Chapter 2
Inventory and Projections of GHG Emissions

Introduction

This chapter summarizes South Carolina's greenhouse gas (GHG) emissions and sinks (carbon storage) from 1990 to 2020. The Center for Climate Strategies (CCS) prepared a draft of South Carolina's GHG emissions inventory and reference case projections for the Climate, Energy, and Commerce Advisory Committee (CECAC) of the Office of the Governor of South Carolina. The draft inventory and reference case projections, completed in June 2007, provided the CECAC with an initial, comprehensive understanding of current and possible future GHG emissions. The draft report was provided to the CECAC and its Technical Work Groups (TWGs) to assist them in understanding past, current, and possible future GHG emissions in South Carolina, and thereby inform the policy recommendation development process. The CECAC and TWGs have reviewed, discussed, and evaluated the draft inventory and methodologies, as well as alternative data and approaches for improving the draft GHG inventory and forecast. The inventory and forecast have since been revised to address the comments provided by the CECAC. The information in this chapter reflects the information presented in the final *South Carolina Greenhouse Gas Inventory and Reference Case Projections* report (hereafter referred to as the Inventory and Projections report).[1]

Historical GHG emissions estimates (1990 through 2005)[2] were developed using a set of generally accepted principles and guidelines for state GHG emissions inventories, relying to the extent possible on South Carolina-specific data and inputs. The reference case projections (2006–2020) are based on a compilation of various existing projections of electricity generation, fuel use, and other GHG-emitting activities, along with a set of simple, transparent assumptions described in the final Inventory and Projections report.

The Inventory and Projections report covers the six types of gases included in the U.S. GHG inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential-weighted basis.[3]

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[1] Center for Climate Strategies for the Climate. Final South Carolina Greenhouse Gas Inventory and Reference Case Projections: 1990–2020. Prepared for the Climate, Energy, and Commerce Advisory Committee of the Office of the Governor of South Carolina. June 2008.

[2] The last year of available historical data for each sector varies between 2000 and 2005.

[3] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth–atmosphere system (IPCC, 2001). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth). See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental

It is important to note that the emissions estimates reflect the GHG emissions associated with the electricity sources used to meet South Carolina's demands, corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the GHG emissions produced by electricity generation facilities in the state—a production-based method. The study covers both methods of accounting for emissions, but for consistency, all total results are reported as consumption-based.

South Carolina GHG Emissions: Sources and Trends

Table 2-1 provides a summary of GHG emissions estimated for South Carolina by sector for 1990, 2000, 2005, 2010, and 2020. As shown in this table, South Carolina is estimated to be a net source of GHG emissions (positive, or gross, emissions). South Carolina's forests serve as sinks of GHG emissions (removal of emissions, or negative emissions). South Carolina's net emissions subtract the equivalent GHG reduction from emission sinks from the gross GHG emissions totals. The following sections discuss GHG emission sources and sinks, trends, projections, and uncertainties.

Emissions of aerosols, particularly "black carbon" from fossil fuel combustion, could have significant climate impacts through their effects on radiative forcing. Estimates of these aerosol emissions on a CO_2e basis were developed for South Carolina based on 2002 and 2018 data from the Visibility Improvement State and Tribal Association of the Southeast (VISTAS) regional planning organization. The results for current levels of black carbon emissions were a total of 7.0 $MMtCO_2e$, which is the mid-point of a range of estimated emissions (4.5–9.6 $MMtCO_2e$) in 2002. Based on an assessment of the primary contributors, it is estimated that black carbon emissions will decrease substantially by 2018 after new engine and fuel standards take effect in the on-road and nonroad diesel engine sectors. These estimates are not incorporated into the totals shown in Table 2-1, because a global warming potential for black carbon has not yet been assigned by the Intergovernmental Panel on Climate Change (IPCC).

Historical Emissions

Overview

In 2005, on a gross emissions consumption basis (i.e., excluding carbon sinks), South Carolina accounted for approximately 94 million metric tons (MMt) of CO_2e emissions, an amount equal to 1.3% of total U.S. gross GHG emissions. On a net emissions basis (i.e., including carbon sinks), South Carolinians accounted for approximately 62 $MMtCO_2e$ of emissions in 2005, an amount equal to 1.0% of total U.S. net GHG emissions.[4] South Carolina's GHG emissions are

Panel on Climate Change Cambridge University Press. Cambridge, United Kingdom. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm

[4] The national emissions used for these comparisons are based on 2005 emissions from U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006*, April 15, 2008, EPA430-R-08-005. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html

rising faster than those of the nation as a whole. From 1990 to 2005, South Carolina's gross GHG emissions increased by 39%, while national gross emissions rose by 16%.[5]

Table 2-1. South Carolina historical and reference case GHG emissions, by sector*

(Million Metric Tons CO_2e)	1990	2000	2005	2010	2020
Energy (Consumption Based)	**59.8**	**78.8**	**83.5**	**91.3**	**112.5**
Electricity Use (Consumption)	**18.5**	**32.0**	**33.0**	**35.7**	**48.2**
Electricity production (in-state)	21.9	36.4	38.0	40.2	54.5
Coal	18.1	31.3	31.9	32.1	44.0
Natural gas	0.32	0.42	0.86	2.99	3.44
Oil	0.05	0.29	0.19	0.55	0.62
Wood (CH_4 and N_2O)	0.02	0.02	0.02	0.02	0.04
MSW/landfill gas	0.00	0.02	0.01	0.01	0.01
Net exported electricity	–3.38	–4.37	–4.98	–4.51	–6.31
Residential/Commercial/Industrial (RCI) Fuel Use	**17.7**	**17.7**	**17.9**	**18.7**	**19.9**
Coal	5.46	4.71	3.64	4.04	4.13
Natural gas	6.49	7.96	6.75	7.36	8.20
Oil	5.64	4.81	7.39	7.18	7.38
Wood (CH_4 and N_2O)	0.16	0.18	0.15	0.16	0.17
Transportation	**22.7**	**28.4**	**31.8**	**36.1**	**43.6**
On-road gasoline	16.2	19.8	21.5	23.8	27.6
On-road diesel	4.09	5.96	7.59	9.25	12.2
Marine vessels	0.84	1.53	1.78	2.08	2.75
Rail, natural gas, LPG, other	0.43	0.28	0.24	0.25	0.27
Jet fuel and aviation gasoline	1.19	0.77	0.68	0.72	0.77
Fossil Fuel Industry	**0.83**	**0.78**	**0.76**	**0.80**	**0.89**
Natural gas industry	0.83	0.78	0.76	0.80	0.89
Transmission	0.32	0.36	0.38	0.40	0.46
Distribution	0.35	0.22	0.25	0.27	0.31
Pipeline fuel use	0.16	0.19	0.13	0.13	0.12
Industrial Processes	**2.61**	**3.28**	**4.14**	**4.98**	**6.63**
Cement manufacture (CO_2)	1.10	1.31	1.64	1.65	1.68
Limestone and dolomite use (CO_2)	0.01	0.01	0.01	0.01	0.01
Soda ash (CO_2)	0.04	0.04	0.04	0.04	0.04
ODS substitutes (HFC, PFC)	0.005	1.07	1.67	2.48	4.07
Electric power transmission and distribution (T&D) (SF_6)	0.62	0.36	0.35	0.36	0.38
Aluminum manufacturing (PFC)	0.84	0.51	0.43	0.44	0.45
Waste Management	**1.65**	**2.77**	**2.88**	**3.01**	**3.38**
Solid waste management	1.48	2.57	2.67	2.79	3.14

[5] During this period, population grew by 21% in South Carolina and by 19% nationally. However, South Carolina's economy grew at a slower rate on a per capita basis (up 30% vs. 34% nationally).

(Million Metric Tons CO_2e)	1990	2000	2005	2010	2020
Wastewater management	0.17	0.20	0.21	0.22	0.24
Agriculture	**3.11**	**3.15**	**2.98**	**2.95**	**2.89**
Enteric fermentation	0.69	0.57	0.54	0.57	0.51
Manure management	0.39	0.47	0.48	0.49	0.57
Agriculture soils and residue burning	1.86	1.76	1.76	1.71	1.63
Agriculture soils (cultivation practices)	0.18	0.18	0.18	0.18	0.18
Total Gross Emissions (Consumption Basis)	**67.2**	**87.8**	**93.5**	**102.2**	**125.4**
Increase relative to 1990		31%	39%	52%	87%
Forestry and Land Use	**–33.2**	**–31.0**	**–31.2**	**–31.2**	**–31.2**
Forested Landscape	–28.78	–28.78	–28.78	–28.78	–28.78
Urban Forestry and Land Use	–4.38	–2.24	–2.46	–2.46	–2.46
Net Emissions (Consumption Basis, Including Forestry and Land Use Sinks)	**34.0**	**56.8**	**62.3**	**71.0**	**94.1**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; CH_4 = methane; N_2O = nitrous oxide; MSW = municipal solid waste; LPG = liquefied petroleum gas; ODS = ozone-depleting substance; HFC = hydrofluorocarbon; PFC = perfluorocarbon; SF_6 = sulfur hexafluoride; NG = natural gas; T&D = transmission and distribution; VISTAS = Visibility Improvement State and Tribal Association of the Southeast.

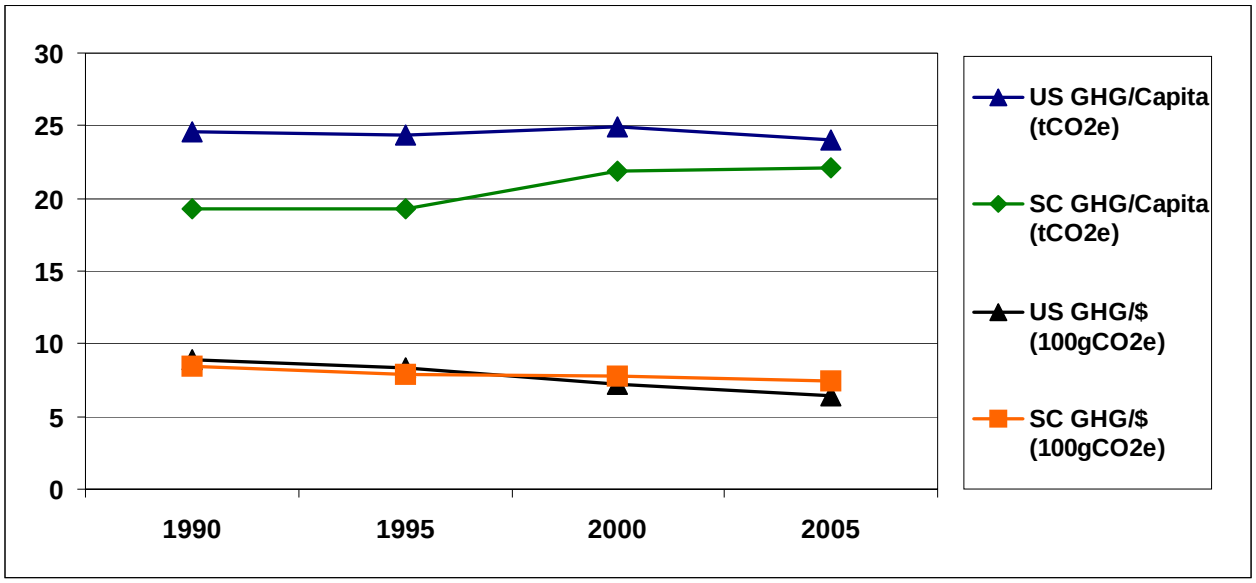
* Totals may not equal exact sum of subtotals shown in this table due to independent rounding.

On a per-capita basis, South Carolinians emitted about 22 metric tons (t) of gross CO_2e in 2005, lower than the national average of about 24 tCO_2e. Figure 2-1 illustrates the state's emissions per capita and per unit of economic output. It also shows that in South Carolina per-capita emissions have increased from 1990 to 2005, but remained fairly flat for the nation as a whole. South Carolina's per capita emissions increased between 1995 and 2001 as a result of an additional 700 megawatts of coal capacity coming on line in the state. In both South Carolina and the nation as a whole, economic growth exceeded emissions growth throughout the 1990–2005 period. From 1990 to 2005, emissions per unit of gross product dropped by 27% nationally, and by 12% in South Carolina.[6]

The principal sources of South Carolina's GHG emissions in 2005 are electricity consumption and transportation, accounting for 35% and 34% of South Carolina's gross GHG emissions, respectively, as shown in Figure 2-2. The direct use of fuels—natural gas, oil products, coal, and wood—in the residential, commercial, and industrial (RCI) sectors accounts for another 19% of the state's emissions in 2005.

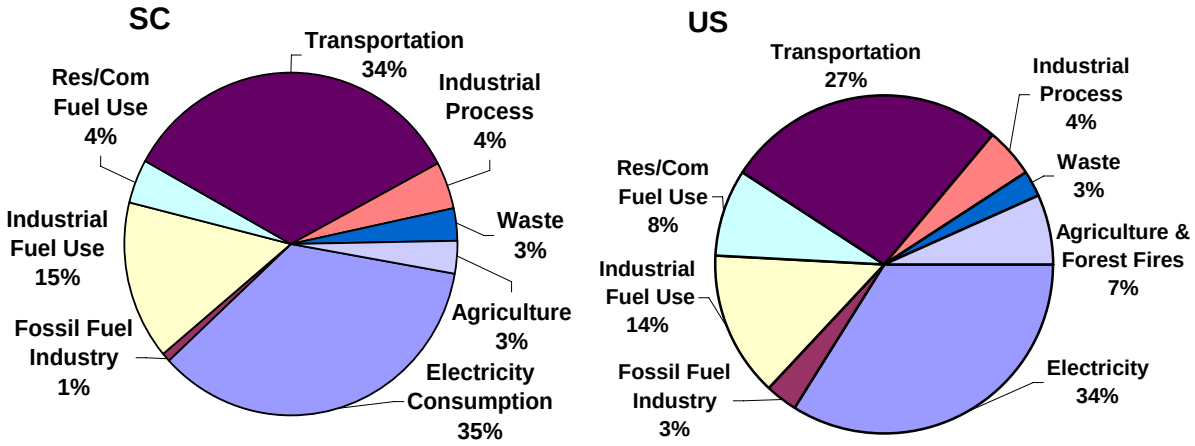
[6] Based on real gross domestic product (millions of chained 2000 dollars), that excludes the effects of inflation, available from the U.S. Department of Commerce, Bureau of Economic Analysis. "Gross Domestic Product by State." Available at: http://www.bea.gov/regional/gsp/

Figure 2-1. South Carolina and U.S. gross GHG emissions, per-capita and per-unit gross product



GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent.; GSP = gross state product; GDP = gross domestic product; g = grams.

Figure 2-2. Gross GHG emissions by sector, 2005: South Carolina and U.S.



Industrial process emissions accounted for about 4% of the state's GHG emissions in 2005, and these emissions are rising due to the increasing use of HFCs and PFCs as substitutes for ozone-depleting chlorofluorocarbons.[7] Other industrial process emissions include CO_2 released by cement manufacturing; CO_2 released during soda ash, limestone, and dolomite use; PFCs released during aluminum production; and SF_6 released from transformers used in electricity

[7] Chlorofluorocarbons are also potent GHGs; however, they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol on Substances That Affect the Ozone Layer. See Appendix I in the Final Inventory and Projections report for South Carolina. Available at: http://www.scclimatechange.us/Inventory_Forecast_Report.cfm

transmission and distribution systems. Agricultural activities, such as manure management, fertilizer use, livestock (enteric fermentation), and changes in soil carbon due to cultivation practices, result in CH_4 and N_2O emissions that accounted for another 3% of state GHG emissions in 2005. Similarly, landfills and wastewater management facilities produce CH_4 and N_2O emissions that accounted for 3% of total gross GHG emissions in South Carolina in 2005. Emissions associated with the transmission and distribution of natural gas accounted for 1% of the gross GHG emissions in 2005.

Forestry emissions refer to the net CO_2 flux[8] from forested lands in South Carolina, which account for about 66% of the state's land area.[9] South Carolina's forests are estimated to be net sinks of CO_2 emissions in the state, reducing net GHG emissions by 31 $MMtCO_2e$ in 2005.

Reference Case Projections

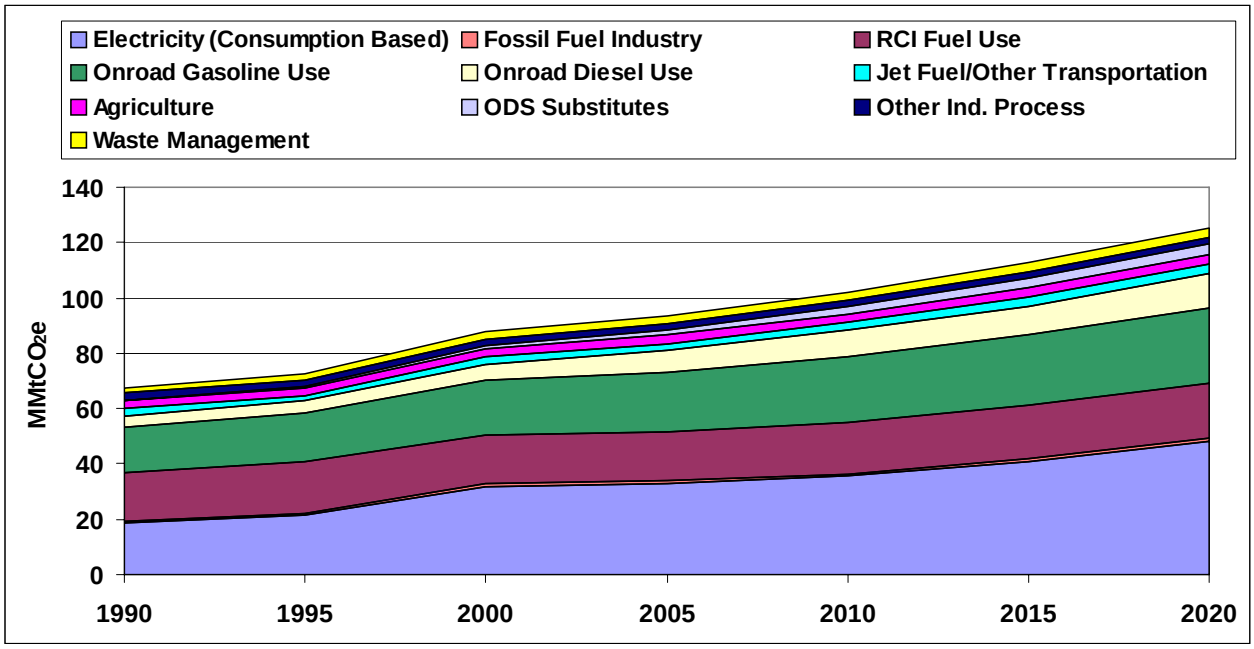
Relying on a variety of sources for projections, as noted in the Inventory and Projections report, a simple reference case projection of GHG emissions through 2020 was developed. As illustrated in Figure 2-3 and shown numerically in Table 2-1, under the reference case projections, South Carolina's gross GHG emissions continue to grow steadily, climbing to about 125 $MMtCO_2e$ by 2020, or 87% above 1990 levels. This equates to a 2% annual rate of growth. By 2020, the share of South Carolina's gross GHG emissions associated with electricity consumption grows to 38%; emissions from the RCI fuel use sector decrease to 16%; while emissions from the transportation sector stay relatively constant, at 35%.

Emissions associated with electricity consumption are projected to be the largest contributor to future GHG emissions growth, followed by emissions associated with the transportation sector, as shown in Figure 2-4. Other sources of emissions growth include the increasing use of HFCs and PFCs as substitutes for ozone-depleting substances (ODS) in refrigeration, air conditioning, and other applications, as well as the RCI fuel use sector. Table 2-2 summarizes the growth rates that drive the growth in the South Carolina reference case projections, as well as the sources of these data.

[8] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.

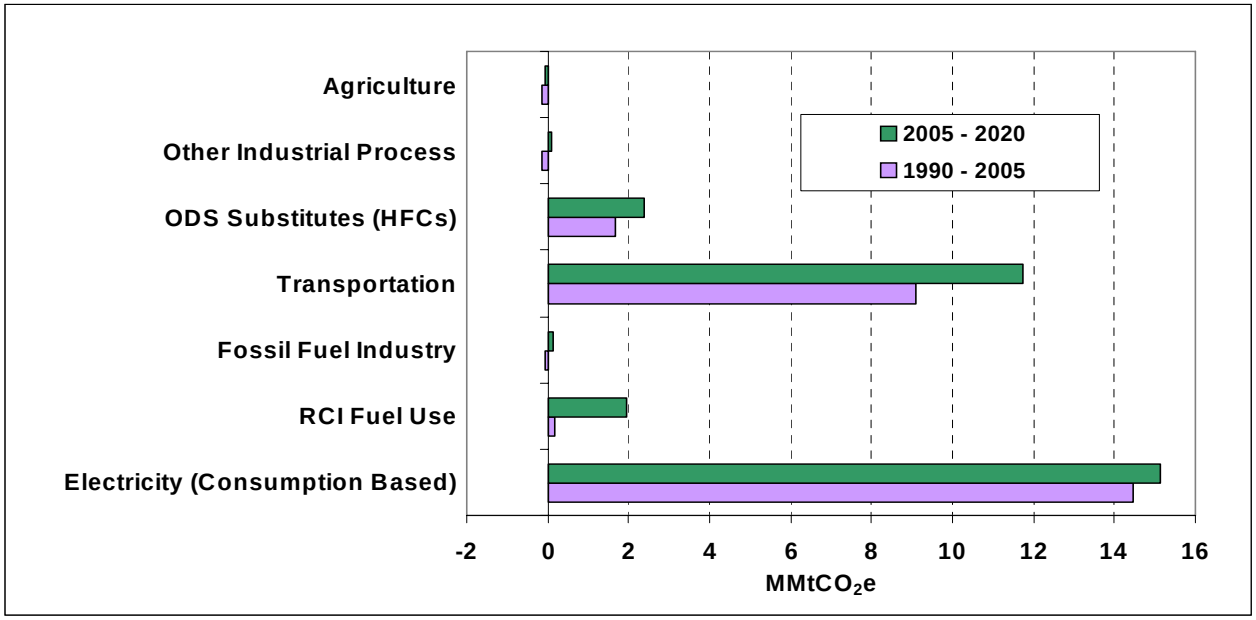
[9] Total forested acreage is 12.7 million acres. For acreage by forest type, see: Richard A. Birdsey and George M. Lewis. "Carbon in United States Forests and Wood Products, 1987–1997: State-by-State Estimates." South Carolina Estimate for 1987–1997. Available from the U.S. Department of Agriculture, Forest Service, Northern Global Change Research Program, at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/SC.htm. The total land area in South Carolina is 19.3 million acres (http://www.50states.com/scarolin.htm).

Figure 2-3. South Carolina gross GHG emissions by sector, 1990–2020: historical and projected



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; RCI = direct fuel use in residential, commercial, and industrial sectors; ODS = ozone-depleting substance; Ind. = industrial.

Figure 2-4. Sector contributions to gross emissions growth in South Carolina, 1990–2020: reference case projections



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; ODS = ozone-depleting substance; HFCs = hydrofluorocarbons; RCI = direct fuel use in residential, commercial, and industrial sectors.

Table 2-2. Key annual growth rates for South Carolina, historical and projected

	1990–2005	2005–2020	Sources
Population[a]	1.3%	1.0%	South Carolina Budget and Control Board, Office of Research and Statistics
Employment[a] Goods Services	 N/A[b] N/A	 0.2% 1.7%	Growth rates based on employment data for 2000–2010 available from the South Carolina Employment Security Commission, Labor Market Information Online, Economic Data, South Carolina Data, Current Employment Statistics, Projections, Industry Projections (http://www.sces.org/lmi/data/project/projections.asp).
Electricity Sales Total sales[c] SC sales[d]	 2.26% 2.57%	 1.58% 1.79%	US DOE Energy Information Administration (EIA) data for 1990–2003. Reference case sales based on data provided by South Carolina utilities for 2003–2020.
Vehicle Miles Traveled	2.4%	2.0%	South Carolina Department of Transportation

[a] For the RCI fuel consumption sectors, population and employment projections for South Carolina were used together with U.S. DOE EIA's Annual Energy Outlook 2006 (AEO 2006) projections of changes in fuel use for the EIA's South Atlantic region on a per-capita basis for the residential sector, and on a per-employee basis for the commercial and industrial sectors.[10] For instance, growth in South Carolina's residential natural gas use is calculated as the South Carolina population growth times the change in per-capita natural gas use for the South Atlantic region.

[b] NA – Not available; historical employment data for South Carolina for the goods producing and services providing sectors could not be identified.

[c] Represents annual growth in total sales of electricity by generators in South Carolina to RCI sectors located within and outside of South Carolina.

[d] Represents annual growth in total sales of electricity by generators in South Carolina to RCI sectors located within South Carolina.

A Closer Look at the Two Major Sources: Electricity Supply and Transportation

As shown in Figure 2-2, electricity use in 2005 accounted for 35% of South Carolina's gross GHG emissions (about 33 $MMtCO_2e$), which is slightly higher than the national share of emissions from electricity generation (34%). On a per-capita basis, South Carolina's GHG emissions from electricity consumption are lower than the national average (in 2005, 7.8 tCO_2e per capita in South Carolina, versus 8.1 tCO_2e per capita nationally). Electricity generation in South Carolina is dominated by steam units, which are primarily powered by coal and nuclear fuel. In 2003, electricity generated by nuclear power accounted for 55% of the in-state net generation. Coal-fired power plants in South Carolina accounted for another 40% of in-state net generation. The remaining in-state generation came from a mix of hydroelectric, natural gas, oil, and refuse-derived fuel facilities.[11]

As noted above, these electricity emission estimates reflect the GHG emissions associated with the electricity sources used to meet South Carolina's demand for electricity, corresponding to a consumption-based approach to emissions accounting. For many years, South Carolina power plants have produced more electricity than is consumed in the state. In 2005, for example,

[10] U.S. Department of Energy, Energy Information Administration. *Annual Energy Outlook 2006: With Projections to 2030.* IDOE/EIA-0383(2006). February 2006. Available at: http://www.scag.ca.gov/rcp/pdf/publications/1_2006AnnualEnergyOutlook.pdf.

[11] Percentages are based on net generation (excluding plant fuel use) associated with the electricity produced by facilities in South Carolina, and include generation associated with electricity exported to other states.

emissions associated with South Carolina's electricity consumption (33 $MMtCO_2e$) were lower than those associated with electricity production (38 $MMtCO_2e$). The higher level for generation-based emissions reflects GHG emissions associated with net exports of electricity to meet the electricity demand of other states.[12] Estimates of electricity sales for 2005 through 2020 indicate that South Carolina will remain a net exporter of electricity.

While estimates are provided for emissions from both electricity production and consumption, unless otherwise indicated, tables, figures, and totals in this report reflect electricity consumption emissions. The consumption-based approach can better reflect the emissions (and emission reductions) associated with activities occurring in the state, particularly with respect to electricity use (and efficiency improvements), and is particularly useful for decision making. Under this approach, emissions associated with electricity exported to other states would need to be covered in those states' inventories in order to avoid double counting or exclusions.

Like electricity emissions, GHG emissions from transportation fuel use have risen steadily from 1990 to 2005, at an average annual rate of 2.3%. In 2005, gasoline-powered on-road vehicles accounted for about 68% of transportation GHG emissions; on-road diesel vehicles for 24%; marine vessels for 6%; aviation fuels for 2%; and rail and other sources (natural gas- and liquefied petroleum gas-fueled vehicles used in transport applications) accounted for the remaining 1%. As a result of South Carolina's population and economic growth and an increase in total vehicle miles traveled (VMT), emissions from on-road gasoline use grew at a rate of 1.9% annually between 1990 and 2005. Meanwhile, emissions from on-road diesel use rose by 4.2% per year from 1990 to 2005, suggesting an even more rapid growth in freight movement within or across the state. Emissions from on-road gasoline vehicles in 2020 are projected to increase by 1.7% annually from 2005 levels, and emissions from on-road diesel vehicles are projected to increase by 3.2% annually from 2005 to 2020, with total transportation emissions expected to reach nearly 44 $MMtCO_2e$ by 2020.

CECAC Revisions

The CECAC made the following revisions that to the inventory and reference case projections, which explain the differences between the final Inventory and Projections report and the draft initial assessment completed during June 2007:

- *Energy Supply*: Incorporated 2003 baseline generation and fuel mix data, sales forecast data for 2003 through 2020, and transmission and distribution line loss data used in the North Carolina GHG emissions inventory and projections supplied by utilities that serve both North Carolina and South Carolina.
- *RCI Direct Fuel Use*: Included State Energy Data (SED) for South Carolina that was [were?] published by the U.S. Department of Energy's Energy Information Administration (EIA) after the draft Inventory and Projections report was prepared; included EIA SED for 2004 and 2005 for natural gas, oil, and coal and 2003 through 2005 data for wood for each of the RCI sectors.

[12] Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer demand. The current estimates reflect some very simple assumptions, as described in Appendix A of the Inventory and Projections report.

- *Transportation*:
    - Incorporated the VMT forecast developed from data provided by the South Carolina Department of Transportation.
    - Included SED for 2003 through 2005 published by EIA after the draft Inventory and Projections report was prepared.
    - Revised the fuel economy values used to convert VMT to fuel consumption. The preliminary draft forecast was based only on new vehicles but this forecast should have included fuel economy associated with existing vehicles in the fleet mix. Thus, the revised forecast is based on new and existing vehicle mix for South Carolina resulting in an increase in emissions associated with a lower overall fleet fuel economy by including older, existing vehicles.
- *Fossil Fuel Production and Distribution Industry*: Added estimates for combustion of natural gas consumed by internal combustion engines to operate pipeline systems in South Carolina, based on SED data for 1990 through 2005, and projecting 2005 emissions using a -1.0% annual rate of decline, representing the state trend in pipeline fuel use during 1990–2005.
- *Industrial Processes*: For the ODS substitutes and electric power transmission and distribution categories, updated the forecasts using average annual growth rates developed from more recent national forecasts prepared by the U.S. Environmental Protection Agency (EPA). For electric power transmission and distribution, use EPA's national "no action" scenario as the basis for developing average annual growth rates to forecast emissions.
- *Forestry*: Added estimates for urban forests based on EPA default methods that were released after the draft inventory and forecast was prepared.

Key Uncertainties

Some data gaps exist in this inventory, particularly in the reference case projections. Key tasks for future refinement of this inventory and projections include review and revision of key drivers, such as the transportation, electricity demand, and RCI fuel use growth rates that will be major determinants of South Carolina's future GHG emissions (see Table 2-2). These growth rates are driven by uncertain economic, demographic, and land-use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion.