

## 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 Arkansas, and for which emissions are estimated in this inventory, include the following:

- Carbon Dioxide (CO<sub>2</sub>) from:
  - Production of cement, lime, iron and steel, and ammonia;
  - Consumption of limestone, dolomite, and soda ash;
- Nitrous oxide (N<sub>2</sub>O) from:
  - Nitric acid production;
- Sulfur hexafluoride (SF<sub>6</sub>) from:
  - Transformers used in electric power transmission and distribution (T&D) systems; and
- Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) from consumption of substitutes for ozone-depleting substances (ODS) used in cooling and refrigeration equipment.

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

- N<sub>2</sub>O from adipic acid production;
- PFCs from aluminum production;
- HFCs from HCFC-22 production;
- SF<sub>6</sub> from Magnesium production and processing;
- HFCs, PFCs, and SF<sub>6</sub> from semiconductor manufacture.

### Emissions and Reference Case Projections

Greenhouse gas emissions for 1990 through 2005 were estimated using the United States Environmental Protection Agency's (US EPA) State Greenhouse Gas Inventory Tool (SIT) software, and the methods provided in the Emission Inventory Improvement Program (EIIP) guidance document for this sector.<sup>1</sup> Table D1 identifies for each emissions source category the information needed for input into SIT to calculate emissions, the data sources used for the analysis described here, and the historical years for which emissions were calculated based on

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<sup>1</sup> 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	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 Arkansas from USGS Minerals Yearbook, Cement Statistics and Information ( <a href="http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb">http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#myb</a> ).
Lime Manufacture	1990-2005	Mt of high-calcium and dolomitic lime produced each year.	Production data for high-calcium lime for 1990-2005 from Arkansas Department of Environmental Quality (ADEQ).
Limestone and Dolomite Consumption	1994 – 2004	Mt of limestone and dolomite consumed.	Historical consumption (sales) for Arkansas from USGS Minerals Yearbook, Crushed Stone Statistics and Information, ( <a href="http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/">http://minerals.usgs.gov/minerals/pubs/commodity/stone_crushed/</a> ). 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 ( <a href="http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/">http://minerals.usgs.gov/minerals/pubs/commodity/soda_ash/</a> ). -- US (2000-2005) and state (2000-2005) population from US Census Bureau ( <a href="http://www.census.gov/popest/states/NST-ann-est.html">http://www.census.gov/popest/states/NST-ann-est.html</a> ). --US (1990-2000) population from US Census Bureau ( <a href="http://www.census.gov/popest/archives/1990s/">http://www.census.gov/popest/archives/1990s/</a> ). -- State (1990-2000) population from US Census Bureau ( <a href="http://www.census.gov/popest/archives/2000s/vintage_2001/CO-EST2001-12/CO-EST2001-12-05.html">http://www.census.gov/popest/archives/2000s/vintage_2001/CO-EST2001-12/CO-EST2001-12-05.html</a> ).
Ammonia Production and Urea Application	1990-2004	Mt of ammonia produced and urea consumed	SIT default activity data for ammonia production and urea application for 1990-2004; activity data is based on national USGS data. Data for 2004 were used for 2005 as a surrogate to fill in the missing production data.
Iron and Steel Production	1990-2007	Mt of crude steel produced by production method.	ADEQ provided steel production data from the Electric Arc Furnace (EAF) production method for 1990-2007. Default SIT emission factor for EAF production method is used for steel production from scrap metal. The emission factor for EAF steel production from crude steel is from U.S. EPA <i>Inventories of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005</i> ( <a href="http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf">http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf</a> ).
Nitric Acid	1990-2005	Mt of nitric acid produced	ADEQ provided production data for the years 1990-2005.
ODS Substitutes - Castings	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 ( <a href="http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf">http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf</a> ). References for US Census Bureau national and state population figures are cited under the data sources for soda ash above.

Source Category	Time Period	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 ( <a href="http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html">http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html</a> ). Reference for US EPA national emissions is cited under the data sources for soda ash above.

the availability of data. To the extent possible, information provided by Arkansas state and local sources was used in this analysis.

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.

**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	Annual growth rate computed from Cement & Concrete Product Manufacturing employment forecast for State.	2004-2014 employment projections from Arkansas Labor Market Information ( <a href="http://www.discoverarkansas.net/publication.asp?PUBLICATIONID=1108&amp;PAGEID=4&amp;SUBID=">http://www.discoverarkansas.net/publication.asp?PUBLICATIONID=1108&amp;PAGEID=4&amp;SUBID=</a> )	1.5	1.5	1.5	1.5
Lime Manufacture	Annual growth rate computed from Arkansas Lime Company production forecasts.	Arkansas lime production forecasts (2006-2025) provided by ADEQ.	11.6	0.0	0.0	0
Limestone and Dolomite Consumption	Annual growth rate computed from Other Nonmetallic Mineral Product Manufacturing employment forecast for State.	2004-2014 employment projections from Arkansas Labor Market Information ( <a href="http://www.discoverarkansas.net/publication.asp?PUBLICATIONID=1108&amp;PAGEID=4&amp;SUBID=">http://www.discoverarkansas.net/publication.asp?PUBLICATIONID=1108&amp;PAGEID=4&amp;SUBID=</a> )	0.3	0.3	0.3	0.3
Soda Ash Consumption	Smallest historical annual decline in state consumption from each of three periods analyzed (1990-2005)	Annual change in Arkansas soda ash consumption: 1990-2005 = -0.4% 1995-2005 = -0.6% 2000-2005 = -0.9%	-0.4	-0.4	-0.4	-0.4

Source Category	Projection Assumptions	Data Source	Annual Growth Rates (%)			
			2005 to 2010	2010 to 2015	2015 to 2020	2020 to 2025
Ammonia & Urea Production	No growth assumption based on analysis of state historical trends	Annual change in Arkansas ammonia consumption: 1990-2004 = -3.6% 1995-2004 = -0.8% 2000-2004 = +0.3%	0.0	0.0	0.0	0.0
Iron and Steel Production	Annual growth rate computed from steel production forecasts from AR steel companies.	Arkansas steel production 2025 forecast provided by ADEQ.	2.8	2.8	2.8	2.8
Nitric Acid Production	No growth assumption based on analysis of state historical trends	Annual change in Arkansas ammonia consumption: 1990-2005 = +0.8% 1995-2005 = -0.6% 2000-2005 = -0.1%	0.0	0.0	0.0	0.0
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 D-1 through D-6 in the US EPA report, <i>Global Anthropogenic Emissions of Non-CO<sub>2</sub> Greenhouse Gases 1990-2020</i> , EPA Report 430-R-06-003, <a href="http://www.epa.gov/nonco2/econ-inv/international.html">http://www.epa.gov/nonco2/econ-inv/international.html</a>	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 D-10 in the US EPA report, <i>Global Anthropogenic Emissions of Non-CO<sub>2</sub> Greenhouse Gases 1990-2020</i> , EPA Report 430-R-06-003; <a href="http://www.epa.gov/nonco2/econ-inv/international.html">http://www.epa.gov/nonco2/econ-inv/international.html</a> .	-1.6	-0.8	-0.7	-0.7

**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 Arkansas GHG emissions were about 2.2 million metric tons of CO<sub>2</sub> equivalence (MMtCO<sub>2</sub>e) in 1990, 4.0 MMtCO<sub>2</sub>e in 2005, and are projected to increase to about 7.5 MMtCO<sub>2</sub>e in 2025. Emissions from the overall industrial processes category are expected to grow by about 3.1% annually from 2005 through 2025, as shown in Figures D1 and D2, with emissions growth primarily associated with increasing use of ODS substitutes.

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

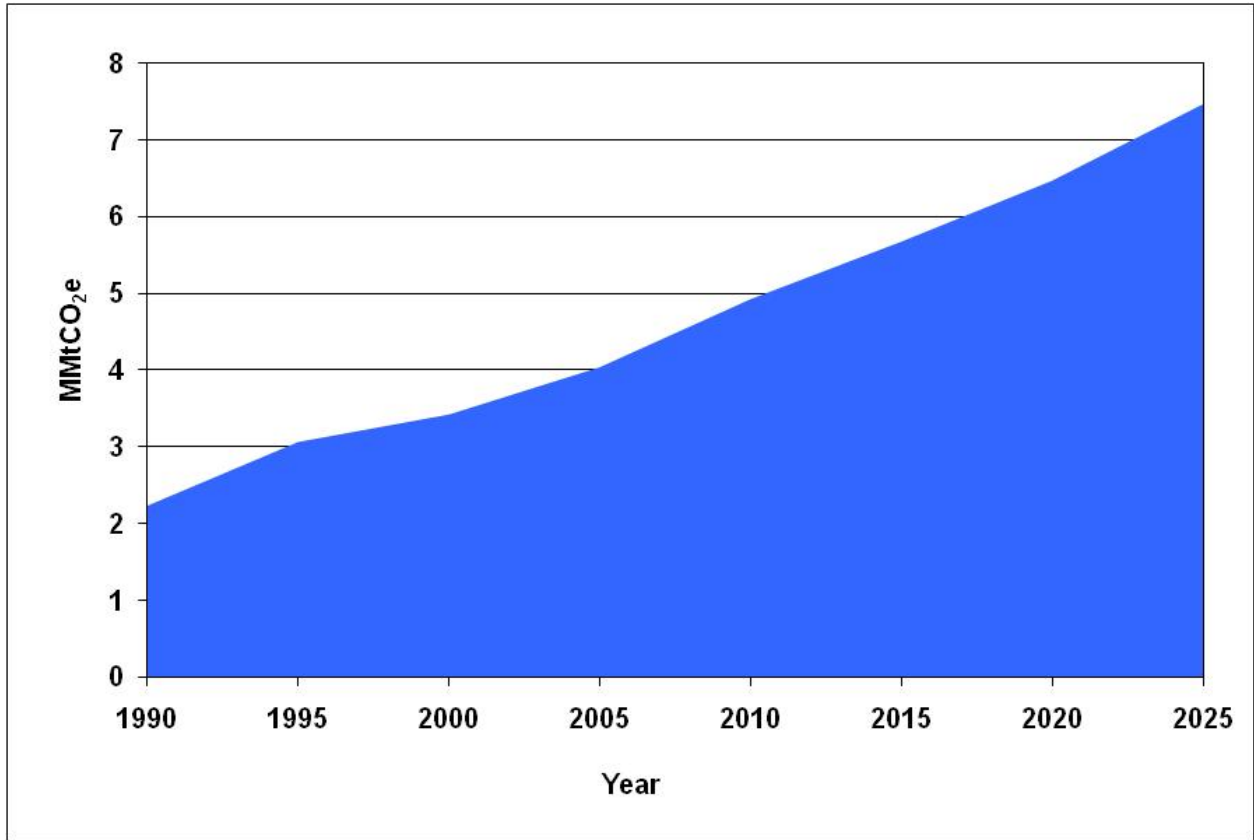


Figure D2. GHG Emissions from Industrial Processes, 1990-2025, by Source

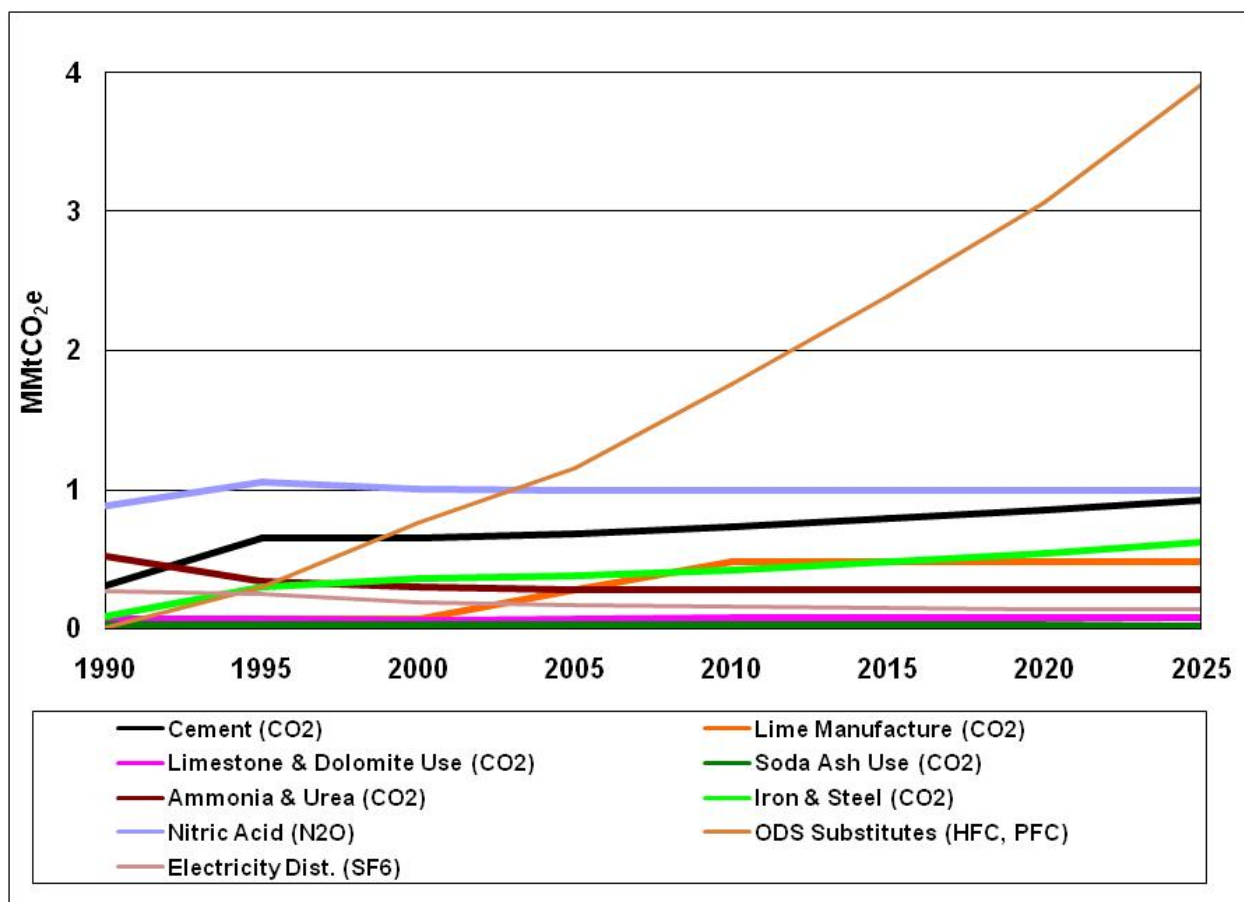


Table D3. Historic and Projected Emissions for the Industrial Processes Sector (MMtCO<sub>2</sub>e)

	1990	1995	2000	2005	2010	2015	2020	2025
Cement (CO <sub>2</sub> )	0.31	0.65	0.65	0.68	0.74	0.79	0.86	0.92
Lime Manufacture (CO <sub>2</sub> )	0.05	0.07	0.07	0.28	0.48	0.48	0.48	0.48
Limestone & Dolomite Use (CO <sub>2</sub> )	0.07	0.07	0.06	0.07	0.07	0.07	0.08	0.08
Soda Ash Use (CO <sub>2</sub> )	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Ammonia & Urea (CO <sub>2</sub> )	0.53	0.34	0.30	0.28	0.28	0.28	0.28	0.28
Iron & Steel (CO <sub>2</sub> )	0.09	0.30	0.36	0.38	0.42	0.48	0.55	0.62
Nitric Acid (N <sub>2</sub> O)	0.88	1.05	1.00	0.99	0.99	0.99	0.99	0.99
ODS Substitutes (HFC, PFC)	0.00	0.30	0.76	1.16	1.76	2.40	3.06	3.91
Electricity Dist. (SF <sub>6</sub> )	0.27	0.25	0.18	0.17	0.15	0.15	0.14	0.14
<b>Total</b>	<b>2.23</b>	<b>3.06</b>	<b>3.41</b>	<b>4.03</b>	<b>4.92</b>	<b>5.67</b>	<b>6.46</b>	<b>7.45</b>

*Cement Manufacture*

The cement production process is one that releases relatively high amounts of CO<sub>2</sub> in the industrial non-fuel combustion sector. Clinker is an intermediate product from which finished Portland and masonry cement are made. Clinker production releases CO<sub>2</sub> when calcium

carbonate ( $\text{CaCO}_3$ ) is heated in a cement kiln to form lime (calcium oxide) and  $\text{CO}_2$  (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  $\text{CO}_2$  emitted per Mt of clinker produced) and cement kiln dust (0.020  $\text{MtCO}_2$  emitted per Mt of clinker  $\text{CO}_2$  emitted).

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 percent. Lime accounts for approximately 60 percent of the added substances. About 0.0224  $\text{MtCO}_2$  is emitted for every Mt of masonry cement produced, relative to the  $\text{CO}_2$  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 0.31  $\text{MMtCO}_2\text{e}$  in 1990, 0.68  $\text{MMtCO}_2\text{e}$  in 2005, and are projected to increase to about 0.92  $\text{MMtCO}_2\text{e}$  by 2025. Historical clinker and masonry cement production data for Arkansas obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate  $\text{CO}_2$  emissions for 1990-2005. Emissions are projected to increase at a rate of 1.5 percent per year based on Cement and Concrete Product Manufacturing sector employment projections available from the State of Arkansas (note that these projections are available to 2014—in lieu of other information, the same rate of increase was used throughout the forecast period to 2025).

### *Lime Manufacture*

Lime is a manufactured product that is used in many chemical, industrial, and environmental applications including steel making, construction, pulp and paper manufacturing, and water and sewage treatment. Lime is manufactured by heating limestone (mostly  $\text{CaCO}_3$ ) in a kiln, creating calcium oxide and  $\text{CO}_2$ . The  $\text{CO}_2$  is driven off as a gas and is normally emitted to the atmosphere, leaving behind a product known as quicklime. Some of this quicklime undergoes slaking (combining with water), which produces hydrated lime. The consumption of lime for certain uses, specifically the production of precipitated  $\text{CaCO}_3$  and refined sugar, results in the reabsorption of some airborne  $\text{CO}_2$  (see Chapter 6 of EIIP guidance document).

Arkansas Lime Company is the only lime manufacturer in the state. Its high-calcium quicklime and hydrated lime production data were provided by the Arkansas Department of Environmental Quality (ADEQ). Emissions associated with lime manufacture were estimated for 1990 through 2005 using the amount of lime produced and an emission factor of 0.75  $\text{MtCO}_2$  per ton high-calcium lime produced. Arkansas Lime Company has also provided projections of lime production to 2025. Based on these forecasts, emissions are assumed to grow annually at 11.6 percent between 2005 and 2010, and stay constant between 2010 and 2025.  $\text{CO}_2$  emissions from lime production are relatively low in 1990 (about 0.05  $\text{MMtCO}_2\text{e}$ ), it increases to 0.28  $\text{MMtCO}_2\text{e}$  by 2005, and is projected to increase further to 0.48  $\text{MMtCO}_2\text{e}$  by 2025.

### *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.<sup>2</sup>

Historical limestone and dolomite consumption (sales) data for Arkansas obtained from the USGS (see Table D1) and the default emission factors in SIT were used to calculate CO<sub>2</sub> emissions for 1994-2004. Data on limestone and dolomite consumption for 1990-1993 were not available for Arkansas; therefore, 1994 production data was used as a surrogate to estimate emissions for 1990-1993. Limestone and dolomite consumption for 2005 is also not available, 2004 production data were used as a surrogate. Emissions are projected to increase at a rate of 0.3 percent per year based on Other Nonmetallic Mineral Product Manufacturing sector employment projections available from the State of Arkansas (note that these projections are available to 2014—in lieu of other information, the same rate of increase was used throughout the forecast period to 2025). Relative to total industrial non-combustion process emissions, CO<sub>2</sub> emissions from limestone and dolomite consumption are low (about 0.07 MMtCO<sub>2</sub>e in 1990, and remaining near this level through 2005), and therefore, appear at the bottom of the graph because of scaling effects (see pink line at the bottom of Figure D2).

#### *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 decrease was assumed for the forecast period based on the negative consumption trends observed over the historical periods analyzed. Relative to total industrial non-combustion process emissions, CO<sub>2</sub> emissions from soda ash consumption are low (about 0.03 MMtCO<sub>2</sub>e in 1990, and 0.02 MMtCO<sub>2</sub>e in 2005), and therefore, appear at the bottom of the graph because of scaling effects (see dark green line at the bottom of Figure D2).

#### *Ammonia and Urea Production*

Ammonia (NH<sub>3</sub>) and urea ((NH<sub>2</sub>)<sub>2</sub>CO) 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 NH<sub>3</sub>. This process involves the release of CO<sub>2</sub> as a byproduct. Urea, a different type of synthetic chemical, is also primarily used as a fertilizer,

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<sup>2</sup> 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 CO<sub>2</sub> 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).

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.

SIT default production data, along with default emission factors for ammonia and urea, were used to calculate CO<sub>2</sub> emissions in Arkansas. In 1990, ammonia production/urea consumption constituted a significant portion of the total Arkansas GHG emissions in the Industrial Processes sector. However, by 2005, this is no longer the case. Emissions from ammonia and urea decreased over the period of 1990-2005, with 0.53 MMtCO<sub>2</sub>e in 1990, and 0.28 MMtCO<sub>2</sub>e in 2005. Projections from 2006-2025 are assumed to stay constant at 2005 levels due to conflicting historical trends.

### *Iron and Steel Production*

Arkansas has four iron and steel production facilities: Nucor-Yamato Steel Company, Nucor Corporation, Quanex Corporation (MacSteel), and Arkansas Steel Associates, LLC. The production of iron and steel generates process-related CO<sub>2</sub> emissions. Iron is produced by reducing iron ore with metallurgical coke in a blast furnace to produce pig iron; this process emits CO<sub>2</sub> emissions. Pig iron is used as a raw material in the production of steel. The production of metallurgical coke from coking coal produces CO<sub>2</sub> emissions as well.

The EPA SIT methodology was used to estimate Arkansas's CO<sub>2</sub> emissions from steel production (see Table D1). The basic activity data needed were the quantities of crude steel produced (defined as first cast product suitable for sale or further processing) by production method. Plant-specific production data by the Electric Arc Furnace (EAF) method were provided by ADEQ for the years 1990 to 2007, and projected 2025 production. Nucor Corporation did not have production data available for 1990 and 1991. It is assumed that 10 percent of steel production from the Nucor-Yamato and Nucor Corporation steel plants are from crude steel and 90 percent from scrap metal.<sup>3</sup> Default SIT emission factor of 0.08 MtCO<sub>2</sub> per Mt production was used for EAF steel production from scrap metal, and 0.004 MtCO<sub>2</sub> per Mt production was used for EAF steel production from crude steel.<sup>4</sup> As shown in Figure D2 (see lime-green line) and Table D3, emissions from iron and steel increased from 0.09 MMtCO<sub>2</sub>e in 1990 to 0.38 MMtCO<sub>2</sub>e in 2005. The annual growth rate estimated from the forecasted 2025 steel production (2.75% per year) was used to project emissions from 2008 to 2025.

### *Nitric Acid Production*

The manufacture of nitric acid (HNO<sub>3</sub>) produces N<sub>2</sub>O as a by-product, via the oxidation of ammonia. Nitric acid is a raw material used primarily to make synthetic commercial fertilizer. It is also a major component in the production of adipic acid (a feedstock for nylon) and explosives. Relatively small quantities of nitric acid are also employed for stainless steel pickling, metal etching, rocket propellants, and nuclear fuel processing.<sup>5</sup>

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<sup>3</sup> Crude steel and scrap metal allocation from personal communications with Nucor Steel plants.

<sup>4</sup> EAF emission factor of 0.004 MtCO<sub>2</sub>/Mt production from US EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005* (<http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf>).

<sup>5</sup> EIIP, Volume VIII: Chapter. 6. "Methods for Estimating Non-Energy Greenhouse Gas Emissions from Industrial Processes", August 2004.

The El Dorado Chemical Company is the only producer of nitric acid in Arkansas. ADEQ provided production data for the years 1990-2005. The SIT was used to estimate N<sub>2</sub>O emissions from nitric acid production. However, the default SIT emission factor of 0.008 MtN<sub>2</sub>O per Mt of nitric acid produced was not used. This is because the default emission factor is based on a weighted-average calculated over the different types of emissions control technologies employed by nitric acid plants nationwide.<sup>6</sup> The Selective Catalytic Reduction (SCR) control technology was used by El Dorado Chemical, so the emission factor of 0.095 MtN<sub>2</sub>O per Mt nitric acid produced was used instead.<sup>7</sup> Relative to total industrial non-combustion process emissions, estimated emissions associated with nitric acid production are significant (about 0.88 MMtCO<sub>2</sub>e in 1990 and 0.99 MMtCO<sub>2</sub>e in 2005), and therefore, appear near the middle of Figure D2 due to scaling effects. Projections from 2006-2025 are assumed to stay constant at 2005 levels due to conflicting historical trends.

### *Substitutes for Ozone-Depleting Substances (ODS)*

HFCs and PFCs are used as substitutes for ODS, most notably CFCs (CFCs are also potent warming gases, with global warming potentials on the order of thousands of times that of CO<sub>2</sub> per unit of emissions) in compliance with the *Montreal Protocol* and the *Clean Air Act Amendments of 1990*.<sup>8</sup> 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 CO<sub>2</sub>e basis. Emissions have increased from 0.00 MMtCO<sub>2</sub>e in 1990 to about 1.16 MMtCO<sub>2</sub>e in 2005, and are expected to increase at an average rate of 6.3% per year from 2005 to 2025 (to 3.91 MMtCO<sub>2</sub>e by 2025) due to increased substitutions of these gases for ODS (see the light-orange colored 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 SF<sub>6</sub> from electrical equipment have experienced declines since the mid nineties (see light brown 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 SF<sub>6</sub> is as an electrical insulator in electricity T&D equipment, such as gas-insulated high-voltage circuit breakers, substations, transformers, and transmission lines, because

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<sup>6</sup> According to Chapter 6 of the EIIP guidance document, the nitric industry controls for oxides of nitrogen through two technologies: non-selective catalytic reduction (NSCR) and SCR. Only one of these technologies, NSCR, is effective at destroying N<sub>2</sub>O emissions in the process of destroying oxides of nitrogen emissions. NSCR technology was widely installed in nitric acid plants built between 1971 and 1977. Due to high-energy costs and associated high gas temperatures, this technology has not been popular with modern plants. Only about 20% of the current plants have NSCR technology installed. All other plants have installed SCR technology. Since 80% of the current plants have SCR technology installed and 20% have NSCR technology, the weighted-average emission factor used in the SGIT is equal to  $(0.0095 \times 0.80) \times (0.002 \times 0.20) = 0.008$  metric tons N<sub>2</sub>O per metric ton of nitric acid produced.

<sup>7</sup> US EPA *Inventories of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005*

(<http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf>).

<sup>8</sup> 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.

of its high dielectric strength and arc-quenching abilities. Not all of the electric utilities in the US use SF<sub>6</sub>; use of the gas is more common in urban areas where the space occupied by electric power T&D facilities is more valuable.<sup>9</sup>

As shown in Figure D2 and Table D3, SF<sub>6</sub> emissions from electric power T&D are about 0.27 MMtCO<sub>2</sub>e in 1990 and 0.17 MMtCO<sub>2</sub>e in 2005. Emissions in 2025 are projected at 0.14MMtCO<sub>2</sub>e. Emissions in Arkansas 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 Arkansas to the US electricity consumption (sales) estimates available from the Energy Information Administration's (EIA) Electric Power Annual and provided in 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 Arkansas. The decline in SF<sub>6</sub> emissions in the future reflects expectations of future actions by the electric power industry to reduce these emissions.

### 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 Arkansas manufacturers in these industries, and the specific nature of the production processes used in Arkansas.
- 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. Reflecting this uncertainty, the lowest historical annual rate of increase/decrease was selected as a conservative assumption for use in projecting future activity level changes. These assumptions on growth should be reviewed by industry experts and revised to reflect their expertise on future trends especially for the cement and lime manufacture, iron and steel production, and ammonia production industries.
- 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. For example, 1994 activity data for limestone and

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<sup>9</sup> US EPA, Draft User's Guide for Estimating Carbon Dioxide, Nitrous Oxide, HFC, PFC, and SF<sub>6</sub> Emissions from Industrial Processes Using the State Inventory Tool, prepared by ICF International, March 2007.

dolomite consumption were used as a surrogate to estimate emissions for 1990 through 1993. 2005 values are also missing for ammonia and urea production. Replacing these values would make future estimates more accurate.

- For the electricity T&D, 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.