	**150.17**	**157.72**	**169.70**	**170.72**	**169.00**	**170.31**	**177.93**	**175.37**	**175.93**
Net Carbon Sinks – LULUCF[c]	**-35.64**	**-35.74**	**-35.91**	**-35.86**	**-35.18**	**-35.24**	**-34.92**	**-34.64**	**-34.48**	**-33.79**	**-34.33**	**-34.78**	**-33.73**
Forest Fires Emissions	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Settlement Soils Emissions	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Soil Fertilization/Liming Emissions	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Landfill Yard/Food Waste Carbon Storage	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64
Agricultural Soil Carbon Flux	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23
Forest Carbon Flux	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31
Net Emissions	**101.25**	**100.24**	**112.75**	**119.80**	**114.99**	**122.48**	**134.78**	**136.08**	**134.52**	**136.52**	**143.60**	**140.60**	**142.20**

Table A-2: North Carolina Historic GHG Emissions Inventory (2003-2015) in MMT CO_2e

Source Sector	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Electricity Use	**71.89**	**76.89**	**79.37**	**77.92**	**84.58**	**82.67**	**73.65**	**81.69**	**73.58**	**66.85**	**62.08**	**63.36**	**58.48**
Electric Power Generation	68.67	69.72	73.27	70.67	76.34	72.69	62.71	71.06	60.71	55.95	54.80	56.23	51.10
Imported Electricity[a]	*3.22*	*7.17*	*6.10*	*7.25*	*8.24*	*9.98*	*10.94*	*10.63*	*12.86*	*10.90*	*7.28*	*7.14*	*7.37*
Residential/Commercial/Industrial[b]	**26.14**	**26.74**	**26.02**	**23.75**	**22.44**	**22.85**	**21.33**	**22.37**	**19.96**	**18.66**	**20.22**	**20.79**	**21.15**
Industrial	13.91	14.17	14.21	13.33	12.55	11.74	10.19	10.74	10.36	10.00	10.58	10.17	9.97
Commercial	4.89	5.30	5.06	4.62	4.19	5.00	5.27	5.11	4.35	4.17	4.29	4.82	5.76
Residential	7.34	7.26	6.75	5.80	5.69	6.11	5.87	6.52	5.26	4.48	5.35	5.80	5.43
Transportation	**52.51**	**53.95**	**55.19**	**54.37**	**55.69**	**53.70**	**48.81**	**48.79**	**47.29**	**46.36**	**50.09**	**50.08**	**49.02**
Gasoline & Diesel Highway	46.45	47.58	48.21	48.56	49.15	48.18	44.42	44.33	42.92	41.60	42.45	43.30	44.00
Non-Highway	6.04	6.34	6.96	5.78	6.50	5.48	4.35	4.41	4.33	4.72	7.60	6.73	4.98
Alternative Fuel Vehicles	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05
Agriculture	**10.91**	**10.88**	**10.65**	**10.51**	**11.15**	**10.74**	**10.63**	**10.09**	**10.28**	**10.56**	**10.15**	**10.57**	**10.38**
Manure Management	6.07	5.97	6.02	5.81	6.39	5.94	5.98	5.72	5.77	5.63	5.55	5.54	5.90
Agricultural Soil Management	2.91	3.01	2.74	2.86	2.89	3.01	2.84	2.62	2.78	3.18	2.87	3.30	2.74
Enteric Fermentation	1.94	1.90	1.89	1.84	1.88	1.79	1.81	1.74	1.73	1.74	1.72	1.73	1.73
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**8.17**	**8.35**	**8.52**	**8.84**	**9.00**	**9.06**	**9.07**	**9.51**	**9.35**	**9.09**	**8.85**	**8.05**	**8.44**
Municipal Solid Waste	6.92	7.04	7.23	7.49	7.65	7.68	7.60	7.99	7.75	7.52	7.27	6.49	6.82
Wastewater	1.26	1.31	1.29	1.35	1.35	1.38	1.47	1.53	1.60	1.57	1.59	1.55	1.61
Industrial Processes	**3.65**	**3.69**	**3.83**	**4.14**	**4.38**	**4.66**	**4.87**	**5.16**	**5.33**	**5.39**	**5.62**	**5.83**	**6.03**
ODS Substitutes	2.67	2.78	2.92	3.17	3.44	3.74	4.05	4.36	4.50	4.66	4.81	5.03	5.27
Iron & Steel Production	0.20	0.10	0.10	0.17	0.17	0.17	0.13	0.16	0.16	0.15	0.17	0.17	0.15
Electricity Transmission & Distribution	0.34	0.32	0.29	0.24	0.22	0.21	0.21	0.21	0.21	0.17	0.16	0.17	0.15
Semiconductor Manufacturing	0.08	0.09	0.09	0.12	0.12	0.11	0.08	0.10	0.12	0.11	0.10	0.13	0.13
Soda Ash	0.08	0.08	0.08	0.08	0.07	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.06
Limestone and Dolomite Use	0.02	0.03	0.03	0.06	0.06	0.04	0.04	0.05	0.05	0.03	0.05	0.05	0.05
Urea Consumption	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aluminum Production	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.00	0.00	0.00	0.00	0.00	0.00
Phosphoric Acid Production	0.14	0.16	0.18	0.18	0.18	0.18	0.17	0.20	0.21	0.19	0.25	0.22	0.22
Natural Gas and Oil Systems	**1.12**	**1.15**	**1.17**	**1.19**	**1.20**	**1.22**	**1.24**	**1.25**	**1.26**	**1.28**	**1.29**	**1.31**	**1.32**
Distribution	0.74	0.77	0.79	0.81	0.82	0.84	0.86	0.87	0.88	0.90	0.91	0.92	0.94
Transmission	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Gross Emissions	**174.40**	**181.65**	**184.74**	**180.72**	**188.44**	**184.90**	**169.59**	**178.86**	**167.05**	**158.18**	**158.29**	**160.00**	**154.82**
Net Carbon Sinks – LULUCF[c]	**-33.12**	**-32.71**	**-32.66**	**-33.26**	**-33.90**	**-33.06**	**-35.56**	**-35.30**	**-32.58**	**-33.97**	**-34.20**	**-34.39**	**-34.16**
Forest Fires Emissions	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Settlement Soils Emissions	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Soil Fertilization/Liming Emissions	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Landfill Yard/Food Waste Carbon Storage	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64	-0.64
Agricultural Soil Carbon Flux	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23	-0.23
Forest Carbon Flux	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31	-35.31
Net Emissions	**141.28**	**148.95**	**152.08**	**147.45**	**154.54**	**151.83**	**134.03**	**143.56**	**134.47**	**124.22**	**124.10**	**125.60**	**120.66**

Notes: Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

[a] Emissions from imported electricity occur outside North Carolina

[b] Onsite fuel combustion in Residential, Commercial and Industrial Sectors (RCI)

[c] Land Use, Land Use Changes and Forestry (LULUCF)

Table A-3: North Carolina GHG Emissions Inventory Data, 2016-2030 in MMT CO_2e

Source Sector	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Electricity Use	**57.41**	**52.60**	**46.16**	**48.39**	**45.74**	**46.38**	**44.53**	**44.12**	**45.32**	**40.59**	**40.97**	**42.01**	**43.25**	**43.23**	**42.46**
Electric Power Generation	50.02	45.32	38.80	41.00	38.34	38.95	37.06	36.61	37.76	32.99	33.35	34.35	35.56	35.50	34.70
Imported Electricity[a]	*7.38*	*7.28*	*7.36*	*7.40*	*7.39*	*7.43*	*7.46*	*7.51*	*7.56*	*7.60*	*7.63*	*7.66*	*7.69*	*7.73*	*7.76*
Residential/Commercial/Industrial[b]	**20.84**	**20.92**	**21.92**	**22.20**	**22.52**	**22.63**	**22.77**	**22.95**	**23.15**	**23.26**	**23.37**	**23.51**	**23.67**	**23.78**	**23.92**
Industrial	9.94	9.93	10.41	10.89	11.32	11.52	11.72	11.90	12.08	12.16	12.23	12.33	12.44	12.53	12.62
Commercial	5.79	5.72	6.02	5.95	5.84	5.77	5.72	5.72	5.73	5.76	5.79	5.82	5.86	5.89	5.93
Residential	5.11	5.28	5.49	5.37	5.36	5.34	5.33	5.33	5.34	5.35	5.35	5.36	5.37	5.37	5.38
Transportation	**49.88**	**48.72**	**47.58**	**46.44**	**45.27**	**44.13**	**42.96**	**41.81**	**41.41**	**41.00**	**40.62**	**40.21**	**39.82**	**39.50**	**39.22**
Gasoline & Diesel Highway	45.22	44.05	42.86	41.68	40.47	39.30	38.09	36.91	36.47	36.02	35.60	35.14	34.71	34.35	34.02
Non-Highway	4.60	4.62	4.67	4.70	4.74	4.77	4.80	4.83	4.87	4.91	4.95	4.99	5.04	5.08	5.12
Alternative Fuel Vehicles	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08
Agriculture	**10.54**	**10.53**	**10.52**	**10.52**	**10.51**	**10.50**	**10.50**	**10.49**	**10.48**	**10.47**	**10.47**	**10.46**	**10.45**	**10.45**	**10.44**
Manure Management	6.05	6.05	6.06	6.06	6.06	6.07	6.07	6.08	6.08	6.09	6.09	6.09	6.10	6.10	6.11
Agricultural Soil Management	2.85	2.84	2.83	2.82	2.82	2.81	2.80	2.80	2.79	2.78	2.78	2.77	2.76	2.75	2.75
Enteric Fermentation	1.64	1.64	1.63	1.63	1.63	1.62	1.62	1.61	1.61	1.60	1.60	1.59	1.59	1.59	1.58
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Management	**8.60**	**8.77**	**8.94**	**9.12**	**9.29**	**9.47**	**9.64**	**9.82**	**10.00**	**10.17**	**10.35**	**10.53**	**10.71**	**10.89**	**11.07**
Municipal Solid Waste	6.94	7.09	7.23	7.38	7.52	7.67	7.81	7.96	8.11	8.26	8.40	8.55	8.70	8.85	9.00
Wastewater	1.65	1.68	1.71	1.74	1.77	1.80	1.83	1.86	1.89	1.92	1.95	1.98	2.01	2.03	2.06
Industrial Processes	**6.63**	**7.18**	**7.73**	**8.29**	**8.84**	**9.33**	**9.83**	**10.32**	**10.81**	**11.31**	**11.59**	**11.88**	**12.16**	**12.45**	**12.73**
Natural Gas and Oil Systems	**1.34**	**1.35**	**1.37**	**1.38**	**1.40**	**1.41**	**1.43**	**1.44**	**1.46**	**1.47**	**1.49**	**1.50**	**1.52**	**1.53**	**1.55**
Gross Emissions	**155.22**	**150.08**	**144.22**	**146.34**	**143.57**	**143.86**	**141.65**	**140.95**	**142.63**	**138.28**	**138.87**	**140.10**	**141.58**	**141.83**	**141.37**
Net Carbon Sinks – LULUCF[c]	**-34.09**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**	**-34.03**
Net Emissions	**121.12**	**116.06**	**110.20**	**112.32**	**109.55**	**109.83**	**107.63**	**106.93**	**108.60**	**104.25**	**104.84**	**106.07**	**107.55**	**107.81**	**107.35**

Notes: Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

[a] Emissions from imported electricity occur outside North Carolina

[b] Onsite fuel combustion in Residential, Commercial and Industrial Sectors (RCI)

[c] Land Use, Land Use Changes and Forestry (LULUCF)

Appendix B. Global Warming Potentials

Each GHG compound has a set of physical properties that determine its ability to increase the temperature of Earth's atmosphere. Two key properties are 1) the ability of a compound to absorb and re-emit energy (radiative efficiency), and 2) how long the compound stays in the atmosphere (atmospheric lifetime). The Global Warming Potential (GWP) is a unitless metric that allows comparisons of the global warming impacts of different GHGs to the warming potential of CO_2. Specifically, GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb relative to the emissions of 1 ton of CO_2 over a given period of time. The larger the GWP, the more that a given gas warms the atmosphere compared to CO_2.

The emissions of each GHG are reported using a common metric called CO_2 equivalent (CO_2e). This approach normalizes the emissions of the various GHGs to reflect the GWP of each compound. For this report the emissions of each GHG are converted to emissions in CO_2e by multiplying the mass of emissions in metric tons by its GWP.

Table B-1 presents the GWPs published by the IPCC's Fourth Assessment Report (AR4) for 20-year and 100-year time horizons. While this inventory uses the 100-year values to calculate GHG emissions as CO_2e, the 20-year value is sometimes used as an alternative. The 20-year values are based on the energy absorbed by a gas over the course of 20 years, which prioritizes gases with shorter lifetimes. Because all GWPs are calculated relative to CO_2, GWPs based on a shorter timeframe will be larger for gases with lifetimes shorter than that of CO_2, and smaller for gases with lifetimes longer than CO_2. In order to comply with international GHG reporting standards under the UNFCCC, and in following EPAs methodology for the Inventory of U.S. Greenhouse Gas Emissions and Sinks, this emissions inventory uses GWP values from AR4 for a 100-year horizon.[108]

[108] Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007, 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, accessed at https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html.

Table B-1: Global Warming Potentials Used to Calculate GHG Emissions

	Global Warming Potentials	
Gas	**20 Year**	**100 Year**
CO_2	1	1
CH_4	72	25
N_2O	289	298
HFC-23	12,000	14,800
HFC-32	2,330	675
HFC-125	6,350	3,500
HFC-134a	3,830	1,430
HFC-143a	5,890	4,470
HFC-152a	437	124
HFC-227ea	5,310	3,220
HFC-236fa	8,100	9,810
HFC-4310mee	4,140	1,640
CF_4	5,210	7,390
C_2F_6	8,630	12,200
C_4F_{10}	6,330	8,860
C_6F_{14}	6,600	9,300
SF_6	16,300	22,800
NF_3	12,300	17,200

Appendix C. Treatment of CO_2 Emissions from Biomass Combustion

Biomass in GHG Inventories

Greenhouse gas (GHG) inventories treat emissions from the combustion of biomass differently than emissions from fossil fuel combustion. Under the methodology employed by both the U.S. EPA and the Intergovernmental Panel on Climate Change (IPCC), only emissions of nitrous oxide and (N_2O) and methane (CH_4) from biomass combusted for energy are included in the calculation of gross GHG emissions.[109] The carbon dioxide (CO_2) released during this combustion is already included in the inventory through the removal of the biomass fuel in the harvested carbon stocks of the Land Use, Land Use Changes and Forestry (LULUCF) sector. For these reasons, CO_2 emissions from biomass combustion for energy are not included in gross emissions, but rather included in the net emissions reported for the LULUCF sector. However, CO_2 emissions from biomass combusted to produce energy are reported for informational purposes below under the listing "wood and biofuel combustion for energy." As discussed further below, these emissions cannot be included as gross emissions as it would result in the double-counting of emissions.

Table C-1: North Carolina Wood and Biofuel Combustion CO_2 Emissions in MMT

	Historic					Projected		
	1990	2005	2012	2015	2017	2020	2025	2030
Wood and Biofuel Combustion for Energy[a]	*8.82*	*8.62*	*12.87*	*13.04*	*12.73*	*12.73*	*12.73*	*12.73*

[a]CO_2 emissions from wood and biofuels combustion are not included in energy consumption sector gross emission totals to avoid double-counting. In keeping with IPCC guidelines, these emissions are accounted for through net carbon flux calculations in the Land Use, Land-Use Change, and Forestry sector, while CH_4 and N_2O emissions from biomass combustion are included in gross emissions for each consuming energy sector.

In GHG inventories for the LULUCF sector, the harvest of biomass is tracked along with the growth of existing and new biomass. The year-to-year increase or decrease in the carbon stocks on forests and other land types, the carbon flux, is estimated for this sector. A positive flux indicates carbon is emitted and a negative flux indicates carbon is sequestered. Biomass that is harvested in a given year is separated into 1) biomass that is stored as a product (such as lumber) and 2) biomass that is not stored (such as biomass combusted for energy). The biomass that is not stored is zeroed out of the total harvested carbon stocks and is assumed to be emitted as carbon.

NC DAQ is using U.S. Forest Service (USFS) data and the U.S. EPA/IPCC LULUCF sector methodology to calculate carbon flux, which includes biomass harvested for energy combustion in North Carolina. The carbon stock and flux data obtained from the USFS is not at a level that allows the user to identify the amount of wood removed for combustion or stored in a product. The DEQ has established a Natural and Working Lands Stakeholder Group that will assist in improving the both the quality and transparency of the LULUC inventory for North Carolina.

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[109] IPCC Task Force on National Greenhouse Gas Inventories (TFI), Fact Sheet, Q2-10, "According to the IPCC Guidelines CO_2 Emissions from the combustion of biomass are reported as zero in the Energy sector. Do the IPCC Guidelines consider biomass used for energy to be carbon neutral?", https://www.ipcc-nggip.iges.or.jp/faq/faq.html

Biomass in Federal Policies

Separate from GHG inventory methodologies, there are several key programs, policies and studies for the U.S. that determine whether a fuel is carbon neutral for regulatory and other purposes. The various approaches are discussed at a high-level in the following paragraphs.

Congress created the renewable fuel standard (RFS) program to reduce GHG emissions and expand the nation's renewable fuels sector while reducing reliance on imported oil.[110] This program was authorized under the Energy Policy Act of 2005 and expanded under the Energy Independence and Security Act of 2007. The RFS program requires a certain volume of renewable fuel to replace or reduce the quantity of petroleum-based transportation fuel, heating oil or jet fuel. EPA determines whether a fuel qualifies as a renewable fuel using a set of requirements. One requirement is that the fuel must achieve a lifecycle reduction in GHG emissions as compared to a 2005 petroleum baseline. Certain fuel feedstocks are grandfathered into the program.

Under U.S. EPA's Second Draft Framework for Assessing Biogenic CO_2 Emissions from Stationary Sources, released in November of 2014, CO_2 emissions from biomass combusted at stationary sources cannot be assumed to be carbon neutral.[111] Instead, EPA developed a method for assessing whether the production, processing, and combustion of biomass for energy results in a net contribution of biogenic CO_2 emissions. An important component of the method is the agricultural or forest feedstock carbon and carbon fluxes associated with the landscape where the feedstock is grown and harvested.

In April of 2018, EPA issued a policy statement titled "EPA's Treatment of Biogenic Carbon Dioxide (CO_2) Emissions from Stationary Sources that Use Forest Biomass for Energy Production."[112] EPA's policy in forthcoming regulatory actions will be to treat biogenic CO_2 emissions resulting from the combustion of biomass from managed forests at stationary sources for energy production as carbon neutral. However, EPA also noted that "This statement of agency policy is not a scientific determination and does not revise or amend any scientific determinations that EPA has previously made." EPA's ongoing work under the Renewable Fuels Standard (RFS) and Title II will not be impacted by this policy and will continue to be governed by the existing regulatory and statutory process and requirements already in place.

[110] https://www.epa.gov/renewable-fuel-standard-program/overview-renewable-fuel-standard
[111] https://yosemite.epa.gov/sab/sabproduct.nsf/0/3235DAC747C16FE985257DA90053F252/$File/Framework-for-Assessing-Biogenic-CO2-Emissions+(Nov+2014).pdf
[112] https://www.epa.gov/sites/production/files/2018-04/documents/biomass_policy_statement_2018_04_23.pdf

Appendix D. Response to Public Comments

The allotted public comment period for the North Carolina Greenhouse Gas Inventory Draft was open from Friday, November 2, 2018 to Friday, December 14, 2018. During this time NC DAQ received comments from the following groups:

1. Cape Fear Public Utility Authority
2. Clean Air Carolina
3. Dogwood Alliance
4. Natural Resources Defense Council
5. Southern Environmental Law Center
6. Sierra Club

NC DAQ thanks these groups for taking the time to review the North Carolina Greenhouse Gas Inventory Draft and provide comments on the report. The following section outlines responses to comments that requested revisions to the draft inventory.

Comment: Several groups suggested that NC DAQ include emissions associated with biofuel (e.g., wood, ethanol, biodiesel) combustion as a line item in the inventory.

Response: Using a methodology derived from the Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2016, developed by EPA, NC DAQ has developed emissions estimates associated with biofuel combustion for energy. These estimates and associated methodology are discussed in Section 3.1.1. For further discussion of the treatment of CO_2 emissions from biomass combustion, please see Appendix C.

Comment: NC DAQ is urged to adopt the recommendation to disaggregate natural and anthropogenic causes of carbon fluxes in forestland as recommended by the USFS in The U.S. Forest Carbon Accounting Framework: Stocks and Stock Change, 1990-2016 at p 41.

Response: NC DAQ agrees that it would be beneficial to disaggregate forestland carbon flux into natural and anthropogenic sources. Although the data that NC DAQ obtained from the USFS are consistent with their Carbon Accounting Framework, the data are not of sufficient resolution to perform this disaggregation. NC DAQ will evaluate the availability of more detailed state-level data from USFS for performing this disaggregation in future versions of the GHG inventory.

Comment: It was recommended that NC DAQ expand the consideration of upstream, fugitive gas emissions outside of the North Carolina Boundary.

Response: NC DAQ performed a brief review of the citations provided by the commenter in support of a 3 percent average estimate for the natural gas well-to-end use leakage rate, but was unable to identify how this estimate was derived. From the preliminary review, it appears that 1.7 percent is the most current/robust average estimate of the total methane loss from natural gas production/distribution as documented in a 2017 Littlefield *et. al.* journal article.[113] The article identifies several major limitations of the data used to develop this estimate, one of which relates to the lack of regional data/understanding of regional variability.[114] While NC DAQ acknowledges the value in developing comprehensive estimates of indirect emissions associated with North Carolina activities, it does not appear that the currently available data are robust enough to develop a defensible estimate of the indirect emissions associated with the out-of-state production/transport of natural gas consumed in North Carolina. Regarding future inventory efforts, NC DAQ will evaluate the current state-of-science concerning suitable data/methods for estimating the out-of-state upstream emissions of natural gas consumption, as well as other indirect GHG-emitting commodities consumed in our State. It should be noted that accounting for upstream emissions from natural gas production/distribution activities in other states is not expected to have significant impacts on the GHG emissions totals and major conclusions described in this report.

Comment: It was recommended that NC DAQ provide additional information regarding projected future gas emissions from natural gas operations.

Response: Duke Energy routinely provides NC DAQ with a unit-level forecast of electricity generation by its fossil fuel plants operating in North Carolina. These forecasts have been used by NC DAQ to develop future year emissions projections to support air quality modeling for State Implementation Plans. State Implementation Plans (SIPs) are legally enforceable plans for complying with the federal Clean Air Act that consist of narrative, rules, technical documentation, and agreements that a state uses to document compliance with the federal emissions standards. These forecasts only include firm retirements and new units since SIPs are legally enforceable and approved by EPA.

The NC DAQ does not use Duke Energy Carolinas (DEC) or Duke Energy Progress (DEP) Integrated Resource Plans (IRPs) for emissions forecasts for several reasons. The first is that the IRPs are used to assess whether new generation capacity is required in a future year to support the expected peak load and is not a unit level forecast of the annual operation of the electricity generating fleet. Second, the IRPs base the retirement date of coal units on the full deprecation date of those units, not the actual planned retirement date. The new capacity required to replace the retiring units and support any growth in generation is included in the IRPs as well and is based on the least-cost resource at the time the IRP is issued. Retirements and new construction are not considered firm until the North Carolina Utilities Commission has given full approval and the new units have secured all required permits. Lastly, the new capacity contained in the IRPs is listed as "undesignated" which means the location of the unit can be anywhere in the DEC and DEP territories, which includes South Carolina. For these reasons, the NC DAQ does not rely on the IRPs for forecasting electricity sector emissions.

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[113] "Synthesis of recent ground-level methane emission measurements from the U.S. natural gas supply chain," Journal of Cleaner Production, Volume 148, 1 April 2017, 118-126, available from https://www.sciencedirect.com/science/article/pii/S0959652617301166.

[114] The list of headings for the data limitations discussed in this article are: activity factors; aggregation; extrapolation/representativeness; augmentation; boundary overlap; known omissions; and voluntary bias.

Comment: It was recommended that NC DAQ update estimates of transportation emissions to reflect currently available data.

Response: NC DAQ downloaded a recently released update to the SIT tool (December 2018), which includes 2016 SEDS data for transportation activities, and revised all references to transportation emissions to reflect currently available data. Section 2.8, Transportation, now reflects historic data up through 2016.

Comment: It was recommended that NC DAQ provide a more accurate accounting with respect to renewables.

Response: NC DAQ used eGRID emissions factors published by US EPA for the SERC Reliability Corporation Virginia-Carolina (SRVC) regional electricity grid to estimate avoided emissions due to renewable energy (RE) electricity generation. It is a complex task to understand what existing fossil and non-fossil resources are replaced by new RE resources over the course of a year of operation since it would vary by hour. The NC DAQ is not aware of any North Carolina-specific data that could be used to develop more accurate emissions factors than eGRID. Therefore, the DAQ feels it is more appropriate to use the published eGRID emissions factors for this estimation.

Note the estimate of avoided GHG emissions due to RE generation is not used to develop the GHG inventory. It is merely provided as added information for the reader to understand the relative impact that RE resources have on GHG emissions from the electricity sector.

The projection of electricity sector emissions developed by the NC DAQ utilizes the forecast of fossil fuel use (as heat input in MMBtu) for electricity generation provided directly by Duke Energy. Duke Energy's 2017 forecast has a specified amount of RE capacity and generation for each future year in the forecast. Since we do not receive a unit-level generation forecast from Duke Energy, the capacity and generation provided by RE resources is not available to the NC DAQ. However, the forecast inherently includes the benefits of RE generation as a decrease in the amount of fossil fuel use required in future years. The NC DAQ does not have a method of quantifying this decrease due to RE resources, therefore these avoided emissions are not estimated. The NC DAQ did project the avoided emissions due the expected implementation of solar capacity under the House Bill 589 on page 31 of the inventory report.