Appendix A. NC GHG Inventory and BAU Projections

1.1. Methodology

The methods described in this section reflect the most current GHG Inventory and BAU Projections available to NCDEQ. The GHG Inventory is scheduled to be updated in 2026 and this section may be updated with additional information later.

Additional information about the state's GHG inventory may be found at:
https://www.deq.nc.gov/energy-climate/climate-change/greenhouse-gas-inventory

The historical GHG emissions are calculated to show how emissions in NC have changed from 1990 through 2020, the last year of available historical data in the U.S. Environmental Protection Agency State Inventory Tool (SIT), a spreadsheet-based tool developed by EPA and designed to assist state agencies in preparing state-level GHG inventories and projections.[1] For this inventory, the NCDEQ Division of Air Quality (DAQ) developed updated 1990-2020 emissions estimates for all sectors.

The historical GHG emissions were primarily prepared using the SIT. The SIT simplifies the effort for preparing state-level GHG inventories that is generally consistent with EPA's national inventory. 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.[2] The use of consistent methodologies ensures that GHG inventories prepared by various entities are comparable.

The SIT is organized into 12 modules for calculating historical emissions and one module for projecting emissions.[3] However, these modules do not correspond to the layout of the sector and source emissions tables presented in the CCAP. 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, emission factors, references, and other pertinent information utilized by the module. There is also a synthesis module which pulls the historical 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. A limited number of source categories utilize data obtained from third-party vendors. The default data in the SIT are also frequently used by

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[1] EPA. "State Inventory and Projection Tool." https://www.epa.gov/statelocalenergy/state-inventory-and-projection-tool, accessed June 2023.
[2] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, The National Greenhouse Gas Inventories Programme, The Intergovernmental Panel on Climate Change. Hayama, Kanagawa, Japan, 2006.
[3] NC only utilizes 12 of these 13 modules because one module estimates emissions from coal production which does not occur in NC.

state and local agencies to develop emission inventories for other air pollutants. For a select number of source categories, the DAQ has replaced the SIT default data with data obtained from NC's state agencies. These data support the development of more accurate emissions estimates for the state. The historical emissions estimation methodologies, and default and substituted data sources used in each module, are presented below.

A detailed discussion of the uncertainty associated with the SIT default data used for the historical GHG emission inventory is outlined in each of the SIT modules, which are available for download from the EPA SIT webpage.[4]

1.2. CO_2 Emissions from Fossil Fuel Combustion

1.2.1. Description

The SIT 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.[5]

Residential	Industrial	Transportation
Commercial	Electric Power	

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

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

1.2.2. 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.[6]

The default historical fuel consumption data provided in the SIT module for NC are used without any adjustments. These default data, which consist of the estimated amount of

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[4] *EPA. "State Inventory and Projection Tool."* https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool, *accessed June 2023.*

[5] *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.*

[6] *EPA. "User's Guide for Estimating Direct Carbon Dioxide Emissions from Fossil Fuel Combustion Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.*

each type of fuel consumed by each sector in each state, are from the Energy Information Administration's (EIA) State Energy Data System (SEDS). [7]

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

1.2.3. Deviations from Defaults

Wood, ethanol, and biodiesel are biomass fuels for which CO_2 emissions are excluded from gross GHG emissions. To provide additional transparency, however, the DAQ developed CO_2 emissions estimates for the consumption of these biomass fuels in NC.

1.2.4. Future Refinements

Future refinements for biomass emissions estimates could investigate the availability of data for estimating CO_2 emissions from the combustion of landfill and manure gas.

1.3. CO_2 Emissions from Transportation

For the onroad mobile source sector, the DAQ applied the 4.0.0 version of EPA's MOVES4 model to estimate emissions for the key years of 2005 and 2021. [8] The MOVES4 model is used in place of the SIT because it is EPA's official onroad mobile source emissions estimation model, it facilitates consistency with all other DAQ onroad mobile source emissions estimation efforts, and it provides emissions forecasting and policy analysis capabilities that are not available from the SIT. Because of the time and resources necessary for performing a MOVES4 run for a given year, it was necessary for the DAQ to limit use of MOVES4 to two historical years: 2005 and 2021. The year 2005 was chosen because it is the baseline year specified by various federal, multi-state, and NC-specific GHG mitigation policies, and 2021 because it was the latest year for which we had a complete set of historical data.

Because ethanol is a biomass fuel, it was necessary to adjust the CO_2 emissions output from MOVES4 to subtract ethanol-related emissions. The DAQ developed adjustment values for 2005 and 2021 from EIA SEDS transportation sector fuel heat input data to back out estimated ethanol-related CO_2 emissions. In 2005, ethanol contributed 0.39% of heat input to transportation sector motor gasoline in NC, and this contribution rose to 6.88% in 2021. The DAQ reduced the CO_2 emission estimates from MOVES4 for these two years using these heat input percentages.

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[7] *EIA. "State Energy Data System (SEDS): 1960-2021 (complete)." June 2023.*

[8] *EPA. "MOVES4: Latest Version of Motor Vehicle Emission Simulator."* https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves. *Accessed September 2023.*

To estimate pre-2005 onroad mobile source emissions, the DAQ relied on emission trends generated by the SIT's Mobile Combustion Module (see discussion in the following section). Specifically, the DAQ calculated pre-2005 adjustment factors reflecting the SIT's 1990-2005 emission trends, and then multiplied these factors by the 2005 MOVES4-based emission values. The MOVES4 model was run with output options allowing reporting of results by vehicle regulatory class categories as well as by the default MOVES4 vehicle use categories. The MOVES4 output was also broken down by fuel type. This allowed better alignment of MOVES4 output data with the vehicle and fuel categorizations used in the SIT.

Because a review of the SIT default VMT data, which had originally been compiled by FHWA and EPA, indicated anomalous values for certain years, the DAQ coordinated with the NC Department of Transportation (NCDOT) to develop VMT data that revised the SIT default values. The DAQ's review of the 2005 VMT data identified substantial differences when compared to the 2005 Highway Performance Monitoring System (HPMS) VMT data published by FHWA. Consultation with NCDOT revealed that for years 2008 and earlier, NCDOT used a methodology that tracked VMT on state-maintained roads and locally maintained roads separately, with fewer traffic counts conducted for roadways with lower traffic volume. The NCDOT VMT data for these years was consistently lower than the corresponding FHWA HPMS data. To improve HPMS VMT data quality, the FHWA changed the state VMT reporting requirements in 2009. To meet these new requirements, NCDOT added traffic count stations to cover lower-functional class roadways and implemented geographic information system-based processes for tracking VMT. This has led to consistency between the VMT data reported by NCDOT and the HPMS VMT data published by FHWA for 2009 and subsequent years. Based on methods recommended by NCDOT, the 1990-2008 VMT data were adjusted by the DAQ to be consistent with the 2009 and later HPMS data. The 2005 VMT data disaggregated at the county-level were used for GHG emissions modeling with MOVES4. For the 2021 GHG emissions modeling, the DAQ used the county-level VMT data directly as provided by NCDOT. No revisions were warranted because NCDOT VMT tracking and reporting procedures were aligned with FHWA HPMS requirements beginning in 2009.

The DAQ developed 2006-2020 onroad CO_2 emission estimates in three steps. The first step was to develop 2006-2020 VMT estimates for the vehicle/fuel type output by MOVES4. These estimates were calculated from state-level VMT for 2006-2020 and interpolated ratios of each vehicle/fuel type's VMT in that year to the state total VMT. The second step was to develop 2006-2020 CO_2 emission factors for the vehicle/fuel type output by MOVES4. These factors were developed by interpolating between the years 2005 and 2021 emission factors that were computed from MOVES4 output for those two years. The final step was to multiply the vehicle/fuel type VMT in each year by the CO_2 emission factors for the vehicle/fuel type in that year.

For the remainder of the Transportation sector, which covers non-highway sources including aircraft, locomotives, and boats, the DAQ generally used the CO_2 emissions estimation methods/data incorporated into the SIT's CH_4 and N_2O Emissions from Mobile

Combustion Module. The DAQ replaced SIT default jet fuel consumption data for aircraft for select years after identifying suspect trends in the SEDS transportation sector jet fuel consumption data that are used to estimate aviation emissions. A review of these SEDS data indicates that, beginning with year 2010, the EIA adopted a substantially different methodology for estimating jet fuel sales. To develop a more consistent series of jet fuel consumption, the DAQ applied the 1990-2010 trend in total NC landing and take-off operations for commercial and military aircraft to backcast NC jet fuel consumption for the years 1990-2009.[9]

In addition, estimates were developed to adjust the SIT's fuel consumption estimates for aircraft and boats to remove international bunker fuels (i.e., fuels consumed outside of the U.S.). Because NC-specific data were not available to perform this adjustment, the DAQ used emissions data from EPA's national GHG inventory to develop these adjustment factors.[10]

1.3.1. Future Refinements

Future refinements could include additional research into ways to better perform the international bunker fuel adjustments to reflect NC activity.

1.4. CH_4 and N_2O Emissions from Mobile Combustion

1.4.1. Description

The SIT 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 as discussed below. The Mobile Combustion Module provides an alternate method for calculating CO_2 emissions for highway vehicles that the DAQ used to extrapolate trends in vehicle CO_2 emissions for historical years not modeled via MOVES4.

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[9] *Federal Aviation Administration. "The Operations Network (OPSNET) > Airport Operations."* *https://aspm.faa.gov/opsnet/sys/Airport.asp. Accessed December 2023.*
[10] *EPA. Table 3-13, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021." EPA 430-R-23-002.* *https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2021. Accessed December 2023.*

1.4.2. 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 the SIT module as well as instructions and information provided in the spreadsheets for each module.[11]

For highway/alternative fuel vehicles, CH_4 and N_2O emissions can be calculated in the SIT based on several factors including VMT, fuel type, engine type, and control technology type for the population of vehicles on roads in NC. However, as noted below, the DAQ used the MOVES4 model to calculate highway vehicle emissions.

CH_4 and N_2O emissions from non-highway mobile sources (e.g., aviation, marine, locomotives, construction equipment) and other non-highway equipment are derived from fuel consumption estimates. The default historical non-highway mobile source fuel consumption estimates provided in the SIT module for NC were used, except where noted above (CO_2 Emissions from Transportation).

1.4.3. Deviations from Defaults

For consistency with the development of highway vehicle CO_2 emission, the DAQ compiled CH_4 and N_2O estimates from the same 2005 and 2021 MOVES4 runs and extrapolation/interpolation procedures that were used to develop onroad vehicle CO_2 estimates. The VMT data that were used to calculate CH_4 and N_2O emissions were the same data that were used to estimate CO_2 emissions.

1.4.4. Future Refinements

No future refinements have been identified at this time.

1.5. CH4 and N2O Emissions from Stationary Combustion

1.5.1. Description

The SIT 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) biofuels. The source sectors included in the module are listed below.

Residential   Industrial

Commercial   Electric Power

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[11] EPA. *"User's Guide for Estimating Methane and Nitrous Oxide Emissions from Mobile Combustion Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, September 2020.*

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

1.5.2. Background and Default Data

The methodology for estimating CH_4 and N_2O emissions from fossil fuel and biofuel 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.[12]

The default historical fuel consumption data provided in the SIT module for NC are used without any adjustments. These default data are from the EIA's SEDS.[13] It consists of the estimated amount of each type of fuel consumed by each sector.

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

1.5.3. Deviations from Defaults

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

1.5.4. Future Refinements

No future refinements have been identified at this time.

1.6. Natural Gas and Oil

1.6.1. Description

The SIT Natural Gas and Oil Module calculates CH_4 (and its CO_2e) 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

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[12] EPA. "User's Guide for Estimating Methane and Nitrous Oxide Emissions from Stationary Combustion Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.
[13] EIA. "State Energy Data System (SEDS): 1960-2021." https://www.eia.gov/state/seds/seds-data-complete.php?sid=NC#Consumption. Accessed September 2023.

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

1.6.2. 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.[14] Default activity data are generally not provided in the Natural Gas and Oil Module of the SIT. The focus for NC was the Natural Gas Transmission and Distribution sectors because the State does not produce or refine any oil or natural gas. CH_4 emission factors in the module for Natural Gas Transmission and Distribution are taken from a study conducted by the Gas Research Institute and EPA.[15] The CH_4 emission factor for natural gas transmission compressor stations used the module's default value of 983.66 metric tons (MT) per compressor station from 1990-2012 because these are years before data were available for estimating NC-specific compressor station emission factors from EPA's GHG Reporting Program.

1.6.3. Deviations from Defaults

A review of the NC emissions data reported to EPA's GHG Reporting Program suggested two periods with significantly different natural gas transmission compressor CH_4 emission rates. The CH_4 emissions factor for natural gas transmission compressor stations was calculated to be 500 metric tons/station from 2013-2014 and 300 metric tons/station from 2015-2020. These updated values reflect the approximate median values calculated from CH_4 emissions reported by NC compressor stations to EPA's GHG reporting program for each timeframe.[16] The 2010-2020 natural gas transmission pipeline miles data are input into the module were obtained from a NC query performed on the webpage of the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration (PHMSA).[17] Natural gas distribution pipeline miles in NC by material and natural gas service data for select years (1990-1997, 2000, 2002, 2004-2005, 2007, 2009-2020) were compiled from PHMSA files.[18] Values for other years were estimated via interpolation.

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[14] *EPA. "User's Guide for Estimating Carbon Dioxide and Methane Emissions from Natural Gas and Oil Systems Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.*
[15] *Gas Research Institute and EPA. "Methane Emissions from the Natural Gas Industry, EPA-600/R96-080a and GRI-94/0257." June 1996.* https://www.epa.gov/sites/production/files/2016-08/documents/1_executiveummary.pdf.
[16] *EPA Greenhouse Gas Reporting Program. "Find and Use GHGRP Data."* https://www.epa.gov/ghgreporting/find-and-use-ghgrp-data. *Accessed December 2023.*
[17] *PHMSA. "2010+ Pipeline Miles and Facilities."* https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-mileage-and-facilities. *Accessed October 2023.*
[18] *PHMSA. "Gas Distribution, Gas Gathering, Gas Transmission, Hazardous Liquids, Liquefied Natural Gas (LNG), and Underground Natural Gas Storage (UNGS) Annual Report Data."* https://www.phmsa.dot.gov/data-and-statistics/pipeline/distribution-transmission-gathering-lng-and-liquid-annual-data. *Accessed October 2023.*

According to the PHMSA there were five liquefied natural gas liquefaction and storage facilities and 13 natural gas compressor stations operating in NC in 2020.[19] Due to a lack of historical data, the NCUC facility/station counts are used for all pre-2020 years. There were no natural gas venting and flaring operations associated with natural gas production in NC from 1990-2020 based on EIA information.[20]

1.6.4. Future Refinements

The EPA's GHGI incorporates a major change to the methodology for this sector. In future revisions to the inventory for this sector, the DAQ will evaluate the merits of this alternative approach relative to the SIT methodology.

1.7. Imported Electricity

1.7.1. Description

Imported electricity is the amount of electricity that NC imports from power plants that are located outside the State via the regional electricity grid system. Note that emissions associated with generating imported electricity do not occur in NC. However, the emissions are generated due to the demand for electricity in NC, therefore, these emissions can be considered part of NC's carbon footprint. Since this electricity is coming from the regional electricity grid, the average emission factors developed by EPA for the regional grid that contains NC were used to estimate GHG emissions from imported electricity.

1.7.2. Background and Defaults

Because the SIT does not specifically estimate emissions associated with imported electricity, the DAQ developed an approach. In keeping with the use of fuel consumption estimates used elsewhere in the SIT, the DAQ used EIA SEDS data to reflect the amount of electricity imported into NC. The DAQ specifically used NC "net interstate flow" of electricity data from SEDS.[21] The SEDS "net interstate flow" of electricity represents the difference between the sum of electricity sales and transmission losses within a state and the total amount of electricity generated within that state.

The average GHG emission factors developed by EPA for NC's regional electrical grid (Southeastern Electric Reliability Council - Virginia/Carolina Subregion or SRVC) as part of the EPA's Emissions & Generation Resource Integrated Database (eGRID) are used to

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[19] PHMSA. "2010+ Pipeline Miles and Facilities." https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-mileage-and-facilities. Accessed October 2023.

[20] EIA. "Natural Gas Gross Withdrawals and Production." https://www.eia.gov/dnav/ng/ng_prod_sum_a_EPG0_VGV_mmcf_a.htm. Accessed October 2023.

[21] EIA. "State Energy Data System (SEDS): 1960-2021 (complete)." https://www.eia.gov/state/seds/seds-data-complete.php?sid=US#Consumption. Accessed October 2023.

calculate emissions from imported electricity.[22] These emission factors are available on a per-kilowatt-hour-of-electricity basis. The EPA does not estimate emission factors for every year. If an emission factor is not available for a given year, the value for the first available year was used (e.g., 2004 CO_2 emission factor is used for all pre-2004 years), or an interpolated value was used. The GHG emissions from imported electricity are reported in the inventory under the "Electricity Generation and Use" sector.

1.7.3. Future Refinements

No future refinements have been identified at this time.

1.8. Agriculture

1.8.1. Description

The SIT 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	Burning of Agricultural Crop Waste	

1.8.2. Background and Defaults

The methodology for estimating CH_4 and N_2O emissions from the Agriculture Sector is described within the SIT User's Guide for this module as well as instructions and information provided in the spreadsheets for each subsector of the module.[23] The default historical activity data provided in the SIT module for NC were used without adjustments for the burning of agricultural crop waste; 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 Agricultural Statistics Service (NASS). Because there is no rice production in NC, 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 methodologies for estimating N_2O from agricultural soils between the SIT and EPA's national inventory.

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[22] *EPA Clean Air Markets Division. "Download Data, eGRID with 2021 data."* https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid. Accessed September 2023.

[23] *EPA. "User's Guide for Estimating Methane and Nitrous Oxide Emissions from Agriculture Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.*

1.8.3. Deviations from Defaults

The default USDA data in the module were revised for the following livestock categories to reflect the most recent set of available livestock inventory estimates: beef cows; milk cows; goats; turkeys; and hogs. These data are from online queries of USDA datasets (note that USDA compiles these data sets in cooperation with the NC Department of Agriculture and Consumer Services).[24] These livestock data were used to calculate emissions for the following subsectors: enteric fermentation, manure management, and agricultural soils, animals and runoff.

1.8.4. Future Refinements

The agricultural soils – plant residues and legumes subsector does not include default production data for the following crop types: 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, 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.

1.9. Municipal Solid Waste

1.9.1. Description

The SIT MSW module of the SIT calculates CH_4 emissions from landfilling 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 (LFG) for electricity production and other energy uses (landfill-gas-to-energy projects or LFGTE). Other landfills flare LFG 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 anthropogenic GHG emissions in this inventory.

1.9.2. Background and Defaults

There are two subsectors in this module, landfills and combustion, and the emissions calculation methodology is different for each. The methodology for estimating GHG emissions from MSW is provided in the User's Guide for this module as well as instructions and information provided in the spreadsheets for the module.[25]

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[24] USDA. "National Agricultural Statistics Service, Quick Stats." NC data obtained October 2023 via online query of data from https://quickstats.nass.usda.gov/.

[25] EPA. "User's Guide for Estimating Emissions from Municipal Solid Waste Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.

The default SIT values were used for landfill flaring which comes from EPA's Landfill Methane Outreach Project (LMOP) database.[26] Default population data from the US Census were included for the LFG emissions calculation.

The CH_4 emissions from industrial landfills in the SIT were assumed to be 7% of the MSW landfill emissions. No additional information has been found so the default value was used. Default fractions for plastics, synthetic rubber, and synthetic fiber combustion were also used.

1.9.3. Deviations from Defaults

For the landfill sector, total landfill disposal data from 1990 to 2022 were obtained from the NC Division of Waste Management.[27] These data are published in an annual report based on fiscal year, (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 fiscal year, the disposal value was 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 was apportioned in the same manner and subtracted from the disposal value. Each annual report encompassed a range of years so the report with the latest values for each year was used.

Information regarding LFGTE projects was extracted from EPA's LMOP database to estimate LFG annual flow and years of use.[28]

To maintain consistency with other modules, NC Office of State Budget and Management (OSBM) population data were used instead of the default population values.

1.9.4. 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.

1.10. Wastewater

1.10.1.   Description

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[26] EPA. "Landfill Technical Data, Landfill and Landfill Gas Energy Project Database, Landfill Methane Outreach Program (LMOP)." https://www.epa.gov/lmop/landfill-technical-data. Accessed September 2023.

[27] NCDEQ. "Solid Waste Management Annual Reports." https://deq.nc.gov/about/divisions/waste-management/sw/data/annual-reports. Accessed September 2023.

[28] EPA. "Landfill Gas Energy Project Data, Landfill and Landfill Gas Energy Project Database, Landfill Methane Outreach Program (LMOP)." https://www.epa.gov/lmop/landfill-technical-data. Accessed September 2023.

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 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.

1.10.2. 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.[29]

The source for Municipal Wastewater default values for CH_4 emissions is reported as state and local public works agencies. The default data were used for the Municipal Wastewater section of this tool.

The Industrial section of this module provides default data for the red meat industry but not for the poultry, pulp and paper, or fruit and vegetable industries. The default red meat data were obtained from the USDA's NASS.[30]

1.10.3. Deviations from Defaults

No source of wastewater activity data for the fruits and vegetables industry was located.

Wastewater emissions for the pulp and paper industry are reported for 2003 and later years because these are the only years with emission source specific emissions covered by the DAQ's Internet-Based Enterprise Application Management – Emissions Data (IBEAM-ED). Other sources of pulp and paper industry wastewater emissions would need to be identified to estimate pre-2003 emissions.

Production data for calculating wastewater emissions for the poultry sector were compiled for broiler chickens and turkeys from the USDA's NASS. These data were cross-referenced with production data for commercial broilers and turkeys from the 2022 NC Agricultural Statistics.[31]

1.10.4. Future Refinements

[29] EPA. "User's Guide for Estimating Emissions from Wastewater Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.
[30] USDA. "National Agricultural Statistics Service, Quick Stats." https://quickstats.nass.usda.gov/.
[31] USDA. "2022 NC Agricultural Statistics." https://www.nass.usda.gov/Statistics_by_State/North_Carolina/Publications/Annual_Statistical_Bulletin/index.php. Accessed December 2023.

NC-specific red meat production data and fruit and vegetable production data would enhance the emission estimates for this module if such data could be identified.

For consistency with other modules, NC OSBM population data could be used instead of the default population values if the SIT would allow replacement of the Wastewater module's default population data.

1.11. Industrial Processes

1.11.1.   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.
- CO_2 and PFC emissions from aluminum production.
- N_2O emissions from nitric acid production and adipic acid production; and
- HFC, PFC, nitrogen trifluoride (NF_3), and SF_6 from HCFC-22 production, consumption of substitutes for Ozone-Depleting Substances (ODS), semiconductor manufacture, electricity transmission and distribution, and magnesium production and processing.

1.11.2.   Background and Defaults

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.[32] The methodology in the Industrial Processes module varies by sector so each sector is discussed separately with specific examples in the SIT's User Guide.

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

Consumption of ODS substitutes reflects national emissions allocated to each state. National emissions are apportioned to each state using a hybrid approach, based on both population and regional emission estimates from specific HFCs. Regional HFC emission estimates were provided by Hu, L., et al. (2017).[33]

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[32] EPA. "User's Guide for Estimating Emissions from Industrial Processes Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.

[33] Hu, L., et al., "Considerable contribution of the Montreal Protocol to declining greenhouse gas emissions from the United States," Geophys. Res. Lett., 44, 8075–8083, 2017.

1.11.3.   Deviations from Defaults

Iron and steel production and semiconductor manufacture are the only sectors in the Industrial Processes module where estimates deviated from SIT defaults. The default values for the Iron and Steel Production sector are based on national averages and appeared to overestimate emissions in NC. There is only one permitted facility in NC that operates using a production method listed in the SIT. Therefore, production/activity data from the DAQ's IBEAM-ED module for that permitted facility were converted to MT. These values were entered into the SIT for calendar years 2001 to 2020.

Semiconductor manufacture GHG estimates for calendar years 1990 through 2015 were calculated using SIT defaults. In the SIT, default estimates of national emissions from the semiconductor manufacturing sector are distributed to NC based on the ratio of the monetary value of NC semiconductor shipments to the value of national semiconductor shipments. For the years available (2016 through 2020), NC semiconductor manufacturer emissions of SF_6, HFC, NF_3, and PFC were obtained directly from the GHG Reporting Program. All three NC permitted facilities in the semiconductor manufacturer sector reported emissions to the GHG Reporting Program, so these emissions were summed and entered into the SIT for each calendar year.

Phosphoric acid production is not included in the SIT Industrial Processes module; however, NC emissions data are reported for this process to EPA's GHG Reporting Program. Because NC has one phosphoric acid production facility that reports emissions to EPA, the DAQ added these emissions for the years for which they were available (2010 through 2020). Calendar year 2002-2009 emissions were estimated using data reported to the DAQ, 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. No throughput data or weight percent of carbon are readily available for calendar years 1990 through 2001, therefore, the 2002 CO_2 emission value is reported for these years as a best estimate.

1.11.4.   Future Refinements

For the two sectors that use national emissions, consumption of ODS substitutes and semiconductor manufacturing, the SIT default population values for NC from 1990 to 2020 were used because these tables are protected and could not be accessed. For consistency with other modules, the NC OSBM's 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 NC. A more in-depth review of the calculation methodology for this sector may be warranted because the projected values for this sector reflect a significantly large increase.

1.12. Land Use, Land Use Change, and Forestry

1.12.1. Description

The LULUCF sector accounts for emissions and/or sequestration of CO_2, CH_4, and N_2O from activities on NWL. These are broken down into subsectors by major land use type, including Forest Lands; Cropland and Grassland; Settlements; and Wetlands. The source of best-available estimates varies by subsector and category, which are summarized in Table A-1 below.

GHG inventories report fluxes occurring within each land use type, as well as those resulting from conversions between land use types. A land use change refers to land converted to a different use within the previous 20 years. This inventory follows the structure of the EPA GHGI, which groups sources of emissions and sinks by current land use category.

Table A-1. Source of LULUCF Sector Emissions/Sink Estimate by Subsector/Category

Data Source/Subsector	Category
SIT Module	
Forest Lands	Forest Carbon Flux*
	Non-CO_2 Emissions from Forest Fires**
Cropland and Grassland	Agricultural Soil Carbon
Settlements	N_2O on Settlement Soils
EPA Greenhouse Gas Inventory for NC	
Settlements***	SRS: Urban Trees
	SRS: Landfilled Yard Trimmings and Food Scraps
	LCS: Ecosystem Carbon
	SRS: Organic Soil
Wetlands	Flooded Lands and Peatlands
NC Coastal Habitats Greenhouse Gas Workgroup	
Wetlands	Coastal Wetlands

* Forest Land Remaining Forest Land and Land Converted to Forest Land. Forest Carbon Flux in the SIT also includes Forest Land Converted to Settlements, see text for details.
** SIT with acreage burned data compiled from NC and federal databases, see text for details.
*** Settlements Categories: Settlements Remaining Settlements (SRS) and Land Converted to Settlements (LCS)

Since the 2022 NC GHG Inventory, EPA has updated data and/or methods in every LULUCF subsector. As a result, some estimates in this report are substantially different from those reported in the 2022 inventory. The LULUCF SIT module includes default data from the USFS and the GHGI for Forest Lands; Cropland and Grassland; and some categories within the Settlements subsector. The GHGI also includes updates to some data sources and/or methodologies which EPA has not yet integrated into the SIT.[34] As with the previous (2022) GHG inventory, this inventory includes EPA estimates of NC emissions/sinks for some Settlements and Wetlands categories missing from the SIT. The DAQ incorporated the EPA state-level estimates for these missing source categories in this inventory and incorporated the updated estimates for other source categories. Estimates used in this inventory for Coastal Wetlands were developed by the NC Coastal Habitats Greenhouse Gas Workgroup.[35]

1.12.2. Background and Defaults

The methodologies used within the SIT for estimating CO_2, CH_4, and N_2O emissions from the LULUCF sector are provided in the User's Guide as well as instructions and information in the spreadsheets of the LULUCF module.[36] The default input data within the SIT are revised periodically to reflect the latest data sources and methodologies, though these updates may not be completed at the same intervals as updates incorporated into EPA's GHGI. The DAQ used the SIT's LULUCF module and default inputs to develop estimates for Forest Carbon Flux (FRF and *Land Converted to Forest Land)*, non-CO_2 emissions from Forest Fires, Agricultural Soil Carbon Flux, and N_2O emissions from fertilization of Settlement Soils. The inputs varied considerably from category to category but included estimates of carbon stock changes in forests, wood products, and agricultural soils, and the amount of synthetic fertilizer applied to soil on developed lands. Carbon dioxide emissions from forest fires are automatically accounted for in the SIT's inventory of forest carbon stocks, and non-CO_2 emissions from forest fires are estimated separately in the SIT. Significant changes to estimates of carbon flux in the forest and agriculture subsectors reflect EPA's updates to the SIT default data since the previous (2022) GHG inventory.

1.12.3. Deviations from Defaults

Forest Fires

Emissions of CH_4 and N_2O from forest fires are estimated in the SIT module, requiring inputs of annual area burned. No single source of acreage burned data is available for all

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[34] EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990-2020." April 2022. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020.
[35] NC Coastal Habitats GHG Workgroup. "NC Coastal Habitat Greenhouse Gas Inventory." September 2023.
[36] EPA. "User's Guide for Estimating Emissions and Sinks from Land Use, Land-Use Change, and Forestry Using the State Inventory Tool." Prepared for EPA's State Energy and Environment Program by ICF, June 2023.

inventory years, and some sources only report data for certain fire types or jurisdictions. To compile forest fire acreage burned data, the DAQ used a combination of approaches and the best-available data sources for each year, consistent with the methods in the previous (2022) NC GHG inventory.

The acreage burned estimates developed for this inventory prioritized wildfire data from the NCFS, supplemented by the federal interagency "SIT-209" database for wildfires and prescribed burning. [37,38] Because data were not accessible from the SIT-209 for every year, the DAQ used other methods/data to estimate values in some (mostly earlier) years. Sources included the National Interagency Fire Center and the EPA's National Emissions Inventory. [39,40] The DAQ is working to identify additional sources of burn acreage data to refine these estimates for future versions of NC's inventory.

Settlements

Three Settlements categories are included in the SIT's LULUCF module. Emissions of N_2O from Settlement Soils were modeled in the SIT using default data. Estimates for carbon stock changes in both the Urban Trees and Landfilled Yard Trimmings and Food Scraps categories differed significantly between the EPA's GHGI and the SIT. In communication with EPA, it was determined that the GHGI estimates were developed using the latest data and methods and are a better representation of NC's carbon sequestration in these categories. Therefore, the DAQ incorporated carbon flux estimates from the 1990-2020 GHGI into this inventory for these categories.

The GHGI also provides estimates for other Settlements categories not included in the SIT. To provide a comprehensive LULUCF sector inventory, the previous NC GHG Inventory supplemented SIT Settlements estimates with additional GHGI Settlements estimates. In the previous NC inventory, GHGI estimates for Land Converted to Settlements (LCS) – *Changes in Ecosystem Carbon Stocks* were incorporated into a category listed as "Categories not included in SIT." At that time, it was not clear that Forest Land Converted to Settlements (FCS) was also included in the SIT's Forest Carbon Flux subsector. The SIT/GHGI overlap is demonstrated in Table A-2 showing LCS estimates by carbon pool from both the SIT (which only includes FCS) and the GHGI (which includes all land use types converted to settlements). The SIT and GHGI estimates for living biomass and dead plant matter are an exact match, because those LCS carbon pools only apply to FCS. SIT data includes estimates

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[37] NCFS. "Wildfire and Acreage Statistics: 1928- Present." https://www.ncforestservice.gov/fire_control/wildfire_statistics.htm. *Accessed November 2023.*

[38] *U.S. Department of Agriculture and the U.S. Department of the Interior. SIT-209 data obtained from Wildland Fire Application Information Portal:* https://www.wildfire.gov/application/sit209. *Accessed October 2023.*

[39] *U.S. Department of Interior, National Interagency Fire Center. Historical year-end fire statistics by state compiled from National Interagency Coordination Center fire records.* https://www.nifc.gov/nicc/predictive-services/intelligence.

[40] *EPA. "Pollutant Emissions Summary Files for Earlier NEIs."* https://www.epa.gov/air-emissions-inventories/pollutant-emissions-summary-files-earlier-neis. *Accessed February 2021.*

for mineral soils in FCS, and GHGI includes those FCS mineral soil estimates as well as mineral and organic soil estimates for other land use types converted to settlements.

Table A-2. LCS Emissions Estimates by Data Source (MMTCO$_2$e)

LCS* Carbon Pools	1990		2005		2020	
	SIT (only FCS**)	GHGI (all LCS)	SIT (only FCS)	GHGI (all LCS)	SIT (only FCS)	GHGI (all LCS)
Aboveground Biomass	1.75	1.75	1.81	1.81	1.85	1.85
Belowground Biomass	0.34	0.34	0.35	0.35	0.36	0.36
Deadwood	0.23	0.23	0.24	0.24	0.24	0.24
Litter	0.41	0.41	0.42	0.42	0.43	0.43
Soil (Mineral)	0.04	0.23	0.07	0.65	0.05	0.41
Soil (Organic)	-	0.05	-	0.08	-	0.03
Total LCS	**2.77**	**3.00**	**2.89**	**3.55**	**2.93**	**3.32**
Non-forest LCS		0.23		0.66		0.39

* Land Converted to Settlements

** Forest Land Converted to Settlements

Because this NC Inventory follows the GHGI's category structure, LCS emissions are reported within the Settlements subsector. The GHGI estimates for LCS, which include all land use types converted to settlements (including FCS), are incorporated into this inventory as LCS: *Ecosystem Carbon Flux*. The removal of previously double-counted FCS estimates results in significantly lower LCS estimates in the current inventory. The correction, summarized in Table A-3 results in lower emissions by about 3 MMT.

The EPA's GHGI estimates for Settlements Remaining Settlements – *Organic Soil Carbon Flux* are also incorporated into this NC inventory.

Table A-3. LCS Emissions Estimates by Inventory Year (MMTCO$_2$e)

Report year/ Subsector	Category/ Subcategory/ Data Source	1990	2005	2010	2015	2018	Average 2005-2018
2022	**Total LCS Reported**	**5.92**	**6.57**	**6.47**	**6.40**	**6.35**	**6.46**
Forest Carbon Flux	FCS from SIT	2.84	2.94	2.95	2.98	2.97	
Categories not included in SIT	LCS from GHGI	3.08	3.64	3.52	3.42	3.38	
2024 Settlements	**Total LCS from GHGI**	**3.00**	**3.55**	**3.43**	**3.35**	**3.32**	**3.42**
Average Difference							-3.04

Wetlands

The Wetlands subsector includes emissions/sequestration estimates for Peatlands, Flooded Lands, and Coastal Wetlands. The GHGI includes estimates for Wetlands subcategories related to Peatlands and Flooded Lands.[41] Three new GHGI subcategories are incorporated into this updated NC inventory: Land Converted to Wetlands – *Changes in Carbon Stocks in Lands Converted to Flooded Lands*, Wetlands Remaining Wetlands – *Flooded Lands Remaining Flooded Lands* (CH$_4$), and Land Converted to Wetlands – *Land Converted to Flooded Lands* (CH$_4$).

In 2023, the NC Coastal Habitats Greenhouse Gas Workgroup (Workgroup), formed within the NC Natural and Working Lands Stakeholder Group, developed a new inventory of GHG emissions/sinks from land converted to/remaining coastal wetlands.[42] In order to refine estimates for NC, the Workgroup utilized high-resolution federal land use and land cover data for coastal wetlands that have not yet been integrated into the SIT or GHGI methodologies. The DAQ has incorporated Workgroup estimates for estuarine coastal wetlands (salinity ≥ 0.5 practical salinity units) into this inventory. The Workgroup also developed estimates of GHG emissions and removals within high-salinity seagrass meadows, which are not inventoried in any EPA inventory. The Workgroup's seagrass estimates are included as a new subcategory in this inventory. NC's Coastal Wetlands are a net GHG emitter, but at a very small scale relative to the overall LULUCF Sector. Table A-4 shows Coastal Wetlands emissions and sinks by gas and category in kilotons (kt) CO$_2$e (1

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[41] *EPA. "Inventory of U.S. Greenhouse Gas Emissions and Sinks by State: 1990-2020." April 2022.*
https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2020.
[42] *NC Coastal Habitats GHG Workgroup. "NC Coastal Habitat Greenhouse Gas Inventory." September 2023.*

MMT = 1,000 kt). The estimates reflect a decrease in both annual carbon sequestered and annual emissions from Coastal Wetlands between 2005 and 2020. For 2020, net Coastal Wetlands flux was estimated at 34.1 kiloton of carbon dioxide equivalent (kt CO_2e) (0.034 MMTCO$_2$e).

Carbon sequestered in high-salinity seagrass meadows has decreased over time due to a loss in coverage area. The Workgroup expects that this trend will continue over the coming decades and has projected acreage and emissions for 2030 and 2050 as shown in Table A-5 below.[43] Because of their small magnitude and the uncertainty surrounding these projected emission changes, this projection is not incorporated into the LULUCF sector forecast for the state.

Table A-4. GHG Emissions and Sinks from Coastal Wetlands (kt CO2e)

Gas/Category	1990	2005	2017	2018	2019	2020
CO$_2$						
Coastal Wetlands Remaining Vegetated Coastal Wetlands	-276.03	-270.57	-279.91	-278.58	-277.25	-275.92
Land Converted to Vegetated Coastal Wetlands	-2.58	-1.24	-2.07	-2.09	-2.11	-2.14
Seagrass Soil Carbon Flux	-70.46	-70.46	-60.53	-59.18	-57.83	-56.49
Coastal Wetlands Carbon Flux	-349.08	-342.27	-342.51	-339.86	-337.20	-334.54
CH$_4$						
Coastal Wetlands Remaining Vegetated Coastal Wetlands	373.29	382.31	373.25	371.32	369.38	367.44
Land Converted to Vegetated Coastal Wetlands	0.07	0.07	0.86	0.97	1.08	1.19
Coastal Wetlands Emissions	373.37	382.37	374.12	372.29	370.46	368.63
Net GHG Flux (kt CO$_2$e)	**24.29**	**40.11**	**31.60**	**32.43**	**33.26**	**34.09**

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[43] *NC Coastal Habitats GHG Workgroup. "High Salinity Seagrass Meadows: Projections of area and carbon net accumulation to 2030 and 2050." Email transmitted by Workgroup to Amanda Crenshaw, NCDAQ, December 2023.*

Table A-5. Workgroup Projections for Seagrass Area (acres) and Emissions (kt CO$_2$e)

Seagrass Projections	2020	2030	2050
Area (acres)	88,526	67,383	36,399
Soil Carbon Flux (kt CO$_2$e)	-56.49	-42.99	-23.22

Planned integration by EPA of coastal land use and land cover datasets into future inventories will result in further refinement of coastal wetlands GHG estimates.

1.13. Inventory and BAU Tables by Sector and Subsector

Table A-6. Multiple GHG Inventory years summarized by subsector and gas (MMTCO$_2$e)

Emissions Source/Sink	2005 Base Year Emissions (MMTCO$_2$e)	Interim Year 1 (2010) (MMTCO$_2$e)	Interim Year 2 (2015) (MMTCO$_2$e)	Most Recent Inventory Year (2020) (MMTCO$_2$e)
Electricity Generation				
CO$_2$	82.29	82.60	58.34	41.63
CH$_4$	0.03	0.04	0.04	0.03
N$_2$O	0.34	0.34	0.20	0.12
HFC, PFC, SF$_6$	0.00	0.00	0.00	0.00
Commercial and Residential Buildings				
CO$_2$	24.59	21.05	19.86	18.73
CH$_4$	0.25	0.27	0.20	0.17
N$_2$O	0.13	0.13	0.12	0.11
HFC, PFC, SF$_6$	0.00	0.00	0.00	0.00
Transportation				
CO$_2$	57.35	57.32	57.49	49.59
CH$_4$	0.39	0.32	0.25	0.15
N$_2$O	0.82	0.81	0.73	0.61
HFC, PFC, SF$_6$	0.00	0.00	0.00	0.00
Agriculture				
CO$_2$	0.00	0.00	0.00	0.00
CH$_4$	8.09	7.64	7.41	7.68
N$_2$O	4.55	4.57	5.14	4.78
HFC, PFC, SF$_6$	0.00	0.00	0.00	0.00
Waste and Materials Management				
CO$_2$	0.05	0.03	0.04	0.04
CH$_4$	6.92	7.69	5.68	6.85
N$_2$O	0.24	0.25	0.27	0.28
HFC, PFC, SF$_6$	0.00	0.00	0.00	0.00
Industry				
CO$_2$	0.52	0.48	0.48	0.34
CH$_4$	0.00	0.00	0.00	0.00
N$_2$O	0.00	0.00	0.00	0.00
HFC, PFC, SF$_6$	4.36	4.51	6.08	6.88

Natural Gas and Oil Systems				
CO_2	0.00	0.00	0.00	0.00
CH_4	1.53	1.62	1.39	1.48
N_2O	0.00	0.00	0.00	0.00
HFC, PFC, SF_6	0.00	0.00	0.00	0.00
Gross Emissions	**192.45**	**189.67**	**163.72**	**139.47**
Sinks	-45.08	-47.26	-48.29	-47.68
Net Emissions	**147.37**	**142.41**	**115.43**	**91.79**

Table A-7. Expanded Inventory Table by sector and subsector (MMTCO2e)

Sector	Base Year Total Emissions (MMTCO₂e)	Inventory Year (2010) Total Emissions (MMTCO₂e)	Inventory Year (2015) Total Emissions (MMTCO₂e)	Inventory Year (2020) Total Emissions (MMTCO₂e)
Electricity Generation and Use	**82.66**	**82.98**	**58.58**	**41.77**
Electricity Generation	75.78	73.32	52.31	37.24
Imported Electricity	6.88	9.66	6.27	4.54
Residential/Commercial/Industrial Combustion	**24.97**	**21.45**	**20.17**	**19.01**
Industrial	13.09	9.73	9.39	9.23
Commercial	5.08	5.13	5.31	4.88
Residential	6.79	6.59	5.47	4.90
Transportation	**58.56**	**58.45**	**58.47**	**50.35**
Gasoline & Diesel Highway	53.78	53.39	52.74	45.45
Non-Highway	4.72	4.95	5.58	4.71
Alternative Fuel Vehicles	0.06	0.10	0.15	0.18
Agriculture	**12.63**	**12.21**	**12.54**	**12.46**
Manure Management	6.58	6.27	6.08	6.49
Agricultural Soil Management	3.95	4.01	4.54	4.12
Enteric Fermentation	2.10	1.93	1.91	1.85
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00
Waste Management	**7.21**	**7.98**	**5.99**	**7.17**
Municipal Solid Waste	5.90	6.48	4.42	5.49
Wastewater	1.31	1.49	1.57	1.69
Industrial Processes	**4.87**	**4.98**	**6.56**	**7.22**
Natural Gas and Oil Systems	**1.53**	**1.62**	**1.39**	**1.48**
Gross Emissions	**192.42**	**189.67**	**163.71**	**139.45**
Sinks	-45.08	-47.26	-48.29	-47.68
Net Emissions	**147.34**	**142.40**	**115.42**	**91.77**

Table A-8. Expanded Inventory of GHG emissions by gas for each sector and subsector for 2020 (MMTCO$_2$E)

Emissions Source/Sink	GHG Emissions by Gas (MMTCO$_2$E)			
	CO$_2$ (79%)	CH$_4$ (12%)	N$_2$O (4%)	HFC, PFC, SF$_6$, and NF$_3$ (5%)
Electricity Generation and Use	**33.00**	**5.01**	**1.67**	**2.09**
Electricity Generation	29.42	4.47	1.49	1.86
Imported Electricity	3.59	0.54	0.18	0.23
Residential/Commercial/Industrial Combustion	**15.02**	**2.28**	**0.76**	**0.95**
Industrial	7.29	1.11	0.37	0.46
Commercial	3.86	0.59	0.20	0.24
Residential	3.87	0.59	0.20	0.25
Transportation	**39.78**	**6.04**	**2.01**	**2.52**
Gasoline & Diesel Highway	34.54	5.45	1.82	2.27
Non-Highway	3.58	0.57	0.19	0.24
Alternative Fuel Vehicles	0.14	0.02	0.01	0.01
Agriculture	**9.84**	**1.50**	**0.50**	**0.62**
Manure Management	5.13	0.78	0.26	0.32
Agricultural Soil Management	3.25	0.49	0.16	0.21
Enteric Fermentation	1.46	0.22	0.07	0.09
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00
Waste Management	**5.66**	**0.86**	**0.29**	**0.36**
Municipal Solid Waste	4.34	0.66	0.22	0.27
Wastewater	1.34	0.20	0.10	0.08
Industrial Processes	**5.70**	**0.72**	**0.29**	**0.36**
Natural Gas and Oil Systems	**1.17**	**0.15**	**0.06**	**0.07**
Gross Emissions	**110.33**	**16.36**	**5.90**	**6.88**
Sinks	-37.67	-5.72	-1.91	-2.38
Net Emissions	**72.66**	**10.64**	**3.99**	**4.50**

1.13.1. Future Refinements

The EPA releases annual state-level estimates of emissions/sinks for the LULUCF sector as part of its state GHGI. For several subsectors, these data have matched the default data in the SIT module. Where the estimates differed between the two sources, DAQ made the determination of which data to include in this inventory through communication with EPA. The DAQ anticipates that future LULUCF sector estimates from EPA will be more closely aligned between the two sources. For those LULUCF sector subcategories that are not estimated in the SIT, EPA's state-level emission/sink estimates are incorporated into NC's inventory. The notable exceptions are coastal wetlands subcategories, which are taken from the NC Coastal Habitats Greenhouse Gas Inventory. Future versions of the LULUCF sector inventory will incorporate emissions/carbon flux estimates reflecting the best information available at that time.

Harvested Wood Products (HWP) are a component of Forest Carbon Flux, estimating carbon sequestered in trees that are cut for wood products such as building materials, furniture, or paper. The EPA and USFS are working to develop refined state-level estimates of carbon flux in HWP. These estimates are of particular interest in NC, where forestry and HWP manufacturing are among the state's largest industries. The DAQ anticipates that more accurate assessments of carbon stored in wood products will be available for inclusion in future versions of NC's inventory.

An expert panel exploring the carbon sequestration potential of NC's NWL found that restoration of peatlands may have the potential to convert them into a net sink, as well as building resilience to fire and creating broad ecosystem benefits.[44] Further study, including data from restoration projects, may allow development of sequestration estimates in NC peatlands for future inventories.

1.14.

1.15. Projected GHG Emissions (2021-2050) – e.g. Business As Usual (BAU)

1.15.1. Description

Because of delays in preparing and releasing historical data by various government agencies, 2020 is generally the last year for which historical data are used in estimating NC's GHG emissions. This section summarizes the methods and data sources that are used to project the 2020 emissions from 2021 through 2050. These projections represent a characterization of future emissions based on information available at the time of this

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[44] *"NC Climate Risk Assessment and Resilience Plan: Appendix B: North Carolina Natural and Working Lands Action Plan." June 2020.*

study and only reflect the effects of "on-the-books" measures to limit GHG emissions where information is available to characterize their effects.

1.15.2.   Background and Defaults

Emissions forecasts are generally 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.[45]

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 is used to develop state-level projections from national forecasts).
(2) Extrapolation of historical trends in emissions or emissions activity.

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

Table A-9. 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
ODS 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.

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[45] *EPA. "User's Guide for States Using the Greenhouse Gas Projection Tool." Prepared for EPA's State Energy Program by ICF, June 2023.*

Note that the Projections Tool does not have a sub-module for the LULUCF sector, therefore, the 2020-year estimates for GHG emissions and carbon sinks are generally carried forward to each forecast year (the one exception, as discussed below, is the Forest Fires category).

1.15.3. 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, NC-specific data, or a methodology that results in projected emissions better in line with NC historical trends. The revisions to the use of Tool defaults are summarized in Table A-7. In addition to the revisions listed in this table, the Tool default population projections are replaced with projections from the NC OSBM.[46]

Table A-10. Summary of Revisions to EPA Projections Tool Defaults

Sector	Revised Projections Approach(es)	Rationale for Use
Electricity Generation and Imported Electricity	Electricity Generation For 2021 & 2022, heat input (in MMBtu) by fuel type from fuel used in 2021 & 2022, which was obtained from EIA Form 923 data.[47] For 2023 through 2050 heat input, two different approaches are used: (a) For Duke Energy facilities: 2024 through 2050 - Duke Energy Corporation's October 2023 Pathway 1/ Core Portfolio 1 forecast of NC fuel use (in MMBtu).[48] For 2023, values interpolated between actual 2022 EIA fuel input and Duke Energy's 2024 forecast fuel use.	Historical fuel use data are preferable to a projection. Duke Energy's forecast is preferred because it is developed via the Integrated Resource Plan process. 2023 interpolated values are used

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[46] *NC Office of State Budget and Management. "County/State Population Projections." https://www.osbm.nc.gov/facts-figures/population-demographics/state-demographer/countystate-population-projections. Accessed November 2023.*

[47] *EIA. "2020-2022 Form EIA-923 detailed data with previous form data (EIA-906/920)." https://www.eia.gov/electricity/data/eia923/. Accessed July 2023.*

[48] *Duke Energy, 2023 CPIRP NCDAQ Data Request – P1.xlsx, e-mail transmittal from Cynthia Winston to Ming Xie, NC Division of Air Quality, October 11, 2023.*

Sector	Revised Projections Approach(es)	Rationale for Use
	(b) All other NC electricity generation reflect the average of the last three available years (2020-2022) of fuel consumption (in MMBtu) compiled from EIA Form 923 data.	because 2023 actual values are not yet available.

The historical average fuel use is used because these sources represent a small percentage of sector emissions and forecasts for all these smaller sources are not available. |
| | Imported Electricity

(a) For 2021-2050, SIT projections of 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 over the last three (2019-2021) available years (11.22%) based on EIA data. [49]	Imported electricity emissions were calculated using the most recent data available for characterizing net imports (2019-2021). This value was held constant for projection years since there are many uncertainties in projecting imported electricity.
	(c) The imported electricity used for a given year is calculated as the projected retail electricity consumption multiplied by the percent imported.	
	(d) Projected GHG emission rates are based on information provided in a recent EPA regulatory impact analysis. [50]	Projected rates for South Carolina are the highest of the rates of adjoining states, so represent a conservative assumption.

[49] EIA, State Energy Data System (SEDS): 1960-2021, available from https://www.eia.gov/state/seds/seds-data-complete.php?sid=NC#Consumption, accessed September 2023.
[50] EPA, "Regulatory Impact Analysis for the Proposed New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions from Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule," EPA-452/R-23-006, May 2023.

Sector	Revised Projections Approach(es)	Rationale for Use
Transportation	*Onroad Vehicles* – MOVES4 model runs with NC historical/forecast VMT inputs used to estimate 2021, 2030, and 2050 emissions. Emissions for 2022-2029 estimated as product of VMT and emission factors interpolated from 2021 and 2030 MOVES4 model run output. Emissions for 2031-2049 estimated similarly from 2030 and 2050 MOVES4 model run output.	A more sophisticated modeling approach that uses official EPA onroad mobile source emissions estimation model, provides additional subsector granularity, and future year modeling flexibility.
	Non-highway – Aviation and Boats use a linear extrapolation of historical emissions data. Locomotives, Farm Equipment, Construction Equipment, and Other Equipment apply the average of 2003-2020 emissions in each category and apply this value to each forecast year.	Forecast emission trends were not in line with historical trends. Forecast approach based on historical emissions trend – if there is a clear trend (Aviation/Boats) or not (all other categories). With Aviation and Boats, a clear trend only started with 2003 emissions (probably due to post-9/11 travel/economic impacts), so pre-2003 data were excluded from use in each forecast approach.
Industrial Processes	*ODS substitutes* – apply HFC emissions growth rates from national EPA non-CO_2 projections report to 2020 NC emissions.[51]	Default Tool projections result in emission values that are unrealistically high.
	Phosphoric acid production is not included in the SIT Industrial	Reported GHG emissions from phosphoric acid production are relatively constant from 2002.

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[51] EPA, "Global Non-CO_2 Greenhouse Gas Emission Projections & Mitigation, 2015–2050," Office of Atmospheric Programs, EPA-430-R-19-010, October 2019.

Sector	Revised Projections Approach(es)	Rationale for Use
	Processes module; however, NC emissions data are reported for this process to EPA's GHG Reporting Program. The 2021 CO_2e value is carried forward every year to 2050.	through 2016, so the 2016 value is held constant for projected years.
Solid Waste/Landfill CH_4 Emissions	Apply average of 2003-2020 emissions to each forecast year.	Best identified approach given historical emissions did not indicate a clear trend (periods with increases and periods with decreases), while the SIT Projection Tool consistently forecast unrealistically large emissions increases.
Land Use/Forest Fires	Forest Fire emissions held constant at the 10-year average for 2011-2020.	Emissions from wildfires and prescribed burns are highly variable. Recent longer-term values capture high, medium, and low occurrence years related to shorter-term climate interactions with normal seasonal trends.

Electricity Generation

To incorporate an initial estimate of the impact associated with the 2030 and 2050 CO_2 emissions reduction targets established in SL 2021-165, the emissions forecast for the electricity generation sector in this report incorporates the generation forecast for Pathway 1/Core Portfolio 1 Duke Energy included in its proposed Carbon Plan/Integrated Resources Plan (CPIRP) submitted to the NCUC on August 17, 2023.[52]

For use in this Electricity Generation forecast, the DAQ summed Duke Energy's proposed Pathway 1/Core Portfolio 1 unit-level fuel use (i.e., heat input) projections by fuel type for each year from 2024 through 2050. These projections were used along with the SIT's Projection Tool fuel-specific emission factors to project GHG emissions for Duke Energy facilities for these years. Because actual 2021 and 2022 heat input by fuel type was available from EIA for Duke Energy facilities, these data were used to develop emission projections for these years. Because 2023 heat input data were not available at the time

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[52] *Duke Energy, 2023 CPIRP NCDAQ Data Request - P1.xlsx, e-mail transmittal from Cynthia Winston to Ming Xie, NC Division of Air Quality, October 11, 2023.*

that this forecast was produced, the DAQ interpolated between the actual 2022 heat input by fuel type and the 2024 proposed CPIRP Pathway 1 fuel type projections to estimate 2023 fuel use for Duke Energy units. The fuel use estimates for Duke Energy for 2021-2023 were combined with the SIT Projection Tool's fuel-specific emission factors to estimate emissions in these years.

For non-Duke Energy units in NC, emission projections reflect use of the Tool's emission factors and the average of the last three available years of fuel consumption data (2020-2022), compiled from the EIA.[53] This approach is consistent with that used in the previous GHG inventory, and reflects the lack of information for projecting fuel use/emissions for these generating units.

The DAQ applied the same approach to estimating net interstate flow of electricity for NC as was used in the previous GHG inventory. This approach relies on electricity demand forecasts for NC from EPA's Projections Tool, and the recent historical average percentage of NC demand met by imports (approximately 11% for 2019-2021). To estimate future year imported electricity CO_2 emission factors per kilowatt-hour (kWh), the DAQ applied the emission rates projected for South Carolina from EPA's regulatory impact analysis for its proposed New Source Performance Standards/Emission Guidelines for GHGs from Electric Generating Units.[54] Because EPA did not develop CH_4 and N_2O emission projections in this regulatory analysis, the DAQ calculated forecast year CH_4 and N_2O emission rates by first calculating ratios of the projected South Carolina CO_2 emission rate in each forecast year to the 2021 CO_2 emission rate. The DAQ then applied these ratios to 2021 CH_4 and N_2O emission rates to develop projected CH_4 and N_2O emission rates for imported electricity.

Onroad Vehicles

Forecasts for the onroad vehicle sector were developed from a 2021 emissions baseline. For the 2021 GHG onroad emissions modeling, the DAQ used 2021 VMT estimates from the NCDOT based on the data compiled for the HPMS. For the 2030 and 2050 onroad vehicle GHG emissions modeling, the DAQ used VMT estimates projected from the 2022 NC HPMS VMT dataset. County-level growth factors for 2023 through 2050, relative to a 2022 base year, were first developed based on population forecasts for each NC county obtained from the NC OSBM State Demographer's Office and on annual per capita VMT forecasts obtained from Annual Energy Outlook (AEO) 2023. The DAQ then developed 2030-year and

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[53] EIA, "2020-2022 Form EIA-923 detailed data with previous form data (EIA-906/920)," available from https://www.eia.gov/electricity/data/eia923/, accessed July 2023.

[54] EPA. "Regulatory Impact Analysis for the Proposed New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions from Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule," EPA-452/R-23-006. May 2023.

2050-year county-level VMT projections by multiplying each county's 2022 annual VMT by their corresponding 2030 and 2050 growth factors.

To evaluate the impact of battery electric vehicles (BEVs) on future GHG emissions, estimates of VMT by vehicle type and fuel type were developed for 2021, 2030, and 2050 from MOVES4 model runs using statewide vehicle fleet and VMT estimates for each year. The output data, which reflected the MOVES4 default fractions of BEVs in the fleet, were compiled to provide statewide annual VMT estimates by vehicle type and fuel type. Estimates of 2030 and 2050 fleet populations of light-, medium-, and heavy-duty BEVs were then developed for the Duke Energy service areas of the state (roughly 83 counties) and were extended to cover the remaining 17 counties serviced by other utilities. Duke Energy provided projected annual numbers of light-, medium-, and heavy-duty BEVs in operation within the Duke Energy service areas for the years 2023 through 2040, consistent with its corresponding projections for BEV-related energy generation.[55] Based on these data, the DAQ developed estimates of BEVs in service for years 2041-2050. The DAQ then used the 2030 and 2050 BEV population estimates to revise the distribution, by vehicle type and fuel type, of the 2030 and 2050 statewide VMT estimates, assuming that BEVs would be one-to-one replacements of light-, medium-, and heavy-duty internal combustion engine vehicles. Under this assumption, each BEV introduced into the fleet effectively zeroes out the GHG emissions from an internal combustion engine vehicle of the same type. This provided 2030 and 2050 VMT estimates consistent with the Duke Energy BEV projections.

To generate statewide GHG onroad mobile source emission factors, MOVES4 modeling runs, using the model default inputs data for NC, were completed for 2021, 2030, and 2050. GHG emission factors, in units of grams per mile, were calculated for each vehicle type and fuel type combination. GHG emissions for each year were calculated by multiplying the annual VMT estimates described above by the corresponding emission factors to provide annual grams per year emissions by vehicle type and fuel type, and then converted to annual MT.

Projected onroad emission estimates for each interim year between the modeled years (2021-2029 and 2031-2049) were developed by first interpolating VMT estimates and emission factors between adjacent modeled years (2021-2030 and 2030-2050) and then multiplying the values as described above. Combined with the modeled years, this provided GHG emissions by vehicle/fuel type for each of the three GHGs for all years from 2021 through 2050.

Ozone-Depleting Substances (ODS)

Although there are some other ODS substitutes, HFCs are by far the most prevalent. The EPA has been working to implement the American Innovation and Manufacturing (AIM) Act,

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[55] Winston, Cynthia, Duke Energy Corporation, "NC EV Forecast," transmitted to Andy Bollman, NCDEQ, October 23, 2023.

which authorizes EPA to reduce production and consumption of HFCs on the same schedule as the Kigali Amendment, which the U.S. recently ratified. The EPA has begun evaluating the impacts on HFC emissions from the AIM Act, but information is not currently sufficient for use in forecasting emissions from ODS substitutes in NC. Therefore, the DAQ applied growth rates reflecting national HFC emission projections developed by EPA in 2019 to forecast this category (this approach was deemed reasonable when described with an EPA ODS substitute contact).[56] While these projections account for other ODS substance reducing policies (e.g., EPA's Significant New Alternatives Policy Program), they do not account for AIM Act-related emission reductions. Therefore, the projections for this category should be considered conservatively high. Future support from EPA will be essential in developing state-level ODS substitute projections reflecting the AIM Act.

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[56] *EPA, "Global Non-CO$_2$ Greenhouse Gas Emission Projections & Mitigation, 2015–2050," Office of Atmospheric Programs, EPA-430-R-19-010, October 2019.*

Table A-11. Expanded BAU projections by sector and subsector (MMTCO₂e)

Sector	Base Year Total Emissions (MMTCO₂e)	Inventory Year (2020) Total Emissions (MMTCO₂e)	Short-Term BAU Projection Year 2030 (MMTCO2e)	Long-Term BAU Projection Year 2050 (MMTCO2e)
Electricity Generation and Use	**82.66**	**41.77**	**26.71**	**8.50**
Electricity Generation	75.78	37.24	24.00	7.12
Imported Electricity	6.88	4.54	2.70	1.38
Residential/Commercial/Industrial Combustion	**24.97**	**19.01**	**21.14**	**22.69**
Industrial	13.09	9.23	10.43	11.51
Commercial	5.08	4.88	5.59	6.20
Residential	6.79	4.90	5.13	4.98
Transportation	**58.56**	**50.35**	**52.07**	**35.84**
Gasoline & Diesel Highway	53.78	45.45	44.95	26.84
Non-Highway	4.72	4.71	6.79	8.70
Alternative Fuel Vehicles	0.06	0.18	0.34	0.29
Agriculture	**12.63**	**12.46**	**12.46**	**13.28**
Manure Management	6.58	6.49	6.58	7.61
Agricultural Soil Management	3.95	4.12	4.16	4.01
Enteric Fermentation	2.10	1.85	1.71	1.66
Burning of Agricultural Crop Waste	0.00	0.00	0.00	0.00
Waste Management	**7.21**	**7.17**	**7.48**	**7.99**
Municipal Solid Waste	5.90	5.49	5.50	5.48
Wastewater	1.31	1.69	1.98	2.52
Industrial Processes	**4.87**	**7.22**	**9.00**	**10.12**
Natural Gas and Oil Systems	**1.53**	**1.48**	**1.65**	**1.65**
Gross Emissions	**192.42**	**139.45**	**130.51**	**100.07**
Sinks	-45.08	-47.68	-47.23	-47.23
Net Emissions	**147.34**	**91.77**	**83.28**	**52.84**

1.15.4. Future Refinements

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 EPA is planning to finalize MHD vehicle CAFE/GHG emissions standards later this year. In addition, projections for a few subsectors are based on EPA national forecasts from many years ago (e.g., the ODS substitute projections are from a 2019 report). The EPA information used to project emissions for this inventory does not account for the impacts of the IRA and IIJA. As these statutes become more fully implemented, it is expected that EPA will release projection information and tools for estimating their associated GHG reductions.[57] Future versions of this inventory will utilize the most recent available forecast data at the time that the inventory is prepared. Finally, it is good practice to review the accuracy of these projections as historical data become available, and to incorporate any lessons learned in preparing future GHG forecasts.

1.15.5. Uncertainty

In keeping with our approach of using the SIT for developing historical emissions estimates, the DAQ generally relied on the SIT's Projection Tool to forecast emissions over the 2019-2050 period (major exceptions are use of Duke Energy heat input forecasts for electricity generation and MOVES4-based emissions forecasts for onroad vehicles). In cases where more state-specific and/or recent data were identified than provided in the SIT, the DAQ replaced default values with these more representative data.

There is associated uncertainty with the forecast capability of the SIT and MOVES4, use of potentially outdated default data, and inherent uncertainty of future GHG policy changes. The DAQ emphasizes our commitment to review the validity of the GHG projections methods used in this effort when undertaking future GHG inventory efforts.

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[57] *The DAQ has incorporated Duke Energy's heat input and electric vehicle projections reflecting their modeling of the estimated impacts of IRA. We anticipate that these projections will be further refined in the future by Duke Energy as additional IRA and IIJA program information becomes available.*