Alaska Greenhouse Gas Emissions Inventory

1990 – 2015

Alaska Department of Environmental Conservation
Division of Air Quality

January 30, 2018

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Exhibit List

Acronyms

ADEC	Alaska Department of Environmental Conservation
AEA	Alaska Energy Authority
CCS	Center for Climate Strategies
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
GHGRR	Greenhouse Gas Reporting Rule
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
MOVES	Motor Vehicle Emission Simulator
MMT	Million Metric Tons
MSW	Municipal Solid Waste
MT	Metric Tons
N_20	Nitrous oxide
ODS	Ozone depleting substance
PCE	Power Cost Equalization (Program)
PFC	Perfluorocarbons
SF_6	Sulfur hexafluoride
SIT	State Inventory Tool
T&D	Transmission and Distribution
USGS	U.S. Geological Survey

1. Summary

This report primarily focuses on Alaska's greenhouse gas (GHG) emissions from anthropogenic (human-caused) sources within Alaska from 1990 through 2015. Emission reservoirs, also known as emission sinks (which remove carbon from the atmosphere), and emissions from wildfires are also discussed in this report.

This report is based on the Environmental Protection Agency's (EPA) 2015 and 2017 State Inventory Tool (SIT) data with some modified inputs for Alaska. The tool calculates emissions across all economic sectors for the six Kyoto Protocol GHGs based on individual state inputs. The industrial sector, including the oil and gas industries, produces the most GHG emissions in Alaska on an annual basis, followed by the transportation, residential and commercial, and the electrical generation sectors. Waste, agriculture, and industrial process sectors each produce relatively small quantities of GHGs in Alaska (less than 1% for each sector).

From approximately 1995 through 2003, gross GHG emissions were quite stable at approximately 50 million metric tons (MMT) of carbon dioxide equivalents (CO_2e). Emissions peaked in 2005 and by 2009 had declined by about 23%. (See Exhibit 3.) While the specific causes of the decline are not known, possible causes include facility upgrades, changes in facility operations, economic downturns, or newly added federal regulatory requirements that impact GHG emissions. Emissions slightly increased in 2010 and 2011, stabilized through 2012, and then decreased again through 2014. By 2015, emission levels were at 2009 levels.

Gross emissions from anthropogenic sources during the time period from 1990 to 2015 have decreased by approximately 8% (3.63 MMT CO_2e decrease in emissions). According to the Energy Information Administration (EIA), and based on total energy-related carbon dioxide emissions for 2014, Alaska ranks 40th in emissions amongst states. On a per capita basis, Alaska ranks fourth highest in the nation.[1] Alaska's GHG emissions comprise about 0.63%[2] of nationwide GHG emissions and 0.09%[3] of global GHG emissions.[4]

The net emissions take into account both the emissions from the anthropogenic sources as well as the sequestering of GHGs in emission sinks. Estimates relating to emission sinks are imprecise and work is underway to improve them. Estimates in this report rely on the EPA inventories of land use and vegetation profiles provided by federal land management agencies for the State of Alaska. Among the factors that can affect the precision of these estimates are changes in the landscape due to wildland fires. The acreage impacted by wildfires is highly variable from year to year. For example, during the low wildfire year of

[1] EIA: Energy-Related Carbon Dioxide Emissions at the State Level, 2000-2014
[2] EPA: Sources of Greenhouse Gas Emissions
[3] Intergovernmental Panel on Climate Change: Climate Change 2014 Synthesis Report Summary for Policymakers
[4] Between 2000 and 2010, total annual anthropogenic GHG emissions were increasing by 2.2% per year. 2.2% was used to calculate estimated GHG emissions for 2015 from the available 2014 data. Emission calculations do not factor in emission sinks.

2014, an estimated 29.80 MMT CO_2e were captured, whereas in the high wildfire year of 2015, carbon sinks only captured an estimated 1.74 MMT CO_2e. For more information on the variability in the net values, see Exhibit 4. At present, net emissions do not include GHG emissions resulting from thawing permafrost. There is no available means to accurately measure and quantify GHGs being released across Alaska.

2. Background

Alaska's first statewide GHG inventory was drafted by the Center for Climate Strategies (CCS) in 2007. The report analyzed GHG emissions from 1990, 2000, and 2005, and projected emissions out to 2025. The Alaska Department of Environmental Conservation (ADEC) then examined GHG emissions from stationary sources operating under Title V operating permits and in January 2008 issued a report of these findings. The final version of the CCS report was completed in July 2009 and included two appendices from ADEC documenting additional analysis of emissions from stationary sources and the aviation sector.

In March 2015, ADEC issued a GHG emissions inventory report that included the EPA emission factor changes and emission estimates with data from the years 1990 through 2010. The March 2015 ADEC GHG Emission Inventory Report did not directly compare its results to the previous CCS 2009 report because of slight methodological changes and changes in emission factor values. Some of the differences between the CCS 2009 and ADEC 2015 reports may appear as large percentage changes, but are actually small quantity changes. Nonetheless, the results of both inventories indicated a similar overall picture; both inventories show the same industries as being the highest emitters and the same overall GHG emission trends through the years.

This latest GHG emission inventory report adds data from 2011 through 2015 to the March 2015 GHG emissions report. The latest report also shows the GHG emission trend since 1990. This report does not include projections to future years.

This report update contains the Alaska State GHG Emissions Inventory results from 1990 through 2015 and follows the methodology set out in the March 2015 report. For some analyses, the 2015 data was not available at the time this report was written. In those cases, the available 2014 data has been used instead. (See Exhibits 8, 11, 10, and 12.)

The six Kyoto Protocol GHGs, as well as the global warming potential (GWP) associated with each GHG, are addressed in Exhibit 1. The Kyoto Protocol was enacted on December 11, 1997. It is an international agreement linked to the United Nations Framework Convention on Climate Change that establishes emission reduction targets using registry systems, reporting, compliance systems, and adaptation.[5] GHG emissions are presented using a common metric, CO_2e, which incorporates the relative contribution of each gas to the global average radiative forcing on a GWP weighted basis. CO_2e is a useful metric that allows other GHGs to be quantified and compared to the amount of CO_2 that would produce a similar impact. The GWP compares the atmospheric warming ability of a compound relative to carbon

[5] United Nations Framework Convention on Climate Change: Kyoto Protocol

dioxide. For example, this comparison means that one pound of methane warms the atmosphere as much as 25 pounds of carbon dioxide.

Exhibit 1 – Kyoto Greenhouse Gases[6]

Greenhouse Gas	Common Sources and Uses	Global Warming Potential
Carbon dioxide (CO_2)	Combustion	1
Methane (CH_4)	Combustion, decomposition	25
Nitrous oxide (N_2O)	Combustion	298
Sulfur hexafluoride (SF_6)	Electrical insulator	22,800
Hydrofluorocarbons (HFC)	Refrigerants	12-14,800
Perfluorocarbons (PFC)	Semiconductors, medical uses	7,390-17,700

Exhibit 1: Each Kyoto GHG is listed with their global warming potential (GWP). The GWP is defined as a unit of measure that allows comparisons of the global warming impacts of different gases. The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period (usually 100 years is used).

2.1 Purpose of Stationary Sources Inventory

In addition to the statewide emissions analysis, this report provides an analysis of the GHG emissions from major Alaska facilities reported directly to the EPA under the Greenhouse Gas Reporting Rule (GHGRR). This analysis of the major stationary sources provides additional insight into major emitters in Alaska. Stationary sources are typically larger industrial facilities operating in Alaska and are subject to state air quality permit requirements.

2.1.1 Federal Greenhouse Gas Reporting Rule (GHGRR)

In 2010, the EPA implemented the federal GHGRR. This rule requires facilities emitting more than 25,000 metric tons (MT) of CO_2e to report their emissions to the EPA annually. Summaries of the information reported are available to the public on the EPA website.[7]

Using the EPA data provides several advantages for Alaska when evaluating emissions from large facilities:

- Consistency – Facilities are required to report emissions under the federal GHGRR according to protocols established by the EPA. This requirement ensures that reporting is consistent from year to year and that all facilities are reporting emissions in the same way.
- Comprehensiveness – The EPA GHG Reporting Tool is set up to record GHG emissions by sector. Fuel quantities reported to the EPA may not include all the GHG emissions emitted from a facility.

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[6] The United Nations Framework Convention on Climate Change (UNFCCC) calls for the stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. The Kyoto Protocol to the Convention commits its parties to binding targets based on as a 'basket' of six GHGs, including carbon-dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), and sulfur hexafluoride (SF_6).

[7] EPA: FLIGHT – 2016 Greenhouse Gas Emissions from Large Facilities

- Frequency – Under the GHGRR, emitters are required to report emissions annually.
- Automation – The EPA uses a web-based system to collect and report GHG emissions data. Much of the analysis is automated.

This report includes a summary of the emissions reported to the EPA in addition to the SIT modules results.

2.2 Sector Descriptions

This inventory reports emissions according to eight sectors:

- **Industrial** emissions are those emitted during industrial production and include direct emissions that are produced at the facility and indirect emissions that occur off site, but are associated with the facility's use of energy. This includes emissions from fuel burned at a facility to produce electricity used solely at that facility. This category also includes fugitive emissions that come from the oil and gas industry. This sector includes emissions from all the natural gas burned by the oil and gas industry and fossil fuel burned in other industries. Most emissions from crude oil refineries are included in this category.

- **Transportation** includes emissions from cars, boats, planes, trains, and other mobile equipment.

- **Residential and Commercial** emissions include fuel combustion at homes and commercial buildings, mostly to generate heat. For example, home and hot water heating or building heat in office buildings.

- **Electrical generation** includes the emissions from fuels combusted to produce electricity provided to the grid. The grid may be the rail belt grid or a small local grid providing electricity to one community. Examples include the Healy Power Plant and diesel generators in rural communities.
- **Industrial Processes** are processes that produce GHG emissions as a result of the chemical reaction taking place or a fugitive emission that occurs in an industrial process. For example, the process of making cement releases carbon dioxide. Other gases reported in this section, HFC, PFC, and SF_6, are primarily released as fugitive emissions.
- **Waste** decomposition can give off methane, such as when waste food decomposes anaerobically.
- **Agriculture** produces GHGs from several mechanisms; examples include fertilizer converting to nitrous oxide and decomposition from agricultural waste that produces methane.
- **Emission Sinks**, or emission reservoirs, are areas in which carbon is removed from the atmosphere and sequestered. Methane and nitrous oxide emissions that result from wildfires are subtracted from the emission sinks.

Additional information regarding emissions for each sector is included in the Alaska specific sector results.

2.3 Projections

This revised inventory does not include projections of expected future emissions. For a number of sectors, the projections for 2010 identified in the initial GHG inventory produced in 2007 turned out to be grossly inaccurate. The 2008 economic downturn and subsequent slow recovery was likely a key driver in some overestimates. The projections for 2010 also predicted an increase in emissions from the natural gas industry that was not realized.

Emission inventory projections rely on several factors being accurate: the initial inventory, having correctly identified the drivers changing the activity, and accurate estimates of changes in the emitting activity. In addition, projections are most useful for evaluating mitigation strategies. For such work, multiple "what if" scenarios may be of the most benefit. This inventory update effort did not include updates to future emissions as there were no specific scenarios identified. Thus, there was little benefit to be gained from the work of preparing projections.

3. Methodology

The EPA provides the State Inventory Tool (SIT) for states to prepare GHG emission inventories. The SIT develops the inventory in a top-down fashion, applying emission factors to statewide activity data (e.g., gallons of fuel used). The tool consists of a set of Excel workbooks, referred to as modules, with one workbook for each emission category. (See Exhibit 2.)

The SIT spreadsheets include applicable formulas, emission factors, conversion factors, and global warming potentials embedded within them. The modules include relevant state-level default data provided by a variety of federal agencies. The user may choose to use the default data or to supply data from other sources. The tool calculates emissions across all sectors for all six Kyoto GHGs.

This revised inventory is based on the January 3, 2017 version of the EPA SIT. Additional data developed by Alaska supplemented the defaults in the tool. The SIT modules contained defaults through 2014. The 2015 data was added manually based on data available in relevant databases. Some data was calculated by staff by using 2014 data and augmenting it based on 2015 Alaska population. The EPA has indicated that they are likely to release the default 2015 SIT inputs in early 2018. (See Appendix A for additional information on the data sources.)

As the SIT modules mature, the key components (i.e. the coefficients, emission factors, formulas, and conversion factors) change nationally and by state as a result of better insight, familiarity, accurateness, and proficiency. As a result of the updates, the current SIT modules for GHG emissions would differ from previously calculated GHG emissions. Any comparison from this GHG emissions inventory (2011 through 2015 data) report to prior reports should keep the emission factor changes in mind. For example, the electricity consumption module results were compared to earlier reports, and there was a +/-3% change. Realistically, a 3% to 5% margin of error would apply. Should future interest and funding allow, a comparison of the 1990 to 2010 results to the current modules dataset could be a worthwhile analysis.

Exhibit 2 – SIT Modules

Module	Description	Gases
Agriculture	Emissions from agricultural activities	CH_4, N_2O
Coal	Emissions from coal mining and abandoned coalmines	CH_4
Electricity Consumption	Electricity emissions are based on electricity consumed in State[8]	CH_4, N_2O
Fossil Fuel Combustion	Emissions from the combustion of fossil fuels – includes fuels combusted across all sectors. Other gases produced are addressed by sector	CO_2
Industrial Processes	Emissions from industrial processes	all Kyoto gases
Land Use, Land Use Change, Forestry	Emissions from forestry practices include the effects of changes in land uses on carbon sinks	CH_4, N_2O, CO_2
Mobile Combustion	Non-CO_2 emissions from mobile sources	CH_4, N_2O
Natural Gas and Oil	Emissions from production and transmission of natural gas and oil	CH_4, N_2O
Solid Waste	Emissions from solid waste disposal	CH_4, N_2O, CO_2
Stationary Combustion	Non-CO_2 emissions from stationary combustion	CH_4, N_2O
Wastewater	Emissions from wastewater and treatment	CH_4, N_2O

Exhibit 2: Each SIT module is linked with one Excel spreadsheet for each emission category; brief descriptions and associated GHGs.

3.1 State Adjustments to Inventory Tool

Instead of using the default values in the SIT, ADEC adjusted the transportation, residential and commercial heat, and electrical generation emissions from diesel fuel. This was done to better account for fuel uses in Alaska. ADEC also applied a 10% lower fuel economy for Alaska vehicles than the national averages included in the tool, which affected both diesel and gasoline emission from on-road vehicles. The vehicle mix in Alaska includes more large vehicles than the national average. These larger vehicles, with lower fuel economy, shift the Alaska average lower than the national average.

[8] For some states, distinguishing between the electricity consumed in-state from the electricity generated in-state is important. Because Alaska does not import or export electricity, this distinction is not important and results represent in-state electricity generation.

The SIT calculates CO_2 from transportation sources in two ways:

1. Total CO_2 emissions based on the total quantity of transportation fuel sold within Alaska
2. Emissions by transportation mode
    - Marine, aviation, and rail are still based on fuel sales data
    - On-road vehicle fuel use is calculated for ten different vehicle and fuel combinations based on vehicle miles traveled and fuel economy

As part of a 2011 assessment on the emissions from on-road vehicles, ADEC developed inputs representing 2011 for the EPA's Motor Vehicle Emissions Simulator (MOVES). This model estimates emissions for on-road vehicles (e.g. cars and trucks). Using these inputs, ADEC estimated that on-road vehicles generated 2.79 MMT CO_2e in 2011.[9] The MOVES estimates confirm the validity of applying the 10% fuel economy adjustment to the on-road emissions SIT. For 2010, the SIT estimates on-road emissions to be 2.57 MMT CO_2e. In the future, the 10% fuel economy adjustment will be reevaluated to determine if it is still applicable.

3.1.1 Rural Fuel Use

The State of Alaska offers rural communities the opportunity to reduce the price of electricity to their customers through the Alaska Energy Authority's (AEA) Power Cost Equalization (PCE) program. Every year, participating communities report their total fuel use to the program. The emissions from these reported fuel quantities are greater than the total emissions the SIT calculated for all electrical generation from diesel for the entire state.

The fuel data in the SIT comes from the U.S. Department of Energy (DOE), which develops the data based on surveys completed at the distributor level. Based on these discrepancies, ADEC assumed that all the diesel fuel going to rural Alaska is labeled as transportation fuel, but some is diverted for other uses, primarily electrical generation and home and business heating.

To better account for the actual uses of fuel in rural Alaska, ADEC adjusted the results of the SIT according to the following descriptions:

Electrical generation adjustments

The use of distillate fuel for electrical generation provided in the SIT likely applies only to the rail belt electrical grid.[10] AEA provided total fuel amounts for the PCE program and the number of residents in participating communities. From this information, average diesel use per person for electrical generation was calculated. ADEC used this value to calculate total diesel use for electrical generation in rural Alaska. The total of the PCE and non-PCE communities was added to the electrical generation sector and subtracted from the transportation sector.

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[9] Inputs were prepared to comply with the EPA 2011 National Emissions Inventory submission requirements.
[10] Default fuel volume data collected by SIT will be evaluated and updated when additional facility information is provided.

Home heating adjustments

Similar to the electrical generation modifications, adjustments for home heating were added to the residential category and subtracted from the transportation sector.

The energy information provided in the tool is sufficient to calculate the total energy use per person in Alaska. DOE estimates that 8%[11] of all energy in Alaska is used in homes and that 36%[9] of all Alaska homes use fuel oil (diesel) for heat. Applying these percentages to the total energy use in Alaska suggests a higher estimate of diesel use in the residential and commercial sector than the SIT provides. The difference between the amount calculated in this manner and the values provided in the SIT were subtracted from the transportation total and added to the residential and commercial total.

Sector specific methodologies are included in each applicable sector discussion of this report.

4. Results

The 1990 to 2015 Alaska gross emissions are represented graphically by sector in Exhibit 3. Exhibit 4 lists the GHG emissions in Alaska for selected years and includes emission sinks as well. Numerical results for all sectors and all years are provided in Appendix B.

Exhibit 3 – Alaska Gross Annual Greenhouse Gas Emissions from 1990 to 2015

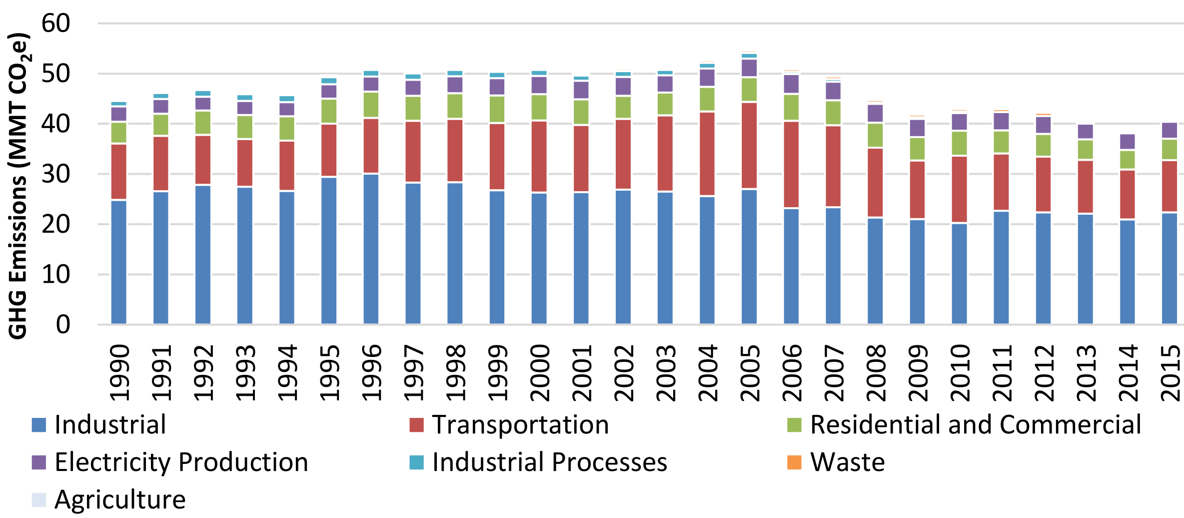

Exhibit 3: Waste, agriculture, and industrial process sectors each account for less than 1% of the overall emissions for Alaska.

Emissions from the industrial sector contribute the most to Alaska's GHG emissions. The transportation sector is the second largest followed by the residential and commercial sector. Electrical generation is the fourth largest sector. Industrial processes, agriculture, and waste all contribute minimally to Alaska's GHG emissions.

Exhibit 5 breaks down the emissions by sectors for 1990, 2000, 2005, 2010, and 2015.

[11] Appendix Exhibit A12: Data sources for rural fuel use adjustments

Exhibit 4 – Alaska's Greenhouse Gas Emissions by Sector and Fuel Type (MMT CO_2e)

	1990	2000	2005	2010	2011	2012	2013	2014	2015
Electrical Generation	**3.05**	**3.62**	**3.69**	**3.51**	**3.64**	**3.61**	**3.11**	**3.35**	**3.38**
Coal	0.45	0.78	0.57	0.56	0.56	0.59	0.55	0.93	1.03
Natural Gas	1.87	1.89	2.10	2.12	2.25	2.14	1.81	1.70	1.61
Petroleum	0.73	0.95	1.02	0.83	0.83	0.88	0.76	0.73	0.75
Residential and Commercial	**4.36**	**5.27**	**4.90**	**5.02**	**4.60**	**4.51**	**4.07**	**3.90**	**4.25**
Coal	0.77	0.80	0.77	0.84	0.92	0.90	0.87	0.81	0.83
Natural Gas	1.80	2.32	1.86	1.85	2.13	2.22	2.02	1.90	1.97
Petroleum	1.78	2.14	2.24	2.30	1.52	1.38	1.15	1.16	1.43
Wood (CH. and N2O)	0.012	0.013	0.019	0.022	0.018	0.017	0.023	0.023	0.018
Industrial	**24.87**	**26.33**	**27.02**	**20.26**	**22.67**	**22.37**	**22.13**	**20.99**	**22.35**
Coal/Coal Mining	0.026	0.026	0.024	0.038	0.045	0.038	0.029	0.028	0.022
Natural Gas/ Natural Gas Industry	13.95	18.70	19.13	14.12	14.00	14.44	14.24	14.30	14.94
Petroleum/Oil Industry	10.90	7.60	7.86	6.10	8.63	7.89	7.86	6.66	7.39
Transportation	**11.18**	**14.31**	**17.37**	**13.36**	**11.41**	**11.10**	**10.70**	**9.90**	**10.42**
Aviation	7.21	10.78	13.18	9.37	8.59	8.23	7.80	6.98	7.45
Marine	1.59	0.87	1.36	1.13	0.08	0.07	0.07	0.08	0.08
On-Road	2.33	2.62	2.75	2.81	2.67	2.72	2.76	2.79	2.83
Rail and Other	0.059	0.043	0.082	0.060	0.070	0.070	0.060	0.057	0.054
Industrial Processes	**1.10**	**1.17**	**1.14**	**0.29**	**0.35**	**0.38**	**0.39**	**0.40**	**0.40**
Ammonia Production	1.050	0.966	0.885	0.000	0.000	0.000	0.000	0.000	0.000
Urea Production	0.001	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Limestone and Dolomite Use	0.000	0.010	0.007	0.000	0.000	0.000	0.000	0.000	0.000
Cement Manufacture	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ODS Substitutes (HFC, PFC)	0.001	0.169	0.224	0.264	0.337	0.350	0.360	0.373	0.373
Soda Ash (CO_2)	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005
Electric Power T&D	0.042	0.023	0.023	0.020	0.011	0.023	0.023	0.023	0.023
Waste	**0.32**	**0.40**	**0.45**	**0.53**	**0.59**	**0.59**	**0.42**	**0.38**	**0.43**
Solid Waste Management	0.27	0.34	0.39	0.46	0.54	0.53	0.36	0.32	0.37
Wastewater Management	0.052	0.060	0.065	0.069	0.059	0.059	0.060	0.060	0.060
Agriculture	**0.05**	**0.05**	**0.07**	**0.08**	**0.07**	**0.07**	**0.07**	**0.08**	**0.08**
Agricultural Soils	0.030	0.026	0.031	0.033	0.030	0.031	0.029	0.034	0.028
Enteric Fermentation	0.015	0.019	0.026	0.025	0.028	0.028	0.026	0.023	0.025
Manure Management	0.001	0.007	0.009	0.021	0.015	0.015	0.014	0.023	0.023
Gross Emissions	**44.93**	**51.16**	**54.64**	**43.04**	**43.34**	**42.63**	**40.88**	**39.01**	**41.30**
Emission Sinks	-6.50	-25.20	5.20	- 22.37	- 29.45	-29.49	-23.57	-29.80	-1.74
Net Emissions	**38.43**	**25.96**	**59.84**	**20.67**	**13.89**	**13.14**	**17.31**	**9.20**	**39.56**
Gross Increase Since 1990 (MMT)	**0.00**	**6.23**	**9.71**	**-1.89**	**-1.59**	**-2.30**	**-4.05**	**-5.92**	**-3.63**
Gross Increase since 1990 (%)	**0%**	**14%**	**22%**	**-4%**	**-4%**	**-5%**	**-9%**	**-13%**	**-8%**

Exhibit 4: The low level of emission sink benefits in 2005 and 2015 is in part due to active wildfire seasons. Coal usage for electrical generation increased from 1990 to 2015. Reduction in the percentage of marine transport emissions since 2010 is related to exclusion of bulk fuel from calculations as the fuel is not burned in Alaska. Production at Agrium USA began to fall beginning in 2001 leading to a sharp decline in emissions from industrial process in 2005 and 2006. Agrium USA officially announced closure in late 2007.

Exhibit 5 – Alaska Emissions by Sector with Total U.S. Emissions for Comparison[12]

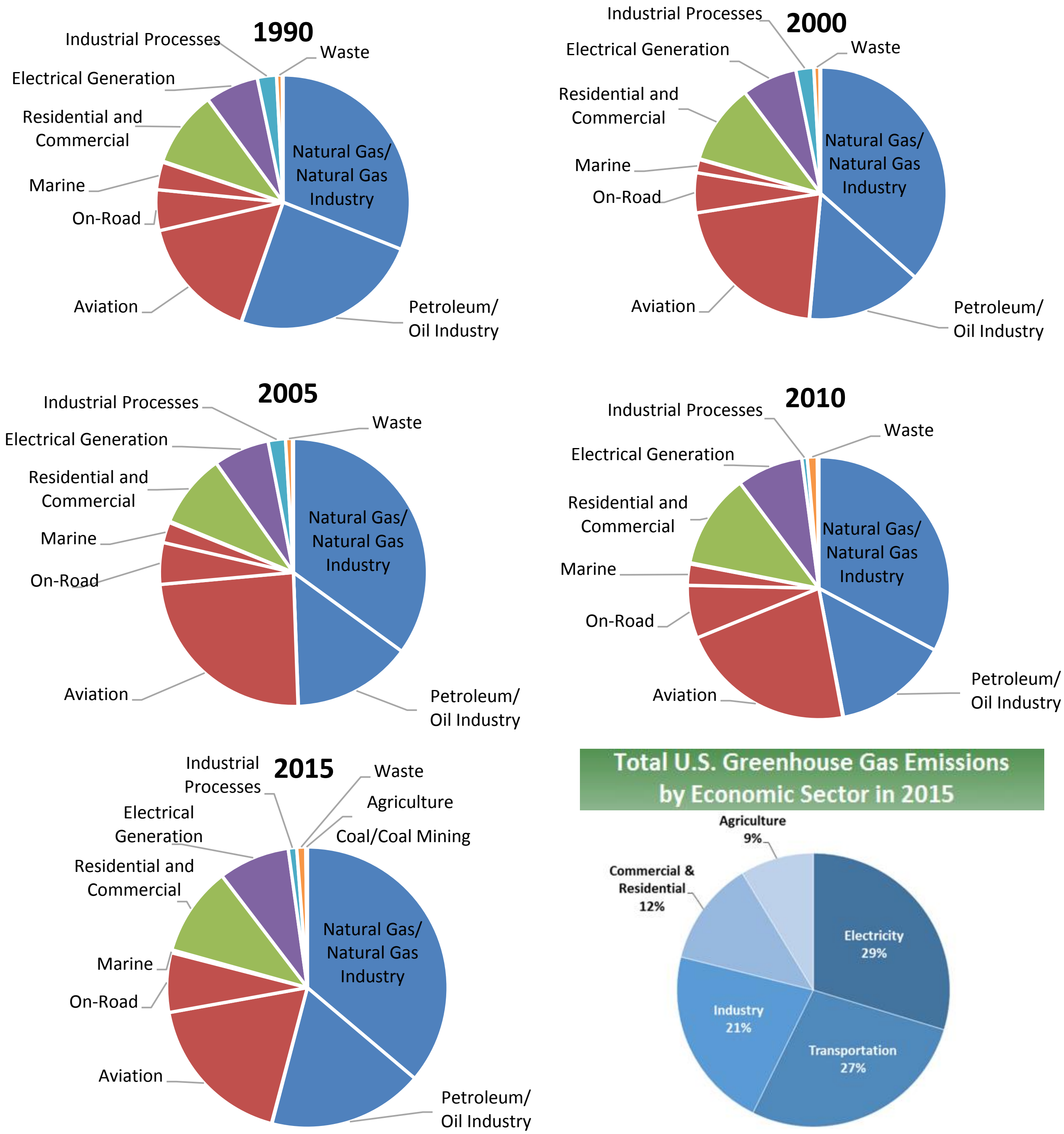

Exhibit 5: Alaska distribution of emissions by sector with total U.S. Greenhouse Gas Emissions by Economic Sector for comparison. In the Alaska Emission charts, the industrial sector has been divided into natural gas/natural gas industry and petroleum/oil industry. The transportation sector has been divided into aviation, on-road, and marine. Total U.S. Greenhouse Gas Emissions by Economic Sector in 2015 shows that the top GHG contributor on average is the electricity sector followed by transportation and industry.

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[12] EPA: Sources of Greenhouse Gas Emissions

4.1 Emission Trends by GHG over Time

This report examines the GHG emissions in Alaska for the six Kyoto gases. Exhibit 6 shows Alaska's emissions trends by GHGs for the last 25 years in million metric tons (MMT). This graph includes the trend for the total emissions (red line) as a comparison. The emissions trend for carbon dioxide closely mirrors the overall emissions trend. Nitrous oxide also follows the trend relatively closely. Methane emissions have steadily decreased over the last 25 years, whereas emissions from HFC, PFC, and SF_6 have increased. For the purpose of this inventory, HFC and PFC emissions are calculated on a per capita basis, and thus track with national trends. EPA asserts that these emissions have increased because of increased use of electronics. Alaska's trends track with national trends.

Exhibit 6 – Alaska Emission Trends by GHG (MMT)

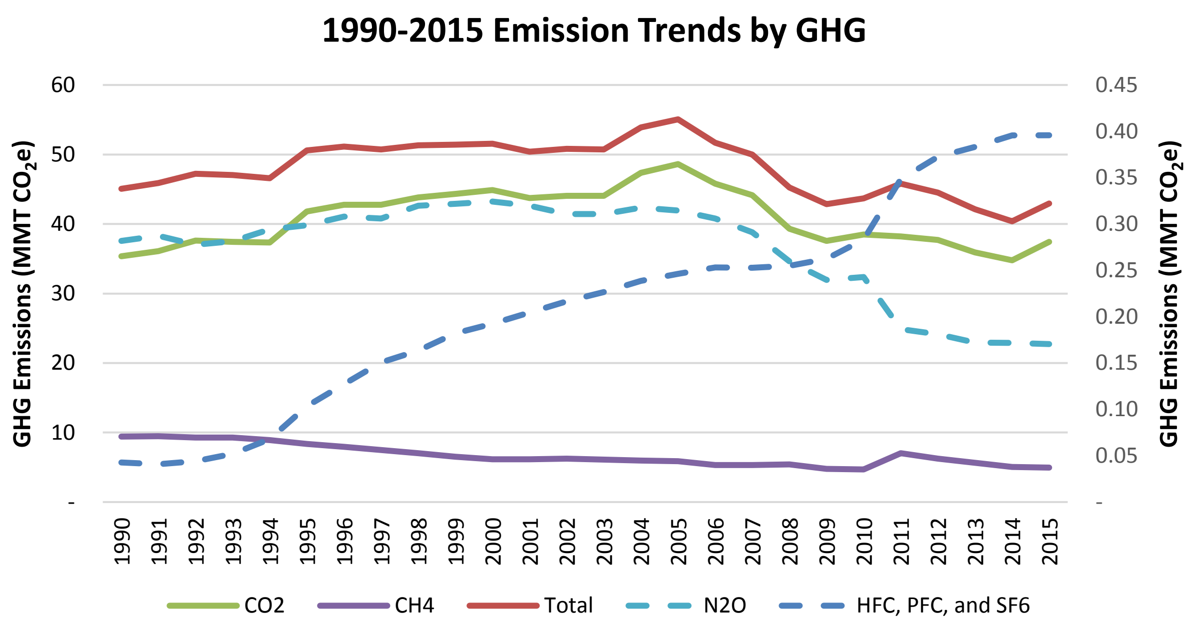

Exhibit 6: N2O and HFC, PFC, and SF_6 are represented by the right vertical y-axis label. The values for CO_2, CH_4, and total emissions are represented with the left vertical y-axis label.

4.2 Alaska in Perspective

The EIA calculates energy-related carbon dioxide emissions for all states each year.[13] The EIA collects detailed data for fuel, energy use, consumption, and sales for each state. The EPA uses the EIA data to estimate GHG emissions for all states. These estimates exclude emissions of other GHGs and all non-energy sources. Although the EIA's estimates do not include all GHGs, a large portion of the country's GHG emissions come from burning fuels for energy. Exhibit 7 compares the Alaska state inventory total from 1990 through 2015 with the totals provided by the EIA from 2000 through 2015. As expected, the EIA values are lower, but do follow a similar trend as the Alaska calculated inventory.

[13] EIA: Energy-Related Carbon Dioxide Emissions at the State Level, 2000-2014

Exhibit 8 compares Alaska's total gross emissions from anthropogenic sources to those of other states. According to the EIA, in 2014, 10 states and the District of Columbia had smaller emissions totals than Alaska. Alaska's GHG emissions comprise about 0.63%[14] of nationwide emissions and 0.09%[15] of global emissions.

Exhibit 7 – Total Gross Emissions Alaska and EIA (MMT)

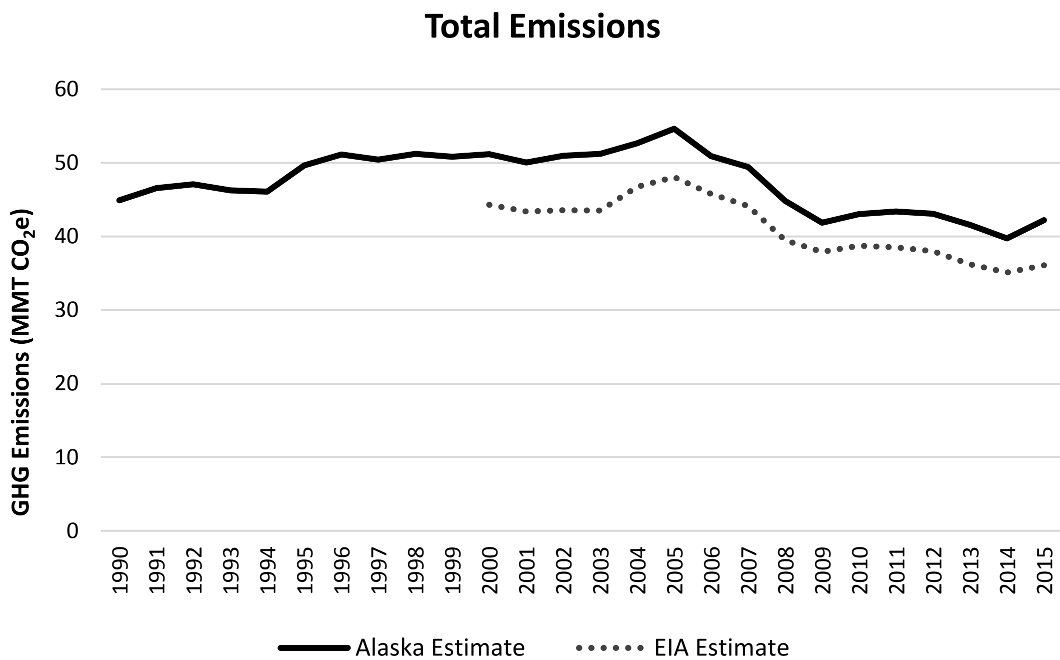

Exhibit 7: Alaska total emissions calculated with SIT from 1990 through 2015 compared to the totals provided by the EIA from 2000 through 2015. Total emissions follow a similar trend, however, the EIA values are lower.

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[14] EPA: Sources of Greenhouse Gas Emissions

[15] Intergovernmental Panel on Climate Change: Climate Change 2014 Synthesis Report Summary for Policymakers

Exhibit 8 – 2014 Total Gross Emissions for All States (MMT)

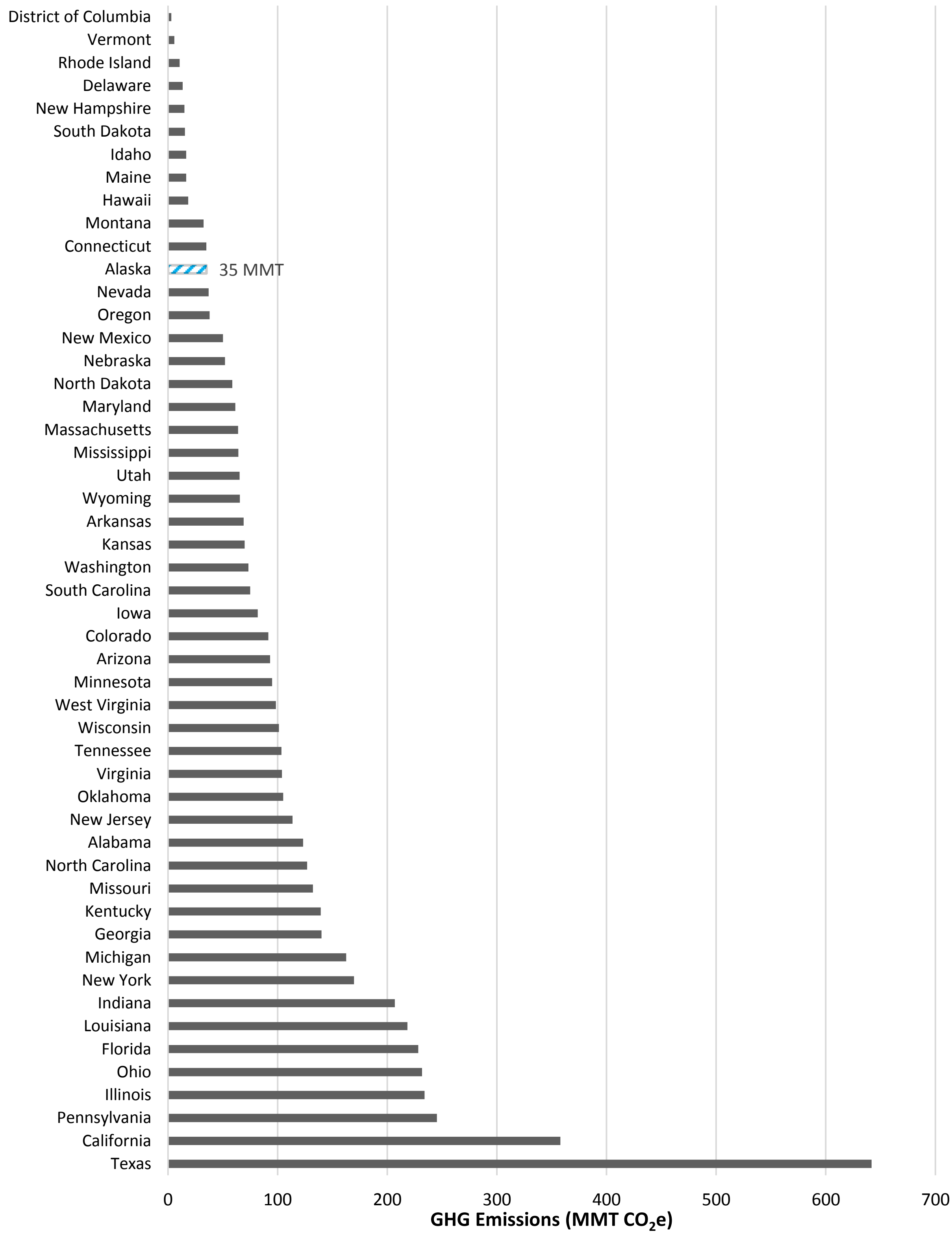

Exhibit 8: A 2014 comparison of Alaska's total emissions to those of other states. The 2014 data covers through the end of 2014. Ten (10) states and the District of Columbia had lower emissions than Alaska in 2014.

4.2.1 Per Capita Emissions

Comparing per capita emissions offers another perspective on Alaska's emissions. This view considers the states' emission in relation to population. Exhibit 9 shows the per capita emission trend in Alaska, as well as the per capita trend of the estimate from the EIA, which includes contributions for industrial emissions. Again, the EIA values are lower, but follow the same trend as the Alaska inventory.

On a per capita basis, at the end of 2014, Alaska emissions were the fourth highest in the nation, behind West Virginia, Wyoming, and North Dakota.[16] (See Exhibit 10.) Alaska has a low population with strong oil and gas industry influences that result in high emissions per capita when compared to the national average. North Dakota and Wyoming are similar to Alaska in this regard. Electrical generation in West Virginia and Wyoming accounts for a large majority of emissions. With lower populations, per capita emissions are higher than the national average.

Without industrial emissions included in the ranking analysis, Alaska remains higher than the national average for per capita emissions. (See Exhibit 11.) California and Texas have the two highest total emissions but are also the two most populous states in the nation, which results in their per capita emissions being lower than the national average. In calculating per capita emissions, the EIA takes into consideration climate, the structure of the state economy, population density, energy sources, building standards, and explicit state policies to reduce emissions. The EIA notes that many rural communities in Alaska rely primarily on diesel electric generators for power, and Alaska ranks second only to Hawaii in the share of its electricity generated from petroleum (e.g. diesel).

Exhibit 9 – Alaska per Capita Emission Trends (MT)

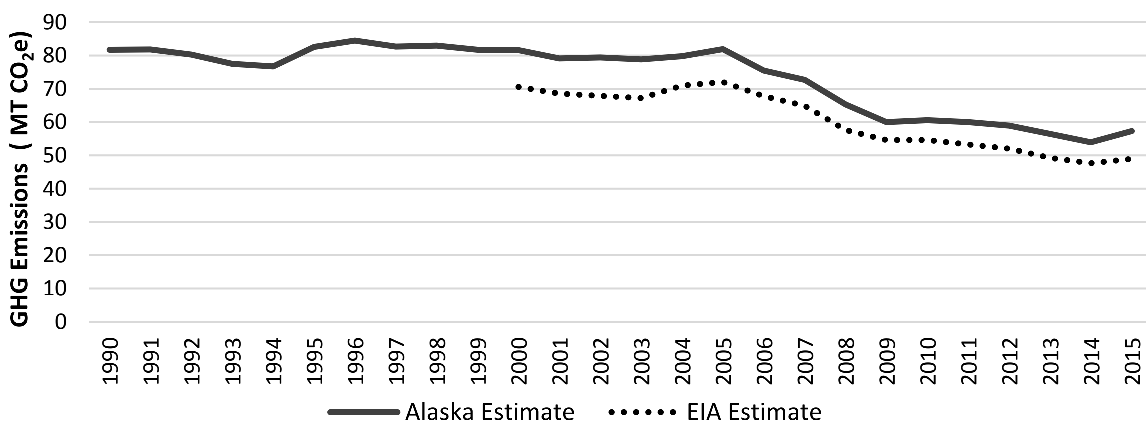

Exhibit 9: Alaska SIT per capita emissions from 1990 through 2015 compared to the per capita trend of the estimate from the EIA. The EIA values are lower but follow the same trend as the Alaska estimate for per capita emissions.

[16] Energy-Related Carbon Dioxide Emissions at the State Level, 2000-2014, January 2017. For the 2015 EIA analysis, the most recent available data was for 2014.

Exhibit 10 – 2014 per Capita Emissions for All States (MT)

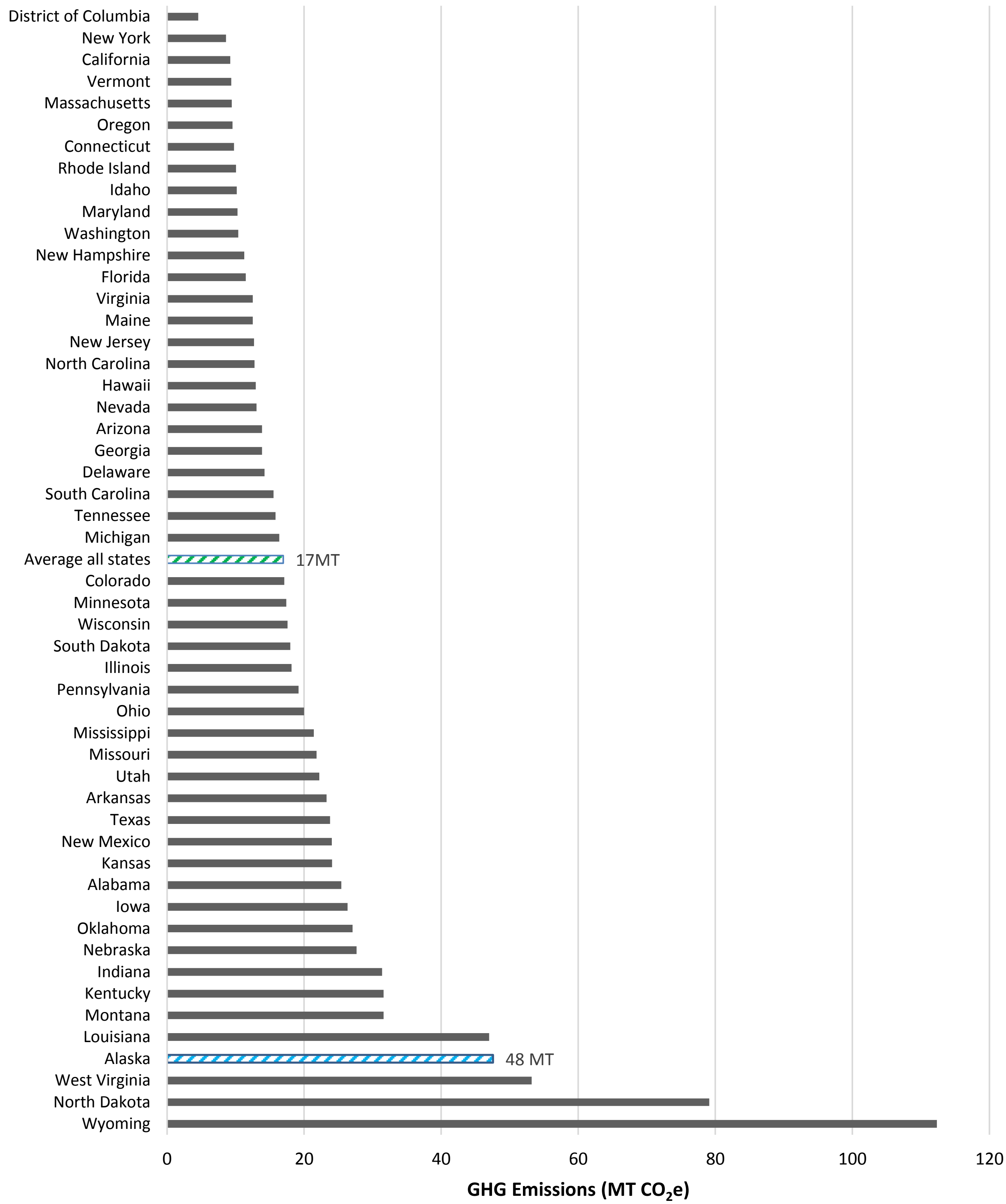

Exhibit 10: The four states with the highest per capita emissions all have low populations with strong industry or electrical generation sectors.

Exhibit 11 – 2014 per Capita Emissions without Industrial Emissions – All States (MT)

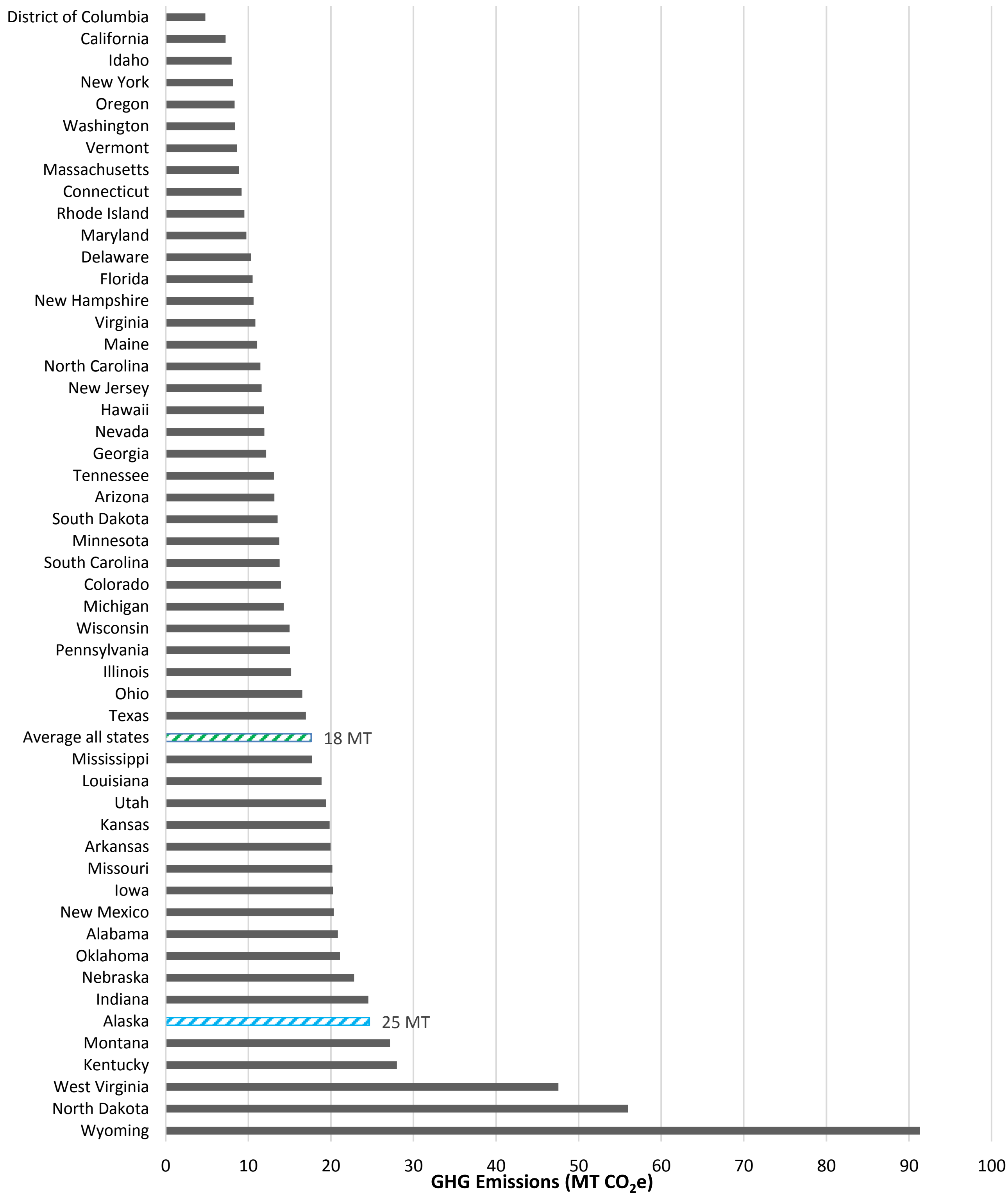

Exhibit 11: 2014 comparison of Alaska's per capita emissions minus industry sector emissions to other states. Alaska per capita emissions without industrial emissions are higher than the national average.

4.2.2 Sector Emissions: State by State Comparison

About 54% of Alaska's energy related carbon dioxide emissions come from the industrial sector and another 35% from the transportation sector. Some states, such as West Virginia and Wyoming, have a large electrical generation sector that emits a significant portion of their emissions. Compared to Alaska, energy emissions in Idaho and Vermont are more driven by the transportation sector. In Louisiana, the industrial sector produces the greatest portion of emissions. Exhibit 12 compares Alaska's sector to that of several other states.

With the major contributors to GHGs varying greatly from state to state, when considering strategies to reduce GHG emissions, there is no one set of policies or programs that will work across the board. Each state must identify the strategies to address their unique mix of sources and other state characteristics.

Exhibit 12 – 2014 Energy-Related CO_2 Emissions Distributions by Sector, Selected States[17]

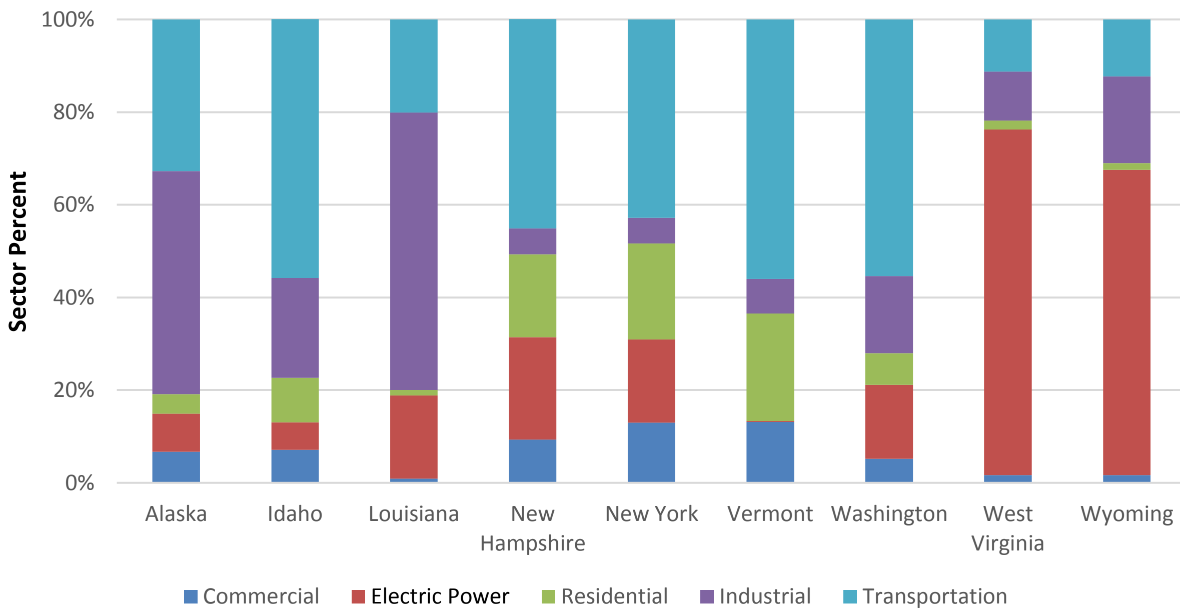

Exhibit 12: 2014 comparison of Alaska's emission by sector to emissions of several other states.

4.3 Alaska Sector Results

4.3.1 Industrial Emissions

In 2015, the industrial sector produced over half of Alaska's GHG emissions. Fugitive methane contributed over 19% of the CO_2e emitted by this sector in 2015. Most of the fugitive methane comes from oil production; a small portion comes from natural gas production. Exhibit 13 shows that in 2015 natural gas production and combustion produced about 67% of the industrial sector's emissions.

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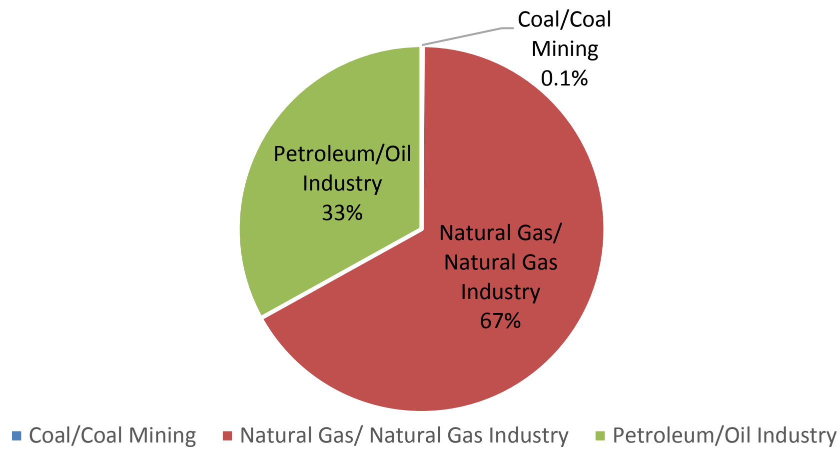
[17] Based on EIA data that only includes CO_2 emissions from energy production. For the 2015 EIA analysis, the most recent available data was for 2014.

Exhibit 13 – 2015 Industrial Sector Emissions



Alaska's fugitive emissions are likely less than the national average used in the tool. The EPA SIT calculates fugitive emissions from the oil and gas sector based on a national average quantity of fugitive emissions per barrel of oil produced. Fugitive emissions are released from pressurized systems, such as internal combustion engines, during industrial operations. Information gathered by Alaska's Climate Change Sub-Cabinet during 2007 and 2008 indicates that some equipment that would be outdoors in other states is housed in buildings in Alaska due to the harsh environment in which Alaska oil and gas operations take place. To prevent the buildup of flammable gases in the confined space of a building, this equipment must be tightly sealed against fugitive emissions, which results in reduced fugitive emissions per barrel.

Exhibit 14 shows that carbon dioxide emissions make up about 81% of the emissions from the industrial sector. Together, these results show that it is largely the combustion of natural gas in industrial applications that drives the emissions in this sector, not necessarily the production of natural gas. Emissions in this sector includes fuel burned at the facility to create electricity for operations. While petroleum products and coal is used, natural gas is the primary fuel source for many industrial facilities and is therefore the most common source of GHG emissions for the industrial sector. Emissions from coal and coal mining make up 0.1% of emissions in this sector. Emissions related to the burning of coal are also included in the electrical generation sector as well as the residential and commercial sector. The amount of CO_2 produced when coal is burned is significantly higher than when natural gas or petroleum is burned. Pounds of CO_2 emitted per million BTU for different fuels are as follows: anthracite coal (228.6), bituminous coal (205.7), lignite coal (215.4), subbituminous coal (214.3), diesel fuel and heating oil (161.3), gasoline without ethanol (157.2), propane (139.0), and natural gas (117.0).[18] Exhibit 15 shows the quantities of CO_2e produced by combustion and from fugitive emissions. Fugitive emissions account for a small percentage of natural gas GHG emissions; however, they contribute half of the emissions from the oil industry.

[18] EIA: "Frequently Asked Questions – How much carbon dioxide is produced when fuels are burned?" https://www.eia.gov/tools/faqs/faq.php?id=73&t=11

Exhibit 14 – 2015 Industrial Sector Emissions by Greenhouse Gas

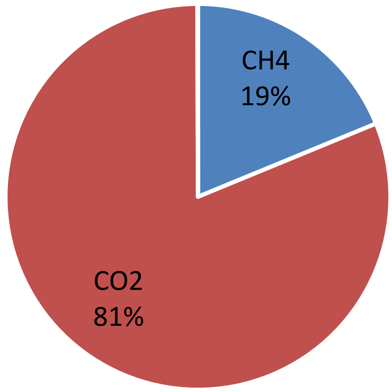


Exhibit 15 – 2015 Industrial Sector Emissions by Fuel and Emission Type (MMT)

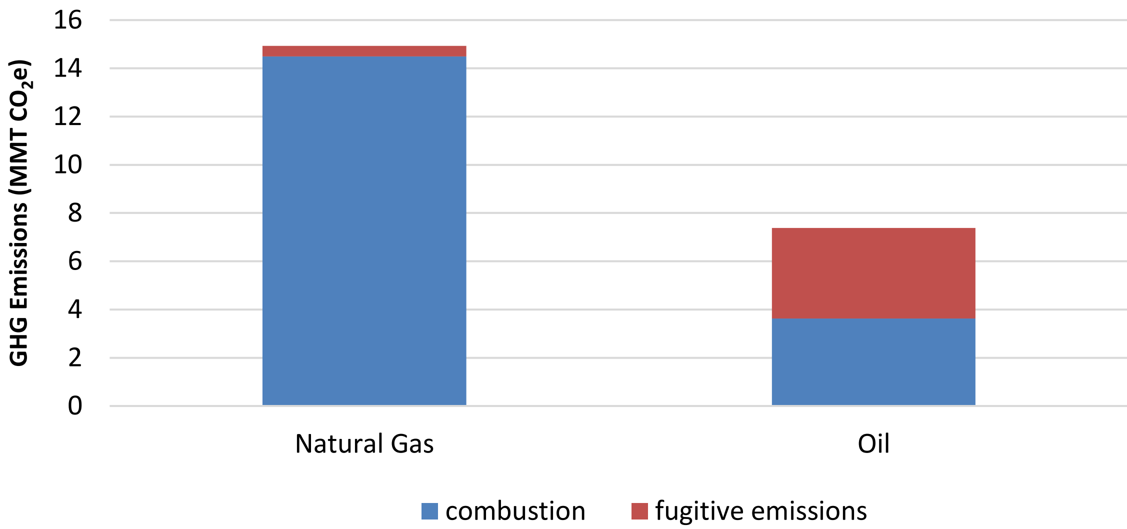


Exhibit 16 displays the emission trends of natural gas, petroleum, and coal from 1990 through 2015. The fugitive emissions for the oil and gas industries are calculated based on the quantity of oil and natural gas produced. Thus, the decline in Alaska's oil production is potentially one factor contributing to diminishing emissions in this sector. Changes in equipment or operations could also account for the decline in emissions. Coal emissions contribute minimally to this sector.

Exhibit 16 – Industrial Emissions by Fuel Type Trends (MMT)

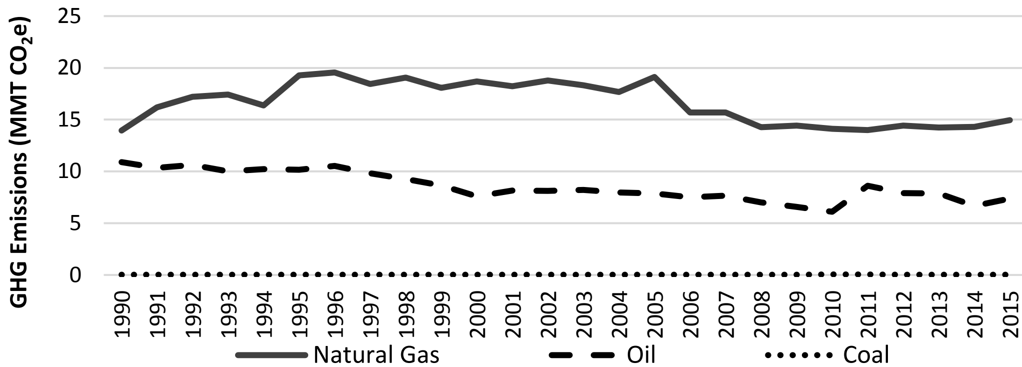


Exhibit 16: Emission trends of natural gas, petroleum, and coal from 1990 through 2015. Natural gas emissions fell between 2004 and 2007. Alaska natural gas gross withdrawals from oil and gas wells most recently peaked in 2004 before declining and has yet to see a notable increase in production.[19]

4.3.2 Industrial Processes

In addition to the fuel used in industrial operations, some industrial processes release GHGs from the chemical processes taking place. Cement manufacturing, soda ash production and consumption, ammonia production, and urea production are examples of carbon dioxide industrial emitters. Industrial processes also includes GHG emissions released at oil refineries from waste water processes. Other industrial applications, such as ozone depleting substance (ODS) substitutes and distribution systems, require compounds with very high GWP, such as hydrofluorocarbons (HFC) and/or perfluorocarbons (PFC). Under the best conditions, small quantities of these materials leak into the atmosphere. The industrial processes sector also captures the sulfur hexafluoride used as an insulator in electricity transmission and distribution (T&D). Sulfur hexafluoride (SF_6) is a powerful GHG contributor, about 23,900 times stronger than carbon dioxide. Processes that emit HFC, PFC, and SF_6 include ozone depleting substances (ODS) substitutes and distribution systems.

In 1990, emissions from industrial processes were primarily from ammonia production. By 2010, HFC, PFC, and SF_6 had become the dominant sources within this sector. (See Exhibit 17.) In 2005, ammonia production and urea consumption resulted in the emission of 884,885 MT CO_2e.[20] In 2006, the emissions from ammonia and urea reduced to 216,113 MT CO_2e. The results from 2015 are comparable to those of the 2010 industrial process emissions. Variations in Alaska's industrial process emissions are due in part to industrial plants closing and opening. Industrial process emissions have shifted over the last 25 years. In 2006, industrial process emissions sharply declined for Alaska. (See Exhibit 18.) The drop in emissions between 2005 and 2006 reflect the decline of production at the Agrium fertilizer plant located in Nikiski beginning in 2001 until facility final closure in in 2007 and the associated reduction in urea and ammonia production.

Overall, industrial processes contributed approximately 1% of Alaska's GHG emissions in 2015, which was the same portion as in 2010.

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[19] EIA: Natural Gas Gross Withdrawals and Production
[20] EPA SIT Industrial Production Module: Ammonia Production and Urea Consumption in Alaska

Exhibit 17 – Industrial Process Emissions: 1990, 2010, and 2015[21]

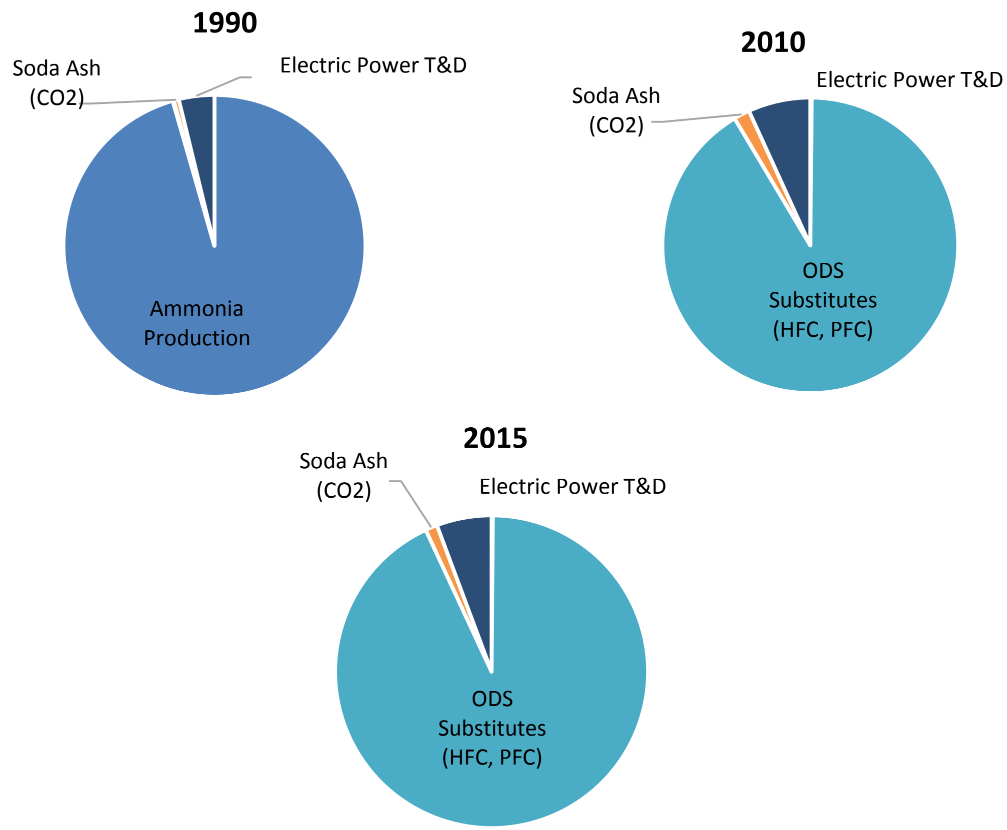


Exhibit 17: The shift from ammonia production to ODS substitutes from 1990 to 2010 is evident based on this schematic.

Exhibit 18 – Industrial Process Emissions (MMT)

Exhibit 18: *Trend of Industrial Process emissions since 1990 indicates a decline in emissions. Industrial processes contribution of GHG amounts to about 1% of Alaska's total GHG emissions. Production at Agrium USA began to fall in 2001, leading to a sharp decline in emissions from industrial process in 2005 and 2006. Agrium USA officially announced closure in late 2007.*

[21] ODS = ozone depleting substitutes, T&D = transmission and distribution

4.3.3 Transportation

Transportation emissions are generated from burning fuel in cars, trucks, snow machines, marine vessels, aircraft, construction equipment, and other mobile equipment. (See Exhibit 'Mobile Composition' in Appendix A7.) The carbon dioxide emissions are directly proportional to the quantity of fuel consumed, but the methane and nitrous oxide emissions depend on the type of equipment. In 2015, transportation contributed approximately one-quarter of Alaska's GHG emissions, about the same percentage as in 2010. (See Exhibit 19 for information on the contribution to the transportation sector by mode of transportation.)

Exhibit 19 – 2010 and 2015 Transportation Emissions

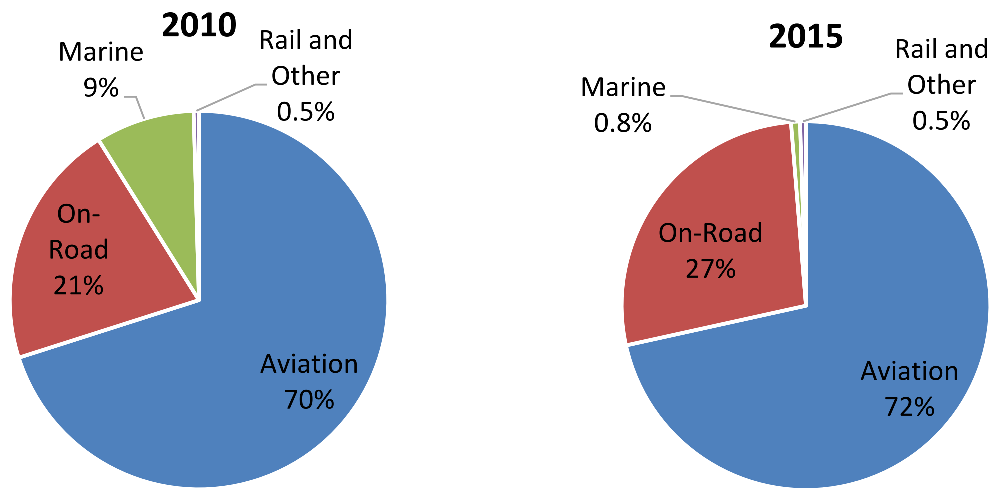


Exhibit 19: Marine emissions reduced by over 90% due to exclusion of bulk fuel data from calculation.

Exhibit 20 depicts the transportation sector emission trends for the last 25 years. The sharp decline in aviation emissions between 2007 and 2009, about 35%, could be partly related to the recession or from changing flight paths, but the actual cause is not known. From 2010 to 2011, there was an increase in aviation emissions followed by a decline. By 2015, aviation emissions did not reach the level of those in 2008. Changes in transport patterns could also affect the aviation emissions from international air traffic.

The marine vessel emissions decrease from 2010 levels could also be attributed to usage of different data sets for years prior 2011 and for years 2011-2015. Beginning in 2011, default SIT module data was used for fuel consumption which resulted in significantly lower fuel consumption volumes and respective emissions in comparison with 2010 and prior years. Fuel consumption data used in 2010 and prior years came from the EIA petroleum and other liquids data and includes residual and distillate fuel oil for vessel bunkering, which is significantly higher than default SIT mobile combustion module volumes.

On-road emissions have increased slowly over the last two and a half decades. Rail and other transportation sources, such as tractors (i.e. farm equipment and construction equipment), make up the smallest portion of this sector.

Exhibit 20 – Transportation Emissions (MMT)

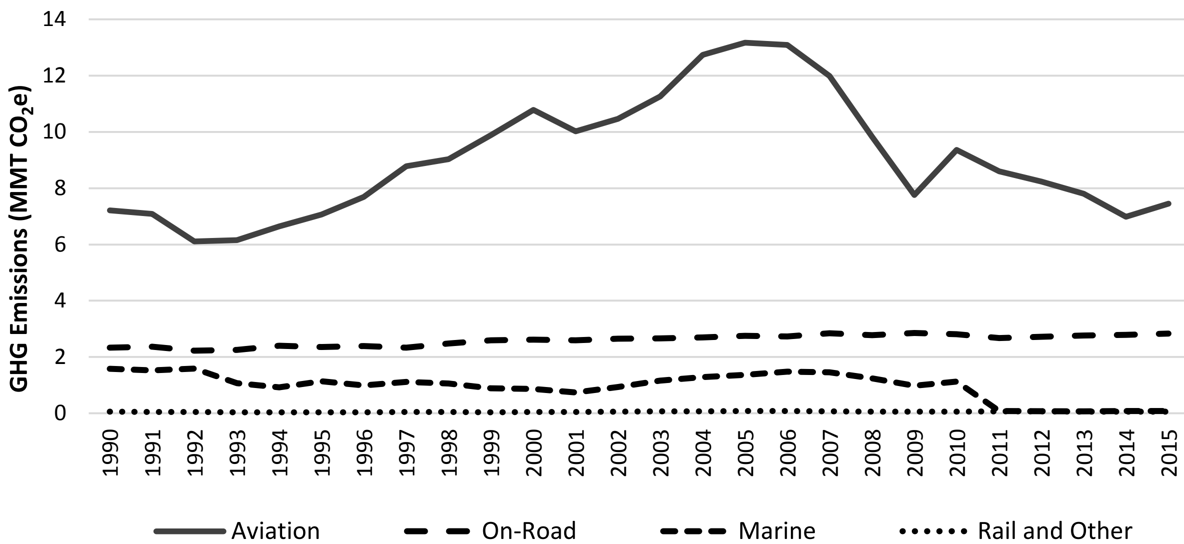


Exhibit 20: Beginning in 2011, different datasets were used, resulting in lower fuel consumption data.

Highway vehicles: Emissions from highway vehicles are calculated in the EPA mobile combustion module by analyzing the miles traveled for each vehicle type, then converting miles traveled to data to be used with emission factors. The miles driven are then distributed by vehicle age, and then emissions are determined for each vehicle type. The age of the vehicle is directly related to the technology by model year, which is separated into the following categories: advanced, moderate, uncontrolled, non-catalyst, oxidation catalyst, early 3-way catalyst, 3-way, and low emission vehicle. For on-road vehicles, over the last two and a half decades, the annual average vehicle miles traveled per person in Alaska has varied from about 6,500 to about 7,600. As population has grown in Alaska, the total miles driven within Alaska has increased.

In all segments of the transportation sector, fuel use is the driving factor determining the GHG emissions. Fuel use is, in turn, related to the distance traveled and vehicle efficiency, as well as the number of vehicles operating.

Aircraft: The calculation of aviation emissions relies upon the quantity and type of fuel purchased In Alaska. Jet fuel kerosene is the primary fuel used by aircraft and commercial aviation is the primary contributor to the aviation emissions category. The International Civil Aviation Organization (ICAO) expects an increase in emissions of 300 to 700% for air traffic in the next 20 years.[22] The ICAO has focused on improvements in technology to improve efficiency measures rather than implement mandatory emission reduction programs. As part of the initial inventory, ADEC supplemented the CCS inventory with additional work on aviation emissions, which was documented in Appendix B of the inventory. The work effort was cursory, but provided a useful estimate of the portion of the emissions contributed by international flights refueling in Alaska.

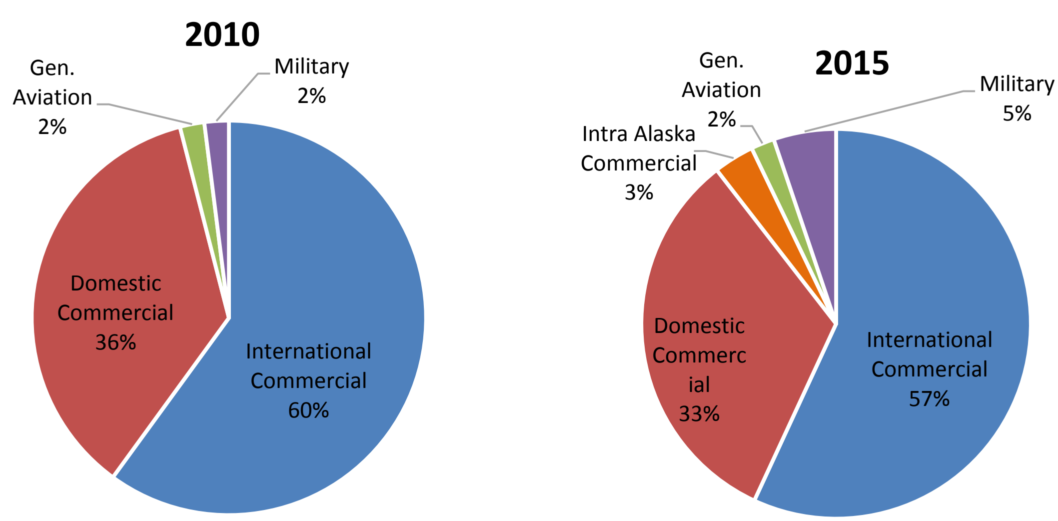
[22] Arctic Deeply: Analysis – Arctic Air Traffic Emission are Likely to Grow

International aviation emissions accounted for 4.47 MMT CO_2e or 57% of aviation emissions in 2015. Based on data provided by the military in response to a request for aviation fuel consumption, it was determined that in 2015, military aviation contributed about 5% and intra-Alaska large certificated carriers (commercial) contributed about 3% for flights from one point in Alaska to another point in Alaska. In 2010, commercial aviation produced an estimated 96% of the aviation emissions with general aviation and military aircraft each contributing about 2%.[23] (See Exhibit 21.) In the 2008 "Summary Report of Improvements to the Alaska Greenhouse Gas Emission Inventory," it is stated that military aviation only includes operations occurring on Alaska's military bases.[24] The previous analysis also estimated the international commercial emissions for 2005 to be 7.65 MMT CO_2e.

About two-thirds of transportation emissions are from the aviation sector. It is difficult to quantify the portion of these emissions that are taking place in Alaska airspace because the inventory is based on fuel sales.

All fuel sold in the State is accounted for in Alaska's inventory although not all of the fuel is used within Alaska's boundaries. Anchorage is a popular refueling stop for many out of state commercial, overseas commercial, and overseas air cargo flights. Aviation emissions in Alaska are significantly affected by the number of aircraft refueled here during out of state and transcontinental trips.

Exhibit 21 – Aviation Emissions



Marine vessels: Marine emissions are calculated with data based on fuel consumption and the associated emission and density factors. Quantification of GHG emissions from international vessels transiting in State waters is not included in the report unless they stop for refueling purposes at a port. As with aviation emissions, marine emissions are based on fuel sales. It

[23] Sierra Research. "Alaska Aviation Emission Inventory." June 2005

[24] Alaska Department of Environmental Conservation (ADEC). "Summary Report of Improvements to the Alaska Greenhouse Gas Emission Inventory." January 2008

is difficult to quantify the portion of marine emissions from international vessels that occur in State waters. The fuel types include: residual fuel oil, distillate fuel oil, and gasoline. Reduction in the percentage of marine transport emissions since 2010 is related to exclusion of bulk fuel from calculations, as the fuel is not burned in Alaska.

Similar to aviation emissions, many marine vessels refuel in Alaska before they transit out of State waters. It is estimated that 3.3 million tons of freight enter Alaska each year.[25]

4.3.4 Electrical Generation

Emissions from the electrical generation sector are calculated from the amount of fuel burned to produce electricity that is delivered to an electric grid serving customers. Coal, natural gas, and diesel are types of fuels used in Alaska to produce power. This sector excludes emissions from electricity produced for industrial use. (North Slope oil and gas electrical generation is included in the industrial sector, not in electrical generation.) Exhibit 22 shows the trend in electric emissions over time. Over the past 25 years, electrical generation has consistently accounted for about 8% of Alaska's GHG emissions.

With recent upgrades to several southcentral Alaska power plants and new renewable generation, it is expected that future per capita emissions from electrical generation will stay stable or slightly decrease.

Exhibit 22 – Electrical Generation Emissions (MMT)

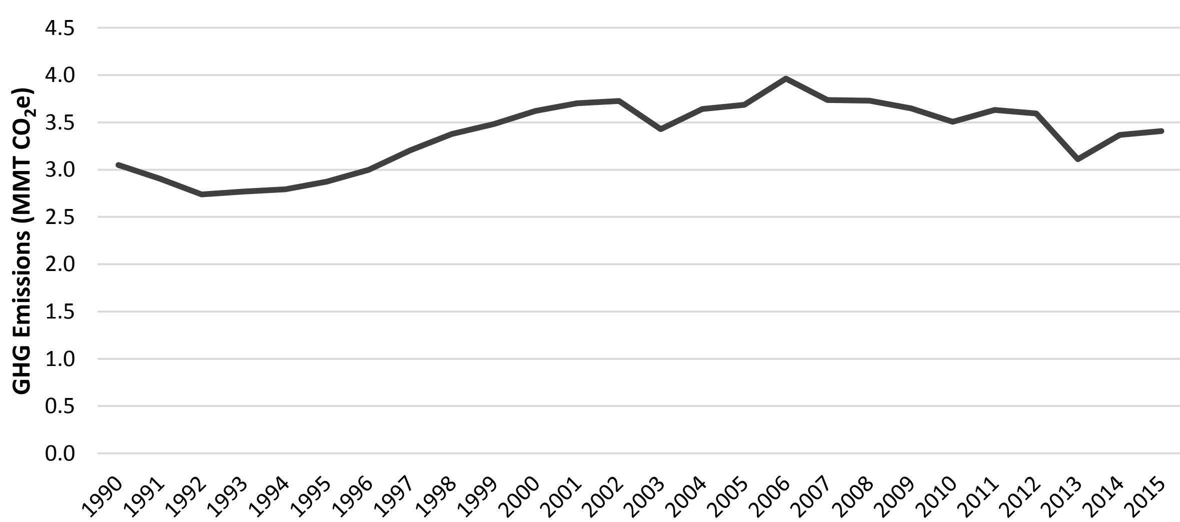


Exhibit 22: Electricity Production from 1990 to 2015. GHG emissions from electrical generation is influenced by the type of fuel used for generation. The GHG emissions in this exhibit incorporates all fuels used in Alaska.

[25]Port of Anchorage: "Southcentral Alaska Ports Freight and Fuel Analysis Update." 2017

4.3.5 Residential and Commercial

Emissions in the residential and commercial sector are calculated from fuel combustion in homes and businesses for uses such as heating. The fuel types included in the analysis of residential and commercial sector emissions include coal, distillate fuel, kerosene, liquefied petroleum gas (LPG), natural gas, wood, motor gasoline, and residual fuel. (See Exhibit A10.) Motor gasoline and residual fuel are included in the commercial emissions calculation but not the residential calculation. Residential EIA fuel consumption data includes living quarters for households. Commercial fuel consumption data includes service-providing facilities and equipment from both private and public organizations and businesses.[26] Exhibit 23 shows that although there are some increases and decreases in this sector's emissions, the trend is roughly flat, possibly indicating that as the population grows, the efficiency of energy use has improved. Increasing efficiency is also evident in looking at the per capita emissions for this sector. In 2015, the residential and commercial sector contributed about 12% of the Alaska's emissions, the same level as in 2010.

Exhibit 23 – Residential and Commercial Emissions (MMT)

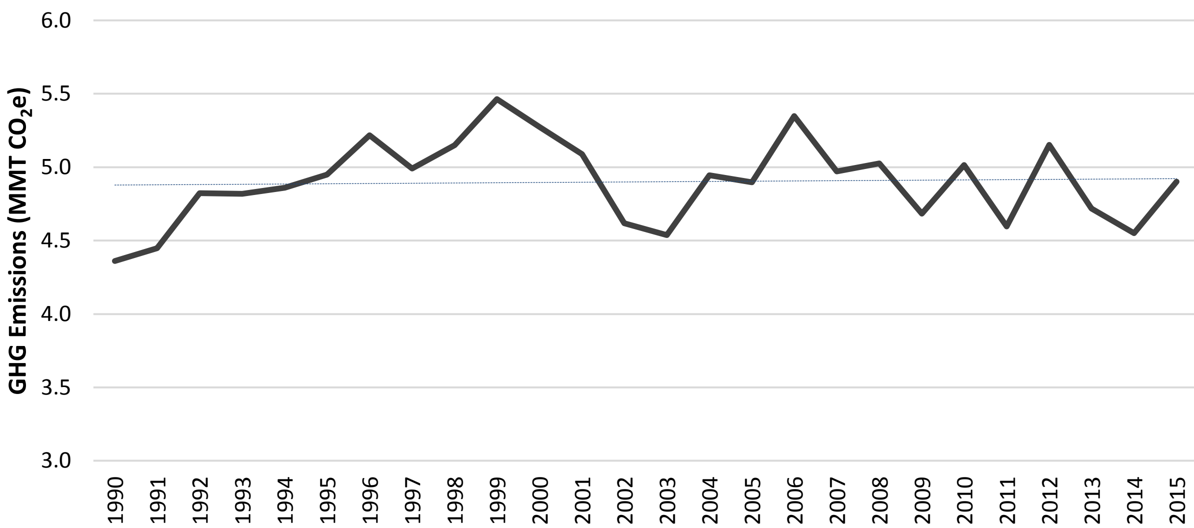


Exhibit 23: Residential and commercial emissions from 1990 to 2015 and trend line.

4.3.6 Waste

Waste disposal generates GHG emissions, primarily methane from decomposition. The waste sector includes emissions from landfills and waste combustion and emissions from wastewater. (See Exhibits A9 and A11 respectively.) Population, time of waste in landfills, and the proportion of plastics, synthetic rubber, and synthetic fibers in discarded material are key variables used in determining emissions in the waste sector. Producing about 1% of Alaska's GHG emissions, the waste sector contributes minimally to Alaska's emissions, but the overall trend is toward increasing emissions. In the end of 2012, the Anchorage landfill commissioned a landfill gas to energy project. Some of the landfill gas is collected and used

[26] EPA: Inventory of U.S. Greenhouse Gas Emissions and Sinks

as fuel gas by Doyon Utilities. The implementation of the landfill gas-to-energy project resulted in a reduction in emissions for the waste sector, which is evident in Exhibit 24.

Exhibit 24 – Waste Emissions (MMT)

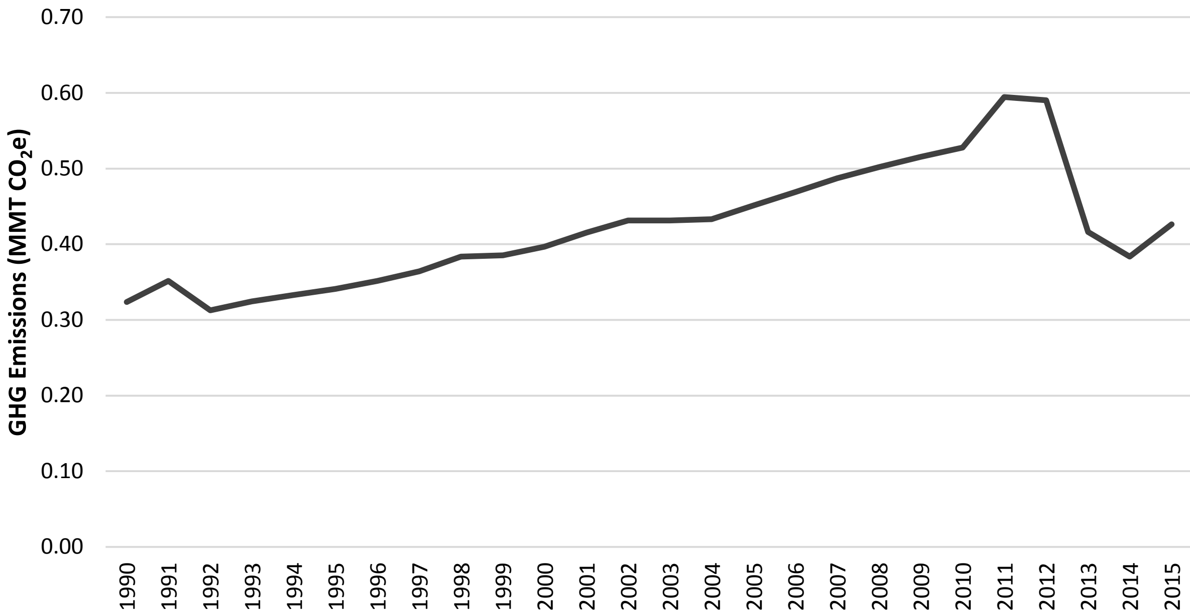


Exhibit 24: Waste emissions from 1990 to 2015. The drop in emissions from 2012 to 2013 is attributed to the implementation of the landfill gas to energy project by the Anchorage landfill.

4.3.7 Agriculture

Crop and livestock production generate GHG emissions through decomposition and other biological processes. The agricultural sector emissions include emissions that result from enteric fermentation, manure management, agricultural soils, and agricultural residue burning. (See Exhibit A1.)

Enteric fermentation is produced by animals such as cattle, sheep, goats, swine, horses, and other animals that have a large fore-stomach, or rumen.[27] Enteric fermentation takes place in the digestive system of the aforementioned animals and is the main contributor of methane from ruminant animals.

Manure management emissions are calculated by multiplying the animal population by the typical animal mass and the average volatile solids produced. Methane production and nitrous oxide production from manure is based on the volatile solids. Agricultural soils from plant residues, legumes, plant fertilizers, and animals are calculated. Agriculture emissions from residues, legumes, and histosols are minimal since the only applicable residue calculations for Alaska are barley and oats. Agricultural residue burning relates to the crop residue produced and subsequently burned.

[27] EPA: Enteric Fermentation—Greenhouse Gases

The trend for the last 25 years is shown in Exhibit 25. Although agricultural emissions have increased over the past 25 years, they remain a small fraction of Alaska's total emissions — less than 1%. Emissions from agricultural equipment burning fuel are represented in the transportation category.

Exhibit 25 – Agriculture Emissions (MMT)

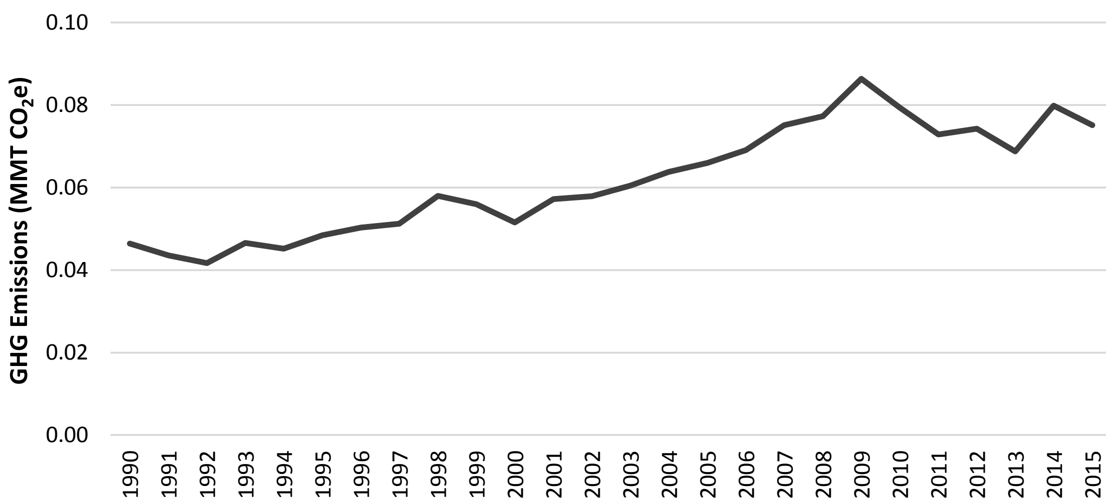


Exhibit 25: Agriculture emissions from 1990 to 2015 indicate a steady increase in emissions from this sector. However, the overall contribution is less than 1% of Alaska's total GHG emissions.

4.3.8 Emission Sinks – Land Use, Land-Use Change, and Forestry

Land use affects the ability of the natural environment to absorb (sequester) carbon, thus removing it from the atmosphere. When carbon is sequestered in a given area, the area is referred to as an "emission sink." The land use, land-use change, and forestry sector calculations take into account a variety of factors that affect the ability of the soil and plants to absorb and store carbon. These factors are relatively stable over time, with the exception of emissions from wildfires which can vary greatly in both frequency of event and acreage from year to year. Carbon dioxide from wildfires is excluded from the emission inventory on the basis that it will be absorbed by other plants as they grow to replace those that burned during the fire. However, in addition to releasing carbon dioxide, wildfires also produce nitrous oxide and methane, which are less readily incorporated into new plant growth. As outlined previously in Exhibit 1, methane contributes 25 times the global warming potential of CO_2 and nitrous oxide contributes 298 times the global warming potential of CO_2.

Carbon emissions and sequestration from forest management and land-use change is dependent upon the following factors: liming of agricultural soils, landfilled yard trimmings and food scraps, forest carbon flux, acreage of urban trees, forest fires, N_2O released from settlement soils, and urea fertilization. Carbon flux is defined as the amount of carbon exchanged between earth's carbon sinks.[28] (See Exhibit A6.) There is little to no effect from all of these factors except forest carbon flux and forest fires. Forest carbon flux includes aboveground and belowground biomass, dead wood, litter, and soil organic carbon. Forest carbon flux can also be represented by the total carbon storage.

Exhibit 26 shows the net emissions from emission sinks and wildfires as well as the number of acres burned in Alaska wildfires[28] for each year from 1990 to 2015. In most years, this sector sequesters carbon from the atmosphere. In years with abundant wildfires, as experienced in 2004, 2005 and 2015, this sector contributes additional emissions to the atmosphere (or sequesters a minimal amount of GHG in the case of 2015). A comparison of the two plot graphs reveals that the trend of emission sinks is directly related to the number of acres burned. Since the other factors taken into consideration for determining emission sinks are relatively stable from year to year, the number of acres burned is the key variable in this calculation. As the number of acres burned approaches five million, the emission sinks begin to emit GHG rather than sequester.

The calculations for total carbon sinks/flux continue to be updated to improve accuracy and consistency with the Inventory of U.S. Greenhouse Gas Emissions and Sinks. For example, until recently, the EPA's inventory for forest lands was limited to Southcentral coastal and Southeast Alaska forests and State wetland acreage was not included. The U.S. Forest Service Pacific Northwest Research Station's Forestry Sciences Laboratory in Alaska is updating the Forest Inventory Analysis (FIA) with Interior Alaska forest data in collaboration with the Alaska Department of Natural Resources, Division of Forestry and the National Aeronautics and Space Administration. This new project will inventory the remaining 15 percent of U.S. forested land not yet covered in the FIA. The EPA is also working with the U.S. Geological Survey to update the carbon storage ecosystems in Alaska. Due to these efforts, it is expected that the 2018 U.S. GHG inventory will be more representative of Alaska's carbon sinks.

This report does not include any consideration of permafrost thawing and subsequent GHG emissions. USGS has been tracking existing and projected GHG fluxes and carbon storage in Alaska ecosystems. As permafrost warms, frozen organic matter begins to thaw causing decomposition, mineralization, and the release of CO_2 and methane (CH_4) to the atmosphere. Storing 1700 petagrams[29] of organic carbon, Arctic and boreal permafrost soils hold more than twice the carbon that is in atmospheric CO_2.[30] Approximately 38% of boreal and Arctic Alaska is currently underlain by near-surface permafrost. Statistically modelled maps indicate that by 2100 Alaska permafrost will be reduced by an estimated 16 to 24%.[31] As permafrost thaws, the large amount of stored carbon and methane is released into the atmosphere.[32]

Regardless of increased GHG emissions from thawing permafrost, other factors indicate a growth in overall carbon sequestration. These factors include: longer growing seasons, changes in vegetation, increased nitrogen cycling, and the response to rising atmospheric CO_2.[32] Wildfire occurrence and acreage burned is expected to increase during the first half of the 21st century due to warming temperatures, low snowpack, and early snowmelt.[33] Should

[28] BLM: Alaska Fire History 1939-2015
[29] One petragram is equal to 10^{15} grams, or one gigaton.
[30] USGS: Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of Alaska
[31] USGS: USGS Projects Large Loss of Alaska Permafrost by 2100
[32] Alaska Department of Natural Resources: Alaska Geological Carbon Sequestration Potential Estimate
[33] USGS: Alaska Landscape Ecology

this be realized, an increase in CO_2 emissions will occur; however, the net primary productivity carbon flux from changes in vegetation and sequestration potential is expected to compensate for heightened wildfire emissions.[30] USGS continues to study Alaska's changing environment by monitoring ecological changes, analyzing the influences of forest fires on ecosystems, modelling Alaska vegetation, and monitoring and measuring how climate change impacts Alaska.

The scientific community continues to assess the impact of thawing permafrost on GHG emissions. The effects of permafrost degradation are still being determined through direct and indirect measurements of temperature[33] as well as through the analysis of topographical and subsurface landscape characteristics using mapping programs such as Landsat.[34] When a tool is developed to accurately measure and quantify the release of emissions on an annual basis they will be included in future reports.

Exhibit 26 – Emissions and Sinks from Land Use, Land-Use Change, and Forestry

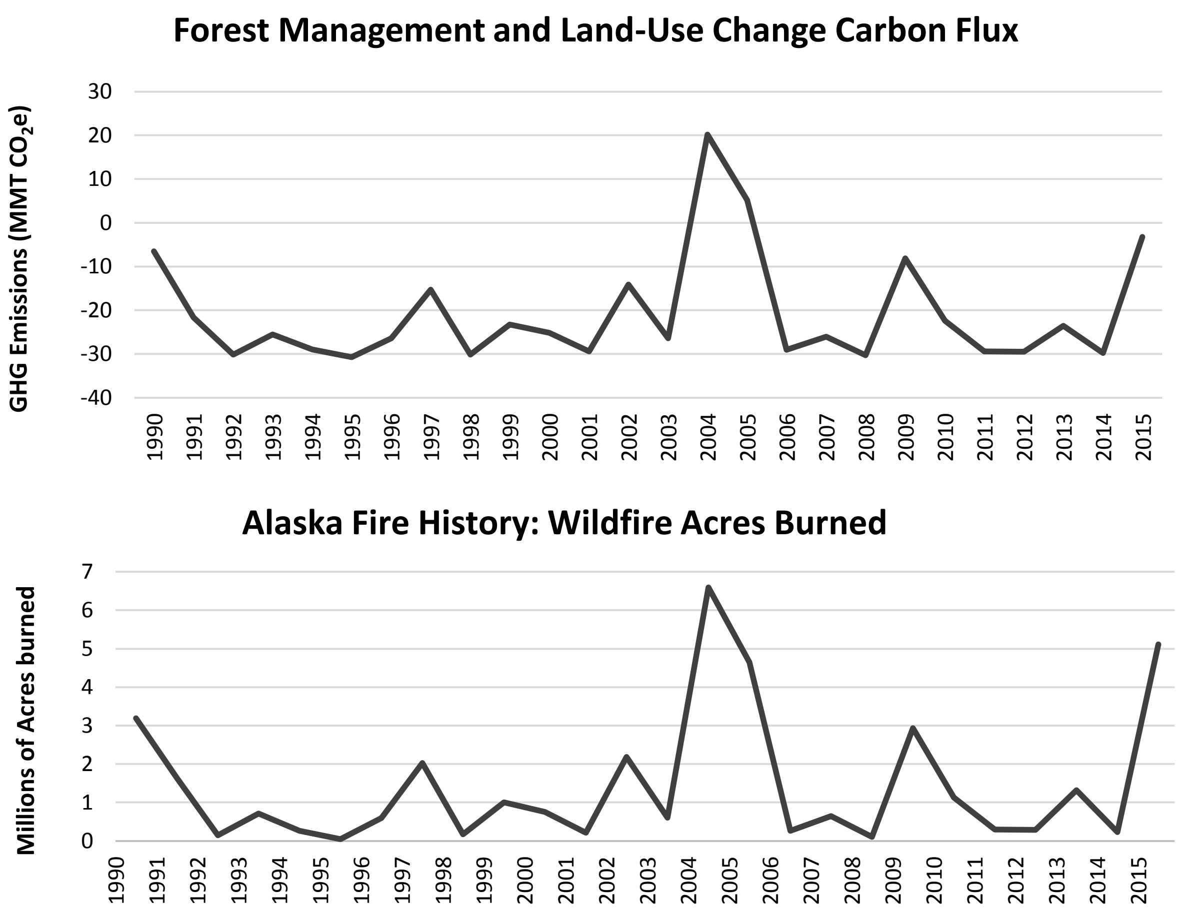


Exhibit 26: Emission sinks from 1990 to 2015 and the associated acres burned from wildfires: a negative value for emission sinks indicates carbon sequestration while a positive value indicates GHG emission.

[34] USGS: Alaska Permafrost Mapping with Landsat

5. Stationary Sources Inventory

During the initial inventory prepared by CCS for ADEC in 2007, emissions from sources identified in air permits were calculated to better understand the contributions of large stationary sources. This step was continued in the previous report for 2010 as well as the current report and supplement the overall inventory.

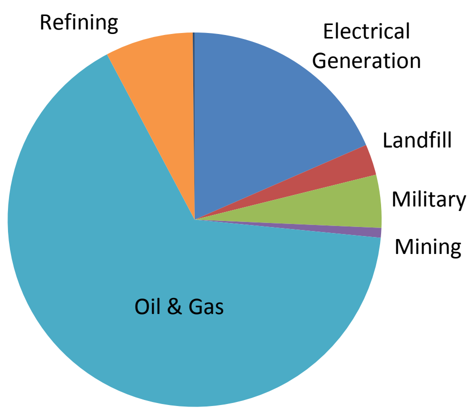
Alaska stationary sources inventory uses a "bottom up" approach, starting with fuel use for each facility to calculate the amount of GHG released by that stationary source. The inventory using the EPA's SIT is a "top down" approach, based on overall state fuel use and other activity data. These inputs are estimated at the state level, not aggregated from individual sources or locations.

Each approach has its own utility: *bottom up* for understanding the contributions of specific facilities and *top down* for aggregate emissions from all sources where collecting individual activity data would be impractical (especially when it comes to collecting data for smaller area and mobile sources). The stationary source inventory is not a direct "slice" of the overall inventory, nor can it be directly compared. Nonetheless, the stationary sources inventory provides additional insight into the emission contributions by Alaska's largest emitters.

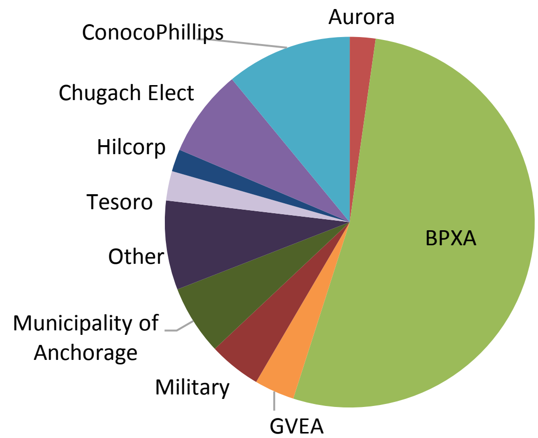
Since 2010 only facilities emitting more than 25,000 metric tons of CO_2e are required to report their GHG emissions to the EPA every year. During the first two years of this reporting period, 31 permitted organizations in Alaska reported emissions. By 2015, 33 reported GHG emission information. (See exhibits 27 and 28.)

Exhibit 27 – Stationary Source Emissions by Sector and Organization

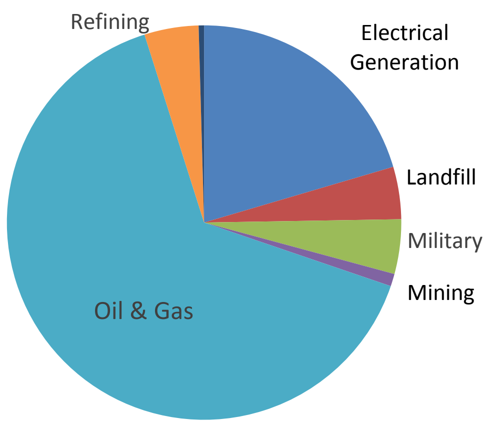
2010 Emissions by Sector



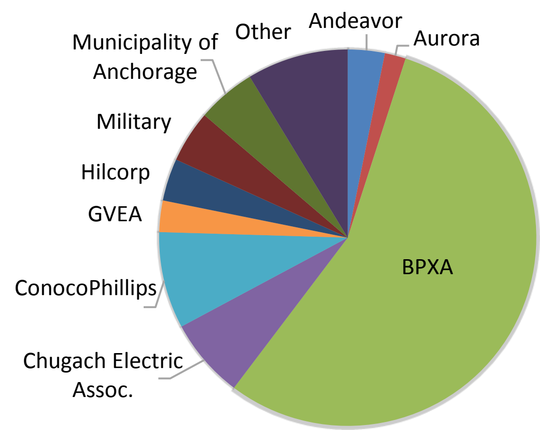
2010 Emissions by Organization



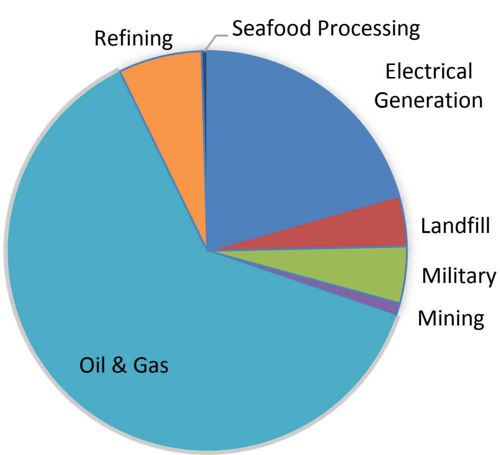
2014 Emissions by Sector



2014 Emissions by Organizations



2015 Emissions by Sector



2015 Emissions by Organization

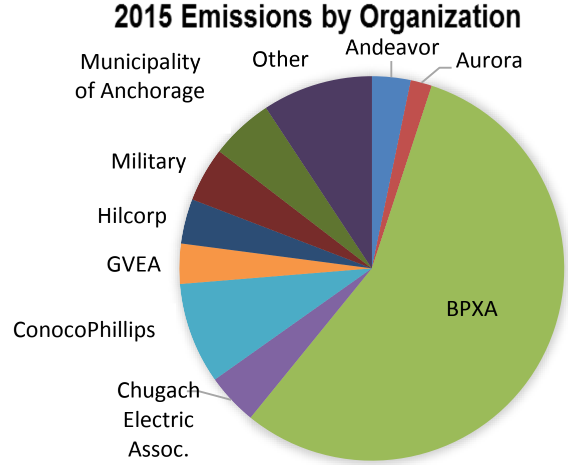


Exhibit 28 – Emissions Reported under GHGRR

			Emissions (MT CO_2e)	
Owners	**2010**	**2011**	**2014**	**2015**
Alaska Electric & Energy Cooperative	181,384	190,487	171,829	198,337
Alaska Electric Generation	--	--	27,364	29,834
Alaska Village Electric Cooperative, Inc.	--	--	31,571	31,204
Alyeska Pipeline Service Company	149,046	168,129	171,102	120,580
Andeavor (formerly Tesoro)	446,365	547,227	577,309	604,584
Aurora Energy	390,101	349,941	328,082	331,719
Barrow Utilities & Electric Cooperative	42,686	42,773	43,786	43,586
BPXA	9,208,430	11,082,731	10,085,020	10,364,556
Chugach Electric Association, Inc.	1,326,183	1,335,234	1,252,245	803,834
City of Unalaska	--	29,616	31,675	30,900
Coeur Alaska	--	25,730	32,330	33,288
ConocoPhillips	1,909,699	2,610,907	1,513,231	1,582,110
Copper Valley Electric Association	27,094	15,952	19,372	19,624
Fairbanks North Star Borough	53,676	55,377	58,709	59,751
Golden Valley Electric Association	608,868	579,671	492,347	625,492
Hecla Greens Creek Mine	--	27,017	3,865	5,025
Hilcorp Alaska LLC	338,339	357,265	661,183	699,843
Kenai Peninsula Borough	41,034	43,113	55,064	55,203
Koch Industries (Flint Hills Refinery)	233,134	218,888	62,695	1,328
Matanuska Electric Association	--	--	--	265,762
Matanuska-Susitna Borough	--	--	31,358	36,304
Military	793,928	892,693	815,091	851,766
Municipality of Anchorage	1,056,174	1,096,073	917,446	984,799
Petro Star/ASRC	53,046	119,681	143,461	92,897
Pioneer Natural Resources Alaska, Inc.	--	36,698	35,529	37,051
Providence Health System	--	--	33,023	36,283
Red Dog Mine	146,803	138,381	149,762	145,486
Trans-Alaska Pipeline System	110,153	122,442	180,239	189,284
Tanadgusix Corporation (TDX)	31,471	48,052	56,427	69,564
Trident Seafoods	--	--	52,025	50,712
University of Alaska Fairbanks	137,465	137,465	123,310	123,165
UniSea, Inc.	28,050	23,365	28,736	32,721
Waste Management, Inc.	--	14,658	40,570	13,580
Total	17,381,356	20,535,692	18,225,754	18,570,170

Exhibit 28: 2010 and 2011 are included for comparison to data published Greenhouse Gas Emission Inventory Report 1990-2010 (March 2015). Total values for 2010 and 2011 include companies that were not listed for 2014 and 2015 such as Aurora, ExxonMobil, Fairbanks Natural Gas, Marathon, and Union. The City of Unalaska did not report emissions in 2010.

6. Future Reporting

This appended GHG emissions inventory report follows the protocols set out by the initial GHG emission inventory report. ADEC was able to update Alaska's GHG inventory analysis as needed. This report identifies data sources and adjustments to the SIT to reflect the Alaska landscape.

In addition to updating the inventory with additional years of data, future work could include projections beyond the current year for specified scenarios or more in-depth quantification of emissions of specific sectors.

References

Alaska Department of Environmental Conservation. "Greenhouse Gas Emissions Inventory for Title V Sources in the State of Alaska." January 2008. http://www.climatechange.alaska.gov/docs/ghg_ei_rpt.pdf, accessed 10/14/2013.

Alaska Department of Environmental Conservation. "Alaska State Greenhouse Gas Emissions Inventory 1990-2010." March 2015. http://dec.alaska.gov/air/anpms/projects-reports/docs/GHG-Inventory-Report-2015.pdf.

Alaska Department of Natural Resources, Division of Forestry. Fire Statistics. http://forestry.alaska.gov/firestats/index, accessed 8/22/2017.

Alaska Department of Natural Resources. "Alaska Geologic Carbon Sequestration Potential Estimate: Screening Saline Basins and Refining Coal Estimates." May 2011. https://uc-ciee.org/downloads/2_Alaska_DNAR.pdf, accessed 8/28/2017.

Alaska Public Land Information Centers. "Permafrost and Climate Change." June 2011. https://www.alaskacenters.gov/sites/alaskacenters.gov/files/akro-im-permafrost-cc-brief-small_0.pdf, accessed 8/28/2017.

Alaska Energy Authority. Power Cost Equalization Program. PCE Statistical Report by Utilities. http://www.akenergyauthority.org/Portals/0/DNNGalleryPro/uploads/2017/2/28/FY16PCEstatistical.pdf.

Bureau of Land Management. "Alaska Fire History 1939-2015." https://fire.ak.blm.gov/content/aicc/Statistics%20Directory/Alaska%20Fire%20History.pdf, accessed 8/28/2017.

Center for Climate Strategies (CCS). "Alaska Greenhouse Gas Inventory and Reference Case Projections, 1900-2020." July 2007. http://dec.alaska.gov/air/doc/AK-GHG-EI-2007.pdf, accessed 10/14/2013.

Energy Information Administration (EIA). Energy-Related Carbon Dioxide Emissions at the State Level. http://www.eia.gov/environment/emissions/state/analysis/, accessed 8/23/2017.

Energy Information Administration (EIA). The State Energy Data System (SEDS) is the source of the U.S. Energy Information Administration's (EIA) comprehensive state energy statistics. https://www.eia.gov/state/seds/.

Energy Information Administration (EIA). "Alaska Natural Gas Gross Withdrawals and Production." https://www.eia.gov/dnav/ng/ng_prod_sum_dc_sak_mmcf_a.htm, accessed 9/1/2017.

Energy Information Administration (EIA). "Frequently Asked Questions: How much carbon dioxide is produced when different fuels are burned?" June 2017. https://www.eia.gov/tools/faqs/faq.php?id=73&t=11, accessed 11/3/2017.

Environmental Protection Agency. "Enteric Fermentation—Greenhouse Gases." 1998. https://www3.epa.gov/ttnchie1/ap42/ch14/final/c14s04.pdf, accessed 8/28/2017.

Environmental Protection Agency. Facility Level information on Greenhouse Gases Tool (FLIGHT). http://ghgdata.epa.gov/ghgp/main.do, accessed 8/17/2017.

Environmental Protection Agency. "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2015." April 2017. https://www.epa.gov/sites/production/files/2017-02/documents/2017_complete_report.pdf, accessed 8/28/2017.

Environmental Protection Agency. Sources of Greenhouse Gas Emissions. 2017. https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions, accessed 11/2/2017.

ICF International. State Inventory User Guides. January 2012. https://www.epa.gov/sites/production/files/2016-06/documents/government_operations_module_users_guide_6-6-16_for_508c.pdf.

Intergovernmental Panel on Climate Change. "Climate Change 2014 Synthesis Report Summary for Policymakers." https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_SPM.pdf, accessed 11/3/2017.

Kotchenruther, Robert A. "The effects of marine vessel fuel Sulphur regulations on ambient PM 2.5 at coastal and near coastal monitoring sites in the U.S." Atmospheric Environment 151. 2017, accessed 8/31/2017.

News Deeply. "Analysis: Arctic Air Traffic Emissions Are Likely to Grow." November 2016. https://www.newsdeeply.com/arctic/articles/2016/11/28/analysis-arctic-air-traffic-emissions-are-likely-to-grow, accessed 9/7/2017.

Port of Anchorage. "Southcentral Alaska Ports Freight and Fuel Analysis 2016 Update." https://www.portofanc.com/wp-content/uploads/McDowell_Group_2016_Report.pdf.

Sierra Research. "Alaska Aviation Emission Inventory (SR2005-06-02)." June 2005 Prepared for Western Regional Air Partnership. Accessed 9/7/2017.

Stanton, Elizabeth A., Frank Ackerman, Kristen Sheeran. "Greenhouse Gases and the American Lifestyle: Understanding Interstate Differences in Emissions." http://www.e3network.org/papers/NRDC_state_emissions_report.pdf.

Todd, Susan K., Jewkes, Holly Ann. "Wildland Fire in Alaska: A History of Organized Fire Suppression and Management in the Last Frontier." Agriculture and Forestry Experiment Station Bulletin No. 114. University of Alaska Fairbanks. March 2006. http://www.uaf.edu/files/snras/B114.pdf, accessed 8/30/2013.

United Nations Framework Convention on Climate Change: "Kyoto Protocol." http://unfccc.int/kyoto_protocol/items/2830.php, accessed 9/6/2017.

United States Department of Agriculture, National Agricultural Statistics Service, https://www.nass.usda.gov/Statistics_by_State/Alaska/Publications/50_Year_Highlights/index.php, accessed 8/17/2017.

United States Department of Agriculture and Forestry, Greenhouse Gas Inventory 1990-2013. https://www.usda.gov/oce/climate_change/AFGG_Inventory/USDA_GHG_Inventory_1990-2013_9_19_16_reduced.pdf.

United States Environmental Protection Agency, Climate and Energy Resources for State Local and Tribal Government, State Inventory and Projection Tool. https://19january2017snapshot.epa.gov/statelocalclimate/state-inventory-and-projection-tool_.html, accessed 8/17/2017.

United States Geological Survey. "Alaska Landscape Ecology: Vulnerabilities of coastal, boreal and tundra ecosystems to changing climate and wildfire regimes." November 2016. https://alaska.usgs.gov/science/program.php?pid=54, accessed 9/8/2017.

United States Geological Survey. "Alaska Permafrost Mapping with Landsat." https://eros.usgs.gov/doi-remote-sensing-activities/2016/alaska-permafrost-mapping-landsat, accessed 8/31/2017.

United States Geological Survey. "Baseline and Projected Future Carbon Storage and Greenhouse-Gas Fluxes in Ecosystems of Alaska." 2016. https://pubs.usgs.gov/pp/1826/pp1826.pdf, accessed 8/28/2017.

United States Geological Survey. "USGS Projects Large Loss of Alaskan Permafrost by 2100." November 2015. https://www.usgs.gov/news/usgs-projects-large-loss-alaska-permafrost-2100, accessed 9/6/2017.

United States Government Publishing Office. "Electronic Code of Federal Regulations." September 2017. https://www.ecfr.gov/cgi-bin/text-idx?SID=364a5fce8172ea4a303e405e64dfbce4&mc=true&node=ap40.21.98_19.1&rgn=div9, accessed 8/28/2017.

World Resources Institute. Climate Analysis Indicators Tool: Climate Data Explorer. http://cait.wri.org/, accessed 11/3/2017.

Appendix A – Description of Data

The EPA's State Inventory Tool (SIT) breaks down sectors into modules. Each of the following exhibits corresponds to one of the modules that make up the SIT. Within each spreadsheet module, there are multiple tabs in which data is input for different variables in a given sector. The exhibits identify the data used for each tab within each module. The last exhibit includes data sources used for the transportation diesel adjustments.

Exhibit A1 – Agriculture Module

Tab	Data Description
Enteric Fermentation	Defaults used
CH_4 from Manure management	Defaults used
N_2O from Manure Management	Data input in previous tab – defaults used
Ag Soils Plant Residues & Legumes	Barley and Oat production data input – http://www.nass.usda.gov/Statistics_by_State/Alaska/Publications/
Ag Soils Plant Fertilizers	Defaults used
Ag Soils Animals	Defaults used
Rice Cultivation	Defaults used – no rice cultivation in Alaska 2013 and 2014; rice data reported in database is deleted as it is considered an error
Ag Residue Burning CH_4	Barley production data input – http://www.nass.usda.gov/Statistics_by_State/Alaska/Publications/
Ag Residue Burning N_2O	Data input in previous tab – input barley production

Exhibit A2 – Carbon Dioxide from Fossil Fuel Combustion

Tab	Data Description
State Energy Data Table	Defaults used
Residential	Defaults used, also see transportation adjustments, Exhibit A12.
Commercial	Defaults used
Transportation	See transportation adjustments, Exhibit A12.
Electric Power	See transportation adjustments, Exhibit A12.
Bunker Fuels	Defaults used
Industrial	Defaults used

Exhibit A3 – Coal

Tab	Data Description
CH_4 from Coal Mining	Defaults used. 2015 data was entered manually and based on EIA the State data for year 2015
CH_4 from Abandoned Coal Mines	Did not use this portion of the module due to insufficient inputs. Because most coal mining in Alaska is done via surface mines, abandoned mines contribute a negligible amount of the state's greenhouse gas emissions.

Exhibit A4 – Electricity Consumption

Tab	Data Description
EF Selection	Defaults used
Residential Consumption	Defaults used
Commercial Consumption	Defaults used
Transportation Consumption	Defaults used
Industrial Consumption	Defaults used

Exhibit A5 – Industrial Processes

Tab	Data Description
MRR Data Input	Defaults used
Cement	"Minerals Yearbook," USGS, 2004, pg. 16.13-14, footnote 3. Same footnote in 2000-2010 yearbooks, but not 1993-1999 yearbooks. http://minerals.usgs.gov/minerals/pubs/commodity/cement/index.html#mcs Deleted 2004 default data. The value did not fit with the information presented in the Minerals Yearbooks.
Lime	Defaults used
Limestone	Defaults used
Soda Ash	Defaults used
Iron & Steel	Defaults used
Ammonia & Urea	Defaults used, except for years 2013 and 2014 for which ammonia production default data was removed because the sole production facility in Alaska was closed in 2007.
Nitric	Defaults used
Adipic	Defaults used
Aluminum	Defaults used

Tab	Data Description
HCFC-22	Defaults used
ODS (ozone depleting substances)	Defaults used, year 2015 was calculated manually based on population and emission per person from previous year.
Semiconductor	Defaults used
Electric Power	Defaults used
Magnesium	Defaults used

Exhibit A6 – Land Use, Land Use Change, Forestry

Tab	Data Description
Liming	Defaults used
Urea Fertilization	Defaults used
Settlement Soils	Defaults used
Urban Trees	Defaults used
Burning CH_4	1990 through 2005: "Wildland Fire in Alaska: A History of Organized Fire Suppression and Management in the Last Frontier." http://www.uaf.edu/files/snras/B114.pdf 2006 through 2015: AICC – annual fire reports. http://fire.ak.blm.gov/predsvcs/intel.php
Burning N_2O	Defaults used
Yard Trimmings	Defaults used
C-Flux	Defaults used

Exhibit A7 – Mobile Combustion

Tab	Data Description
Highway 1 –N_2O factors	Defaults
Highway 1 –CH_4 factors	Defaults
Highway 1 – VMT	1990-2010 State VMT totals distributed among vehicle types based on default distribution. http://www.dot.alaska.gov/stwdplng/transdata/traffic_maps_home.shtml 2011-2014 defaults. Year 2015 was recalculated proportionally to 2014 for all related categories with the exception that the default for total miles traveled was used.
Highway 2	Defaults
Highway 3	Defaults

Tab	Data Description
Aviation	Defaults, 2015 fuel consumption data was entered manually based on EIA data for the year.
Boats	Year 1990-2010 non-default data used for residual fuel oil and distillate fuel oil which include bunkering fuel for out of state and international travel. 2011-2013 Defaults. Residual fuel and distilled fuel consumption for years 2013-2015 was calculated based on gasoline consumption proportion to fuel oil consumption.
Locomotives	Defaults
Other	Defaults, 2015 assume to be as 2014, as data for 2015 was not available.
AFV	Defaults, 2015 assumed to be as 2014, as data for 2015 was not available.

Exhibit A8 – Natural Gas and Oil

Tab	Data Description
Natural Gas Production	Defaults, year 2015 wells data was added manually.
Natural Gas Transmission	No defaults provided. Used data from Pipeline and Hazardous Materials Safety Administration: http://phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=a872dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print https://hip.phmsa.dot.gov/analyticsSOAP/saw.dll?Portalpages
Natural Gas Distribution	No defaults provided. Use same source as Natural Gas Transmission. https://www.phmsa.dot.gov/pipeline/library/data-stats/distribution-transmission-and-gathering-lng-and-liquid-annual-data
Natural Gas Venting and Flaring	Defaults, year 2015 data was added manually.
Petroleum Systems	Defaults year 2015 data was added manually

Exhibit A9 – Solid Waste

Tab	Data Description
Flaring	Defaults
LFGTE	Defaults

Tab	Data Description
State Population	Defaults
State Disposal	Defaults
State MSW Combusted	Defaults
CO_2 Plastics	Defaults
CO_2 Syn Rubber	Defaults
CO_2 Syn Fibers	Defaults

Exhibit A10 – Stationary Combustion

Tab	Data Description
State Energy Data	Modified wood energy. Department of Natural Resources and Fairbanks North Star Borough show increase in wood harvest in the last few years. Beginning in 2005, DOE methodology changed. Determined rate of increase from 1990 to 2004 and extended to subsequent years.
Residential N_2O	Defaults
Residential CH_4	Defaults
Commercial N2O	Defaults
Commercial CH_4	Defaults
Electric Power N_2O	Defaults
Electric Power CH_4	Defaults
Industrial N_2O	Defaults
Industrial CH_4	Defaults

Exhibit A11 – Wastewater

Tab	Data Description
Municipal WW CH_4	Defaults
Municipal WW N_2O, direct	Defaults
Municipal WW N_2O, effluent	Defaults
Ind WW Fruit	Defaults
Ind WW Meat	Defaults
Ind WW Poultry	Defaults
Ind WW P&P	Defaults

Exhibit A12 – Data Sources for Rural Fuel Use Adjustments

Tab	Data Description
Rural population	Population tables provided by Alaska Department of Commerce, Community, and Economic Development for all communities in the state for 1990, 2000, 2010, and 2012. Population for intervening years was interpolated.
Power Cost Equalization (PCE) Fuel Use	PCE reports provided by Alaska Energy Authority
Power Cost Equalization Population	PCE reports provided by Alaska Energy Authority
Portion of BTUs for residential heat	http://apps1.eere.energy.gov/states/consumption.cfm/state=AK
Portion of residential heat from distillate	http://apps1.eere.energy.gov/states/residential.cfm/state=AK#sources

Appendix B – Sector Results for All Years

Unless otherwise noted in the table, all emissions are in million metric tons carbon dioxide equivalents (MMT CO_2e)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Electrical Generation	**3.05**	**2.91**	**2.74**	**2.77**	**2.79**	**2.87**	**3.00**	**3.21**	**3.38**	**3.48**	**3.62**	**3.70**	**3.73**	**3.43**	**3.64**	**3.69**	**3.96**	**3.74**	**3.73**	**3.65**	**3.51**	**3.64**	**3.61**	**3.11**	**3.35**	**3.38**
Coal	0.45	0.46	0.43	0.46	0.41	0.45	0.35	0.36	0.76	0.73	0.78	0.80	0.85	0.52	0.59	0.57	0.58	0.58	0.58	0.59	0.56	0.56	0.59	0.55	0.93	1.03
Natural Gas	1.87	1.67	1.54	1.49	1.54	1.59	1.66	1.78	1.53	1.62	1.89	1.74	1.70	1.83	2.01	2.10	2.31	2.19	2.31	2.03	2.12	2.25	2.14	1.81	1.70	1.61
Petroleum	0.73	0.78	0.77	0.82	0.83	0.84	0.99	1.07	1.09	1.13	0.95	1.17	1.18	1.07	1.04	1.02	1.07	0.96	0.84	1.02	0.83	0.83	0.88	0.76	0.73	0.75
Residential and Commercial	**4.36**	**4.45**	**4.82**	**4.82**	**4.86**	**4.95**	**5.22**	**4.99**	**5.15**	**5.46**	**5.27**	**5.09**	**4.62**	**4.54**	**4.94**	**4.90**	**5.35**	**4.97**	**5.03**	**4.68**	**5.02**	**4.60**	**4.51**	**4.07**	**3.90**	**4.25**
Coal	0.77	0.79	0.80	0.88	0.81	0.81	0.74	0.78	0.82	0.85	0.80	0.73	0.72	0.69	0.76	0.77	0.86	0.73	0.84	0.80	0.84	0.92	0.90	0.87	0.81	0.83
Natural Gas	1.80	1.83	1.90	1.79	1.89	2.15	2.29	2.23	2.27	2.41	2.32	1.75	1.70	1.82	1.95	1.86	2.09	2.06	2.06	1.95	1.85	2.13	2.22	2.02	1.90	1.97
Petroleum	1.78	1.81	2.11	2.14	2.14	1.97	2.18	1.96	2.05	2.20	2.14	2.59	2.17	2.01	2.21	2.24	2.38	2.16	2.11	1.91	2.30	1.52	1.38	1.15	1.16	1.43
Wood (CH. and N2O)	0.012	0.013	0.013	0.016	0.015	0.015	0.016	0.013	0.012	0.012	0.013	0.021	0.022	0.023	0.023	0.019	0.019	0.020	0.020	0.021	0.022	0.018	0.017	0.023	0.023	0.018
Industrial	**24.87**	**26.55**	**27.85**	**27.45**	**26.62**	**29.45**	**30.11**	**28.30**	**28.34**	**26.76**	**26.33**	**26.38**	**26.90**	**26.54**	**25.63**	**27.02**	**23.21**	**23.36**	**21.33**	**21.04**	**20.26**	**22.67**	**22.37**	**22.13**	**20.99**	**22.35**
Coal/Coal Mining	0.026	0.022	0.023	0.027	0.032	0.025	0.026	0.026	0.022	0.026	0.026	0.025	0.019	0.017	0.024	0.024	0.025	0.023	0.022	0.034	0.038	0.045	0.038	0.029	0.028	0.022
Natural Gas/ Natural Gas Industry	13.95	16.17	17.22	17.44	16.36	19.27	19.56	18.45	19.07	18.08	18.70	18.22	18.77	18.30	17.66	19.13	15.70	15.69	14.28	14.43	14.12	14.00	14.44	14.24	14.30	14.94
Petroleum/Oil Industry	10.90	10.36	10.61	9.99	10.23	10.16	10.52	9.82	9.25	8.65	7.60	8.14	8.11	8.22	7.95	7.86	7.49	7.65	7.02	6.57	6.10	8.63	7.89	7.86	6.66	7.39
Transportation	**11.18**	**11.03**	**9.97**	**9.51**	**10.00**	**10.60**	**11.10**	**12.28**	**12.61**	**13.40**	**14.31**	**13.42**	**14.09**	**15.16**	**16.80**	**17.37**	**17.37**	**16.35**	**13.89**	**11.64**	**13.36**	**11.41**	**11.10**	**10.70**	**9.90**	**10.42**
Aviation	7.21	7.09	6.11	6.15	6.64	7.06	7.69	8.79	9.03	9.89	10.78	10.03	10.46	11.26	12.74	13.18	13.09	11.98	9.82	7.75	9.37	8.59	8.23	7.80	6.98	7.45
Marine	1.59	1.53	1.59	1.07	0.92	1.14	0.99	1.12	1.05	0.89	0.87	0.75	0.93	1.16	1.29	1.36	1.48	1.46	1.24	0.98	1.13	0.08	0.07	0.07	0.08	0.08
On-Road	2.33	2.36	2.23	2.25	2.40	2.36	2.39	2.33	2.48	2.59	2.62	2.60	2.65	2.66	2.70	2.75	2.73	2.84	2.77	2.85	2.81	2.67	2.72	2.76	2.79	2.83
Rail and Other	0.059	0.051	0.049	0.040	0.034	0.040	0.037	0.045	0.048	0.038	0.043	0.052	0.056	0.074	0.074	0.082	0.078	0.067	0.058	0.056	0.060	0.070	0.070	0.060	0.057	0.054
Industrial Processes	**1.10**	**1.23**	**1.35**	**1.33**	**1.42**	**1.40**	**1.31**	**1.25**	**1.28**	**1.29**	**1.17**	**1.00**	**1.16**	**1.06**	**1.15**	**1.14**	**0.48**	**0.47**	**0.26**	**0.27**	**0.29**	**0.35**	**0.38**	**0.39**	**0.40**	**0.40**
Ammonia Production	1.050	1.040	1.129	1.080	1.129	1.070	1.135	1.078	1.104	1.085	0.966	0.783	0.924	0.815	0.893	0.885	0.216	0.214	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Urea Production	0.001	0.001	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Limestone and Dolomite Use	0.000	0.000	0.000	0.000	0.000	0.012	0.006	0.012	0.011	0.013	0.010	0.008	0.008	0.008	0.007	0.007	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cement Manufacture	0.000	0.139	0.173	0.193	0.214	0.207	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ODS Substitutes (HFC, PFC)	0.001	0.001	0.004	0.014	0.032	0.070	0.097	0.123	0.140	0.157	0.169	0.180	0.194	0.204	0.216	0.224	0.231	0.232	0.234	0.242	0.264	0.337	0.350	0.360	0.373	0.373
Soda Ash (CO2)	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Electric Power T&D	0.042	0.039	0.040	0.038	0.036	0.033	0.030	0.028	0.024	0.025	0.023	0.024	0.023	0.022	0.023	0.023	0.022	0.020	0.021	0.021	0.020	0.011	0.023	0.023	0.023	0.023
Waste	**0.32**	**0.35**	**0.31**	**0.32**	**0.33**	**0.34**	**0.35**	**0.36**	**0.38**	**0.39**	**0.40**	**0.42**	**0.43**	**0.43**	**0.43**	**0.45**	**0.47**	**0.49**	**0.50**	**0.52**	**0.53**	**0.59**	**0.59**	**0.42**	**0.38**	**0.43**
Solid Waste Management	0.27	0.30	0.26	0.27	0.28	0.28	0.29	0.31	0.32	0.33	0.34	0.35	0.37	0.37	0.37	0.39	0.40	0.42	0.44	0.45	0.46	0.54	0.53	0.36	0.32	0.37
Wastewater Management	0.052	0.054	0.056	0.057	0.057	0.057	0.058	0.058	0.059	0.060	0.060	0.061	0.062	0.063	0.064	0.065	0.066	0.066	0.067	0.068	0.069	0.059	0.059	0.060	0.060	0.060
Agriculture	**0.05**	**0.04**	**0.04**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.06**	**0.06**	**0.05**	**0.06**	**0.06**	**0.06**	**0.06**	**0.07**	**0.07**	**0.08**	**0.08**	**0.09**	**0.08**	**0.07**	**0.07**	**0.07**	**0.08**	**0.08**
Agricultural Soils	0.030	0.028	0.026	0.031	0.026	0.028	0.029	0.027	0.030	0.026	0.026	0.030	0.028	0.030	0.030	0.031	0.034	0.038	0.037	0.040	0.033	0.030	0.031	0.029	0.034	0.028
Enteric Fermentation	0.015	0.014	0.015	0.015	0.017	0.018	0.019	0.021	0.022	0.023	0.019	0.020	0.021	0.022	0.024	0.026	0.028	0.029	0.026	0.025	0.025	0.028	0.028	0.026	0.023	0.025
Manure Management	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.003	0.006	0.007	0.007	0.008	0.008	0.009	0.010	0.009	0.008	0.008	0.014	0.021	0.021	0.015	0.015	0.014	0.023	0.023
Gross Emissions	**44.93**	**46.55**	**47.09**	**46.25**	**46.07**	**49.67**	**51.13**	**50.43**	**51.21**	**50.83**	**51.16**	**50.07**	**50.98**	**51.21**	**52.66**	**54.64**	**50.92**	**49.45**	**44.81**	**41.88**	**43.04**	**43.34**	**42.63**	**40.88**	**39.01**	**41.30**
Emission Sinks	-6.50	-21.65	-30.17	-25.53	-29.01	-30.73	-26.41	-15.30	-30.15	-23.26	-25.20	-29.40	-14.09	-26.41	20.20	5.20	-29.04	-26.06	-30.31	-8.15	-22.37	-29.45	-29.49	-23.57	-29.80	-1.74
Net Emissions	**38.43**	**24.90**	**16.93**	**20.72**	**17.06**	**18.94**	**24.72**	**35.13**	**21.07**	**27.57**	**25.96**	**20.67**	**36.89**	**24.80**	**72.86**	**59.84**	**21.87**	**23.39**	**14.50**	**33.74**	**20.67**	**13.89**	**13.14**	**17.31**	**9.20**	**39.56**
Gross Increase Since 1990 (MMT)	**0.00**	**1.62**	**2.16**	**1.32**	**1.14**	**4.74**	**6.20**	**5.50**	**6.28**	**5.90**	**6.23**	**5.14**	**6.05**	**6.28**	**7.73**	**9.71**	**5.99**	**4.52**	**-0.12**	**-3.05**	**-1.89**	**-1.59**	**-2.30**	**-4.05**	**-5.92**	**-3.63**
Gross Increase Since 1990 (%)	**0%**	**4%**	**5%**	**3%**	**3%**	**11%**	**14%**	**12%**	**14%**	**13%**	**14%**	**11%**	**13%**	**14%**	**17%**	**22%**	**13%**	**10%**	**0%**	**-7%**	**-4%**	**-4%**	**-5%**	**-9%**	**-13%**	**-8%**
Net Increase Since 1990 (MMT)	**0.00**	**-13.53**	**-21.50**	**-17.71**	**-21.37**	**-19.50**	**-13.71**	**-3.30**	**-17.37**	**-10.86**	**-12.47**	**-17.76**	**-1.54**	**-13.63**	**34.43**	**21.40**	**-16.56**	**-15.04**	**-23.93**	**-4.70**	**-17.76**	**-24.54**	**-25.30**	**-21.12**	**-29.23**	**1.13**
Net Increase Since 1990 (%)	**0%**	**-35%**	**-56%**	**-46%**	**-56%**	**-51%**	**-36%**	**-9%**	**-45%**	**-28%**	**-32%**	**-46%**	**-4%**	**-35%**	**90%**	**56%**	**-43%**	**-39%**	**-62%**	**-12%**	**-46%**	**-64%**	**-66%**	**-55%**	**-76%**	**3%**
Emissions Per Person (MT)	**81.69**	**81.81**	**80.27**	**77.49**	**76.71**	**82.57**	**84.49**	**82.73**	**82.99**	**81.72**	**81.61**	**79.14**	**79.44**	**78.85**	**79.83**	**81.90**	**75.48**	**72.71**	**65.24**	**60.02**	**60.60**	**59.96**	**58.29**	**55.56**	**52.94**	**56.02**
EIA Estimate											**44.32**	**43.40**	**43.56**	**43.51**	**46.76**	**48.06**	**45.79**	**44.12**	**39.46**	**37.92**	**38.73**	**38.50**	**38.00**	**36.20**	**35.10**	**36.08**
EIA Per Capita (MT)											**70.60**	**68.51**	**67.86**	**67.18**	**70.93**	**72.05**	**67.81**	**64.89**	**57.56**	**54.58**	**54.63**	**53.26**	**51.97**	**49.19**	**47.64**	**48.95**