

Appendix D. Industrial Processes

Overview

Emissions in the industrial processes category span a wide range of activities, and reflect non-combustion sources of greenhouse gas (GHG) emissions from several industries. The industrial processes that exist in Florida, and for which emissions are estimated in this inventory, include the following:

- Carbon Dioxide (CO₂) from:
 - Production of cement, iron and steel, and ammonia;¹
 - Consumption of limestone, dolomite, and soda ash;
- Sulfur hexafluoride (SF₆) from:
 - Transformers used in electric power transmission and distribution (T&D) systems;
- Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) from consumption of substitutes for ozone-depleting substances (ODS) used in cooling and refrigeration equipment; and
- HFCs, PFCs, and SF₆ from semiconductor manufacture.

Other industrial processes that are sources of GHG emissions but are not found in Florida include the following:

- CO₂ from lime production;
- Nitrous oxide (N₂O) from nitric and adipic acid production;
- PFCs from aluminum production;
- SF₆ from magnesium production and processing;
- HFCs from HCFC-22 production.

Emissions and Reference Case Projections

Greenhouse gas emissions for 1990 through 2005 were estimated using the United States Environmental Protection Agency (US EPA)'s State Greenhouse Gas Inventory Tool (SIT) software, and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for this sector.² Table D1 identifies for each emissions source category the information needed for input into SIT to calculate emissions, the data sources used for the analyses described here, and the historical years for which emissions were calculated based on the availability of data.

¹ Note that CO₂ emissions from urea application is estimated as part of the same category as ammonia production.

² GHG emissions were calculated using SIT, with reference to EIIP, Volume VIII: Chapter. 6. "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes", August 2004. Referred to as "EIIP" below.

Table D1. Approach to Estimating Historical Emissions

Source Category	Time Period for which Data Available	Required Data for SIT	Data Source
Cement Manufacture	1990 - 2005	Metric tons (Mt) of clinker produced and masonry cement produced each year.	Historical production for Florida from USGS Minerals Yearbook, Cement Statistics and Information (http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb).
Limestone and Dolomite Consumption	1994 - 2004	Mt of limestone and dolomite consumed.	Historical consumption (sales) for Florida from USGS Minerals Yearbook, Crushed Stone Statistics and Information, (http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/). In SIT, the state's total limestone consumption (as reported by USGS) is multiplied by the ratio of national limestone consumption for industrial uses to total national limestone consumption. Additional information on these calculations, including a definition of industrial uses, is available in Chapter 6 of the EIIP guidance document. Default limestone production data are not available in SIT for 1990 – 1993 and for 2005; data for 1994 were used for 1990 – 1993 as a surrogate to fill in production data missing for these years; data for 2004 were used for 2005 production.
Soda Ash Consumption	1990 - 2005	Mt of soda ash consumed for use in consumer products such as glass, soap and detergents, paper, textiles, and food.	Historical emissions are calculated in SIT based on the state's population and national per capita soda ash consumption from the US EPA national GHG inventory. -- National historical consumption (sales) for US from USGS Minerals Yearbook, Soda Ash Statistics and Information (http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/). -- US (1990-2000 and 2000-2005) and state (2000-2005) population from US Census Bureau (http://www.census.gov/popest/states/NST-ann-est.html). -- State (1990-2000) population from US Census Bureau (http://www.census.gov/popest/archives/2000s/vintage_2001/CO-EST2001-12/CO-EST2001-12-12.html).
Ammonia Production and Urea Consumption	1990-2004	Mt of Ammonia produced and Urea consumed in the state.	SIT default activity data for ammonia production and urea application for 1990-2004; activity data is based on national USGS data. No data was available for 2005, so 2004 production data was used as a surrogate for 2005 production.
Iron and Steel Production	1997-2005	Mt of crude steel produced by production method.	The basic activity data needed are the quantities of crude steel produced (defined as first cast product suitable for sale or further processing) by production method. Default SIT values are based on the state-level production data assigned to production method based on the national distribution of production by method. National production data are from the Annual Statistics Report published by the American Iron and Steel Institute, Washington, DC (http://www.steel.org/AM/Template.cfm?Section=Bookstore&CONTENT_ID=12259&TEMPLATE=/CM/HTMLDisplay.cfm). Default production data are not available in SIT for 1990-1996; 1997 production data were used as surrogate for 1990-1996 production.
ODS Substitutes	1990 - 2005	Based on state's population and estimates of emissions per capita from the US EPA national GHG inventory.	National emissions from <i>US Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005</i> , US EPA, Report #430-R-07-002, April 2007 (http://epa.gov/climatechange/emissions/usinventoryreport.html). References for US Census Bureau national and state population figures are cited under the data sources for soda ash above.

Source Category	Time Period for which Data Available	Required Data for SIT	Data Source
Electric Power T&D Systems	1990 - 2005	Emissions from 1990 to 2005 based on the national emissions per kilowatt-hour (kWh) and state's electricity use provided in SIT.	National emissions are apportioned to the state based on the ratio of state-to-national electricity sales data provided in the Energy Information Administration's (EIA) Electric Power Annual (http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html). Reference for US EPA national emissions is cited under the data sources for ODS substitutes above.
Semiconductor Manufacture	1990 - 2005	State and national value of semiconductor shipments for NAICS code 334413 (Semiconductor and Related Device Manufacturing).	Method uses ratio of state-to-national value of semiconductor shipments to estimate state's proportion of national emissions for 1990–2005. Value of shipments from U.S Census Bureau's 1997 Economic Census (http://www.census.gov/econ/census02/); 2002 Economic Census withheld value of shipments data for Florida. Reference for US EPA national emissions is cited under the data sources for ODS substitutes above.

Table D2 lists the data and methods that were used to estimate future activity levels related to industrial process emissions and the annual compound growth rates computed from the data/methods for the reference case projections. Because available forecast information is generally for economic sectors that are too broad to reflect trends in the specific emissions producing processes, the majority of projections are based on historical activity trends. In particular, state historical trends were analyzed for three periods: 1990-2005, 1995-2005, and 2000-2005 (or the closest available approximation of these periods). A no growth assumption was assumed when the historical periods indicated divergent activity trends (i.e., growth in certain periods and decline in other periods). In cases where the historical periods indicated either continual growth or decline, the smallest annual rate of growth/decline was selected from the values computed for each period. This conservative assumption was adopted because of the uncertainty associated with utilizing historical trends to estimate future emission activity levels.

Results

Figures D1 and D2 show historic and projected emissions for the industrial processes sector from 1990 to 2025. Table D3 shows the historic and projected emission values upon which Figures D1 and D2 are based. Total gross Florida GHG emissions were about 4.4 MMtCO₂e in 1990, 12.8 MMtCO₂e in 2005, and are projected to increase to about 36.2 MMtCO₂e in 2025. Emissions from the overall industrial processes category are expected to grow by about 5% annually from 2005 through 2025, as shown in Figures D1 and D2, with emissions growth primarily associated with increasing use of HFCs and PFCs in refrigeration and air conditioning equipment.

Table D2. Approach to Estimating Projections for 2005 through 2025

Source Category	Projection Assumptions	Data Source	Annual Growth Rates (%)			
			2005 to 2010	2010 to 2015	2015 to 2020	2020 to 2025
Cement Manufacture	Smallest historical annual increase in state production from each of three periods analyzed (1990-2005).	Annual change in Florida clinker & masonry cement production: 1990-2005 = +5.7%; 1995-2005 = +6.9%; and 2000-2005 = +9.2%	5.7	5.7	5.7	5.7
Limestone and Dolomite Consumption	Annual growth rate computed from Nonmetallic Mineral Product Manufacturing sector employment forecast for state.	2007-2015 employment projections from Florida Agency for Workforce Innovation http://labormarketinfo.com/library/ep.htm .	1.4	1.4	1.4	1.4
Soda Ash Consumption	Smallest historical annual increase in state consumption from each of three periods analyzed (2000-2005).	Annual change in Florida soda ash consumption: 1990-2005 = +0.6%; 1995-2005 = +0.6%; and 2000-2005 = +0.4%	0.4	0.4	0.4	0.4
Ammonia Production and Urea Application	No growth assumption based on analysis of state historical production/consumption trends.	Annual change in Florida ammonia production and urea consumption: 1990-2004 = -2.3%; 1995-2004 = +4.4%; and 2000-2004 = +2.2%	0	0	0	0
Iron and Steel Production	Annual growth rate computed from Primary Metal Mfg sector employment forecast for state.	2007-2015 employment projections from Florida Agency for Workforce Innovation http://labormarketinfo.com/library/ep.htm .	0.5	0.5	0.5	0.5
ODS Substitutes	National growth in emissions associated with the use of ODS substitutes.	Annual growth rates calculated based on sum of US national emissions projections from 2005-2020 for six categories of ODS substitutes presented in Appendix D, Tables D1 through D-6 in the US EPA report, <i>Global Anthropogenic Emissions of Non-CO₂ Greenhouse Gases 1990-2020</i> , EPA Report 430-R-06-003, http://www.epa.gov/nonco2/econ-inv/international.html .	8.7	6.4	5.0	5.0
Electric Power T&D Systems	National growth rate (based on technology adoption forecast scenario reflecting industry participation in EPA voluntary stewardship program to control emissions).	Annual growth rates calculated based on US national emissions projections from 2005-2020 presented in Appendix D, Table D8 in the US EPA report, <i>Global Anthropogenic Emissions of Non-CO₂ Greenhouse Gases 1990-2020</i> , EPA Report 430-R-06-003; http://www.epa.gov/nonco2/econ-inv/international.html .	-1.6	-0.8	-0.7	-0.7
Semiconductor Manufacturing	National growth rate (based on technology adoption forecast scenario reflecting industry participation in EPA voluntary stewardship program to control emissions).	Annual growth rates calculated based on US national emissions projections from 2005-2020 presented in Appendix D, Table D10 in the US EPA report, <i>Global Anthropogenic Emissions of Non-CO₂ Greenhouse Gases 1990-2020</i> , EPA Report 430-R-06-003; http://www.epa.gov/nonco2/econ-inv/international.html .	0.7	-4.2	-1.4	-1.4

Cement Manufacture

The cement production process is one that releases relatively high amounts of CO₂ in the industrial non-fuel combustion sector. Clinker is an intermediate product from which finished Portland and masonry cement are made. Clinker production releases CO₂ when calcium carbonate (CaCO₃) is heated in a cement kiln to form lime (calcium oxide) and CO₂ (see Chapter 6 of EIIP guidance document). Emissions are calculated by multiplying annual clinker production by emission factors to estimate emissions associated with the clinker production process (0.507 metric ton (Mt) of CO₂ emitted per Mt of clinker produced) and cement kiln dust (0.020 MtCO₂e emitted per Mt of clinker produced).

Masonry cement requires additional lime, over and above the lime used in the clinker. During the production of masonry cement, non-plasticizer additives such as lime, slag, and shale are added to the cement, increasing its weight by 5%. Lime accounts for approximately 60% of the added substances. About 0.0224 MtCO₂ is emitted for every Mt of masonry cement produced, relative to the CO₂ emitted during the production of a Mt of clinker (see Chapter 6 of EIIP guidance document).

As shown in Figure D2 (see black line) and Table D3, emissions from this source are estimated to be about 1.2 MMtCO₂e in 1990, 2.8 MMtCO₂e in 2005, and are projected to increase to about 8.3 MMtCO₂e by 2025. Historical clinker and masonry cement production data for Florida obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate CO₂ emissions for 1990-2005. The annual rate of increase in Florida clinker/masonry cement production over the 1990-2005 period (5.7% per year) was used to project emissions from 2006 to 2025.

Figure D1. GHG Emissions from Industrial Processes, 1990-2025

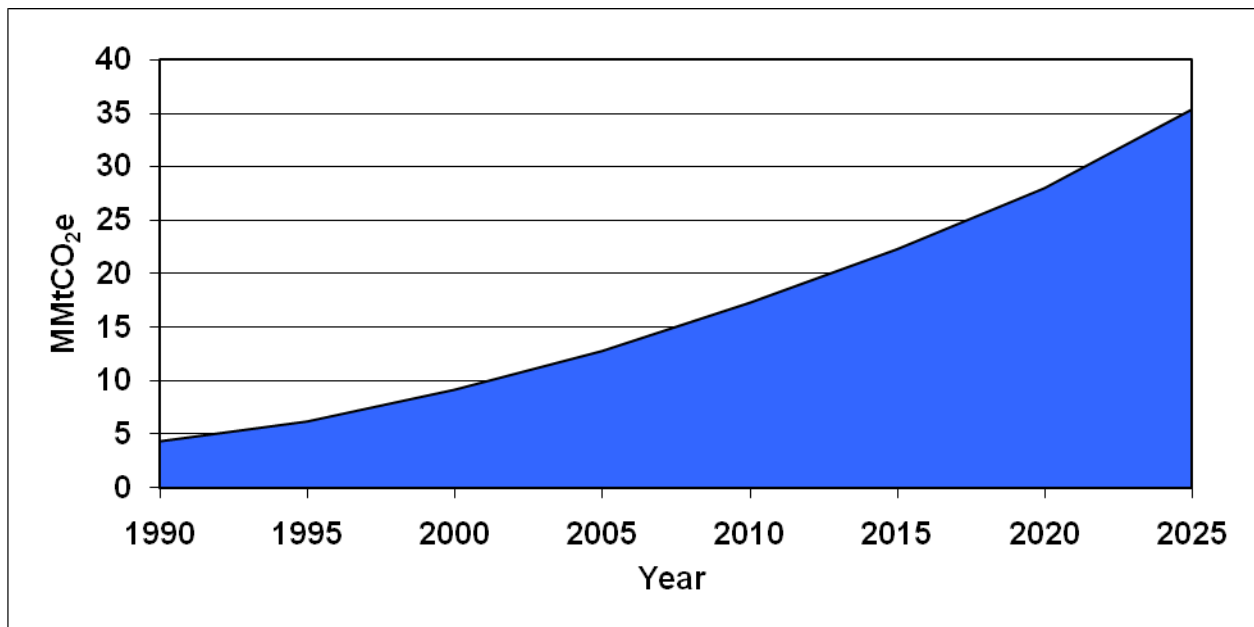


Figure D2. GHG Emissions from Industrial Processes, 1990-2025, by Source

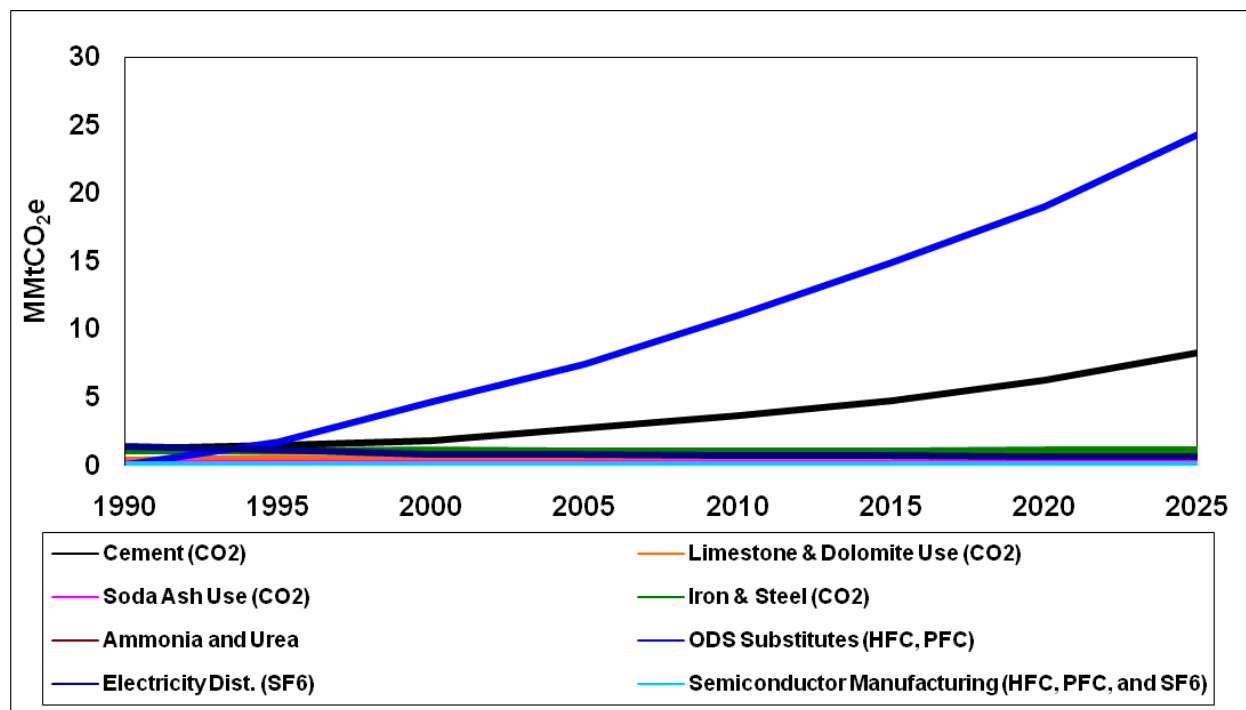


Table D3. Historic and Projected Emissions for the Industrial Processes Sector (MMtCO₂e)

Industry / Pollutant	1990	1995	2000	2005	2010	2015	2020	2025
Cement (CO ₂)	1.20	1.45	1.81	2.75	3.63	4.79	6.31	8.32
Limestone & Dolomite Use (CO ₂)	0.38	0.51	0.46	0.49	0.52	0.56	0.60	0.64
Soda Ash Use (CO ₂)	0.14	0.15	0.15	0.15	0.16	0.16	0.16	0.17
Iron & Steel (CO ₂)	1.09	1.09	1.15	1.03	1.06	1.09	1.12	1.15
Ammonia and Urea	0.09	0.04	0.06	0.06	0.06	0.06	0.06	0.06
ODS Substitutes (HFC, PFC)	0.02	1.74	4.64	7.45	11.32	15.42	19.71	25.20
Electricity Dist. (SF ₆)	1.44	1.21	0.87	0.81	0.75	0.72	0.69	0.67
Semiconductor Manufacturing (HFC, PFC, and SF ₆)	0.02	0.04	0.07	0.06	0.06	0.05	0.05	0.05
Total	4.4	6.2	9.2	12.8	17.6	22.8	28.7	36.2

Limestone and Dolomite Consumption

Limestone and dolomite are basic raw materials used by a wide variety of industries, including the construction, agriculture, chemical, glass manufacturing, and environmental pollution control industries, as well as in metallurgical industries such as magnesium production. Emissions associated with the use of limestone and dolomite to manufacture steel and glass and for use in

flue-gas desulfurization scrubbers to control sulfur dioxide emissions from the combustion of coal in boilers are included in the industrial processes sector.³

Historical limestone and dolomite consumption (sales) data for Florida obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate CO₂ emissions for 1990-2005. Data on limestone and dolomite consumption for 1990-1993 were not available for Florida; therefore, 1994 production data were used as a surrogate to estimate emissions for 1990-1993. Limestone and dolomite consumption for 2005 were also not available, 2004 production data were used as a surrogate. Relative to total industrial non-combustion process emissions, CO₂ emissions from limestone and dolomite consumption are low (0.38 MMtCO₂e in 1990, 0.49 MMtCO₂e in 2005). Emission projections from 2005 to 2025 are assumed to increase at a rate of 1.4 percent per year to 0.64 MMtCO₂e in 2025; this is based on Nonmetallic Mineral Product Manufacturing sector employment projections available from the State of Florida (note that these projections are available for 2015—in lieu of other information, the same rate of increase was used throughout the forecast period to 2025).

Soda Ash Consumption

Commercial soda ash (sodium carbonate) is used in many consumer products such as glass, soap and detergents, paper, textiles, and food. Carbon dioxide is also released when soda ash is consumed (see Chapter 6 of EIIP guidance document). SIT estimates historical emissions (see dark pink line in Figure D2) based on the state's population and national per capita soda ash consumption from the US EPA national GHG inventory. An annual 0.4 percent increase was assumed for the forecast period based on the positive consumption trends observed over the historical periods analyzed. Relative to total industrial non-combustion process emissions, CO₂ emissions from soda ash consumption are low (about 0.14 MMtCO₂e in 1990, 0.15 MMtCO₂e in 2005, and increasing to 0.17 MMtCO₂e in 2025) and therefore, appear at the bottom of the graph because of scaling effects (see pink line at the bottom of Figure D2).

Ammonia Production/Urea Application

Ammonia (NH₃) and urea ((NH₂)₂CO) are both synthetically created chemicals with a wide variety of uses. Ammonia is primarily used as a fertilizer, though it also has applications as a refrigerant, a disinfectant, and in the production of chemicals such as urea and nitric acid. Ammonia production involves the conversion of a fossil fuel hydrocarbon into pure hydrogen, which is then combined with nitrogen to create NH₃. This process involves the release of carbon dioxide as a byproduct. Urea, a different type of synthetic chemical, is also primarily used as a fertilizer, though it is also used commercially in several industrial and chemical processes. Urea is created by a chemical process with ammonia as a key component.

³ In accordance with EIIP Chapter 6 methods, emissions associated with the following uses of limestone and dolomite are not included in this category: (1) crushed limestone consumed for road construction or similar uses (because these uses do not result in CO₂ emissions), (2) limestone used for agricultural purposes (which is counted under the methods for the agricultural sector), and (3) limestone used in cement production (which is counted in the methods for cement production).

Ammonia and urea are typically produced from conventional catalytic reforming of natural gas feedstock. Default SIT activity data were used to calculate the ammonia and urea emissions in Florida. Relative to total industrial non-combustion process emissions, CO₂ emissions from ammonia production/urea application are low (about 0.09 MMtCO₂e in 1990, decreasing to 0.06 MMtCO₂e in 2005) and cannot be seen in Figure D2 due to scaling effects. A no growth assumption was adopted for this category based on the conflicting trends observed over the historical periods analyzed.

Iron and Steel Production

The production of iron and steel generate process-related CO₂ emissions. Iron is produced by reducing iron ore with metallurgical coke in a blast furnace to produce pig iron; this process emits CO₂ emissions. Pig iron is used as a raw material in the production of steel. The production of metallurgical coke from coking coal produces CO₂ emissions as well.

Historical CO₂ emissions were estimated using the SIT default activity data (see Table D1) for 1997-2005 and emission factors for the following production methods: basic oxygen furnace at integrated mill with coke ovens, basic oxygen furnace at integrated mill without coke ovens, electric arc furnace, and open hearth furnace. The basic activity data needed are the quantities of crude steel produced (defined as first cast product suitable for sale or further processing) by production method. Default values are based on the state-level production data assigned to each production method based on the national distribution of production by method. The national production data were obtained from the Annual Statistics Report published by the American Iron and Steel Institute, Washington, DC (see Table D1). Production data are not available in SIT for 1990-1996; data for these years are based on 1997 production. As shown in Figure D2 (see green line) and Table D3, emissions in 1997 were 1.09 MMtCO₂e and decline to about 1.03 MMtCO₂e in 2005. Post-2005 emissions are projected to increase at a rate of 0.5% per year based on Primary Metal Manufacturing sector employment projections available from the State of Florida (note that these projections are available for 2017—in lieu of other information, the same rate of decrease was used throughout the forecast period to 2025).

Substitutes for Ozone-Depleting Substances (ODS)

HFCs and PFCs are used as substitutes for ODS, most notably chlorofluorocarbons (CFCs are also potent warming gases, with global warming potentials on the order of thousands of times that of CO₂ per unit of emissions) in compliance with the *Montreal Protocol* and the *Clean Air Act Amendments of 1990*.⁴ Even low amounts of HFC and PFC emissions, for example, from leaks and other releases associated with normal use of the products, can lead to high GHG emissions on a CO₂e basis. Emissions have increased from 0.02 MMtCO₂e in 1990 to about 7.45 MMtCO₂e in 2005, and are expected to increase at an average rate of 6.3% per year from 2005 to

⁴ As noted in EIIP Chapter 6, ODS substitutes are primarily associated with refrigeration and air conditioning, but also many other uses including as fire control agents, cleaning solvents, aerosols, foam blowing agents, and in sterilization applications. The applications, stocks, and emissions of ODS substitutes depend on technology characteristics in a range of equipment types. For the US national inventory, a detailed stock vintaging model was used to track ODS substitutes uses and emissions, but this modeling approach has not been completed at the state level.

2025 due to increased substitutions of these gases for ODS (see blue line in Figure D2). The projected rate of increase for these emissions is based on projections for national emissions from the US EPA report referenced in Table D2.

Electric Power Transmission and Distribution

Emissions of SF₆ from electrical equipment have experienced declines since the mid-1990s (see dark blue line in Figure D2), mostly due to voluntary action by industry. Sulfur hexafluoride is used as an electrical insulator and interrupter in the electric power T&D system. The largest use for SF₆ is as an electrical insulator in electricity T&D equipment, such as gas-insulated high-voltage circuit breakers, substations, transformers, and transmission lines, because of its high dielectric strength and arc-quenching abilities. Not all of the electric utilities in the US use SF₆; use of the gas is more common in urban areas where the space occupied by electric power T&D facilities is more valuable.⁵

As shown in Figure D2 and Table D3, SF₆ emissions from electric power T&D are about 1.44 MMtCO₂e in 1990 and 0.81 MMtCO₂e in 2005. Emissions in Florida from 1990 to 2005 were estimated based on the estimates of emissions per kilowatt-hour (kWh) of electricity consumed from the US EPA GHG inventory, and the ratio of Florida's to the US electricity consumption (sales) estimates available from the Energy Information Administration's (EIA) Electric Power Annual and provided in the SIT (see Table D1). The national trend in US emissions estimated for 2005-2025 for the technology-adoption scenario shows expected decreases in these emissions at the national level (see Table D2), and the same rate of decline is assumed for emissions in Florida. The decline in SF₆ emissions in the future reflects expectations of future actions by the electric power industry to reduce these emissions.

Semiconductor Manufacture

The semiconductor industry uses fluorinated gases (PFCs [CF₄, C₂F₆, and C₃F₈]; HFC-23; and SF₆) in plasma etching and chemical vapor deposition processes. Emissions of SF₆ and HFCs from the manufacture of semiconductors have experienced declines since 2000. Emissions for Florida from 1990 to 2005 were estimated based on the default estimates provided in SIT, which uses the ratio of the state-to-national value of semiconductor shipments to estimate the state's proportion of national emissions from the US EPA GHG inventory (see Table D1). The national trend in US emissions estimated for 2005-2025 for the technology-adoption scenario shows expected decreases in these emissions at the national level (see Table D2), and the same rate of decline is assumed for emissions in Florida. The projected emissions decrease reflects expectations of future actions by the semiconductor industry to reduce these emissions. Relative to total industrial non-combustion process emissions, estimated emissions associated with semiconductor manufacturing are low (about 0.02 MMtCO₂e in 1990 and 0.06 MMtCO₂e in 2005, and therefore, cannot be seen in Figure D2 due to scaling effects).

⁵ US EPA, Draft User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF₆ Emissions from Industrial Processes Using the State Inventory Tool, prepared by ICF International, March 2007.

Key Uncertainties

Key sources of uncertainty underlying the estimates above are as follows:

- Since emissions from industrial processes are determined by the level of production and the production processes of a few key industries—and in some cases, a few key plants—there is relatively high uncertainty regarding future emissions from the industrial processes category as a whole. Future emissions depend on the competitiveness of Florida manufacturers in these industries, and the specific nature of the production processes used in Florida.
- The projected largest source of future industrial emissions, HFCs and PFCs used in cooling applications, is subject to several uncertainties as well. Emissions through 2025 and beyond will be driven by future choices regarding mobile and stationary air conditioning technologies and the use of refrigerants in commercial applications, for which several options currently exist.
- Due to the lack of reasonably specific projection surrogates, historical trend data were used to project emission activity level changes for multiple industrial processes. There is significant uncertainty associated with any projection, including a projection that assumes that past historical trends will continue in future periods. All assumptions on growth should be reviewed by industry experts and revised to reflect their expertise on future trends especially for the cement manufacturing industry, and for limestone and dolomite consumption and ODS substitutes.
- For the industries for which EPA default activity data and methods were used to estimate historical emissions, future work should include efforts to obtain state-specific data to replace the default assumptions. In cases where no data exists at all, the nearest year available can be used as a surrogate, but this decreases the overall accuracy of the inventory. Replacing as much default data with state-specific information from all years will significantly increase the reliability of the inventory.
- For the electricity T&D and semiconductor industries, future efforts should include a survey of companies within these industries to determine the extent to which they are implementing techniques to minimize emissions to improve the emission projections for these industries.