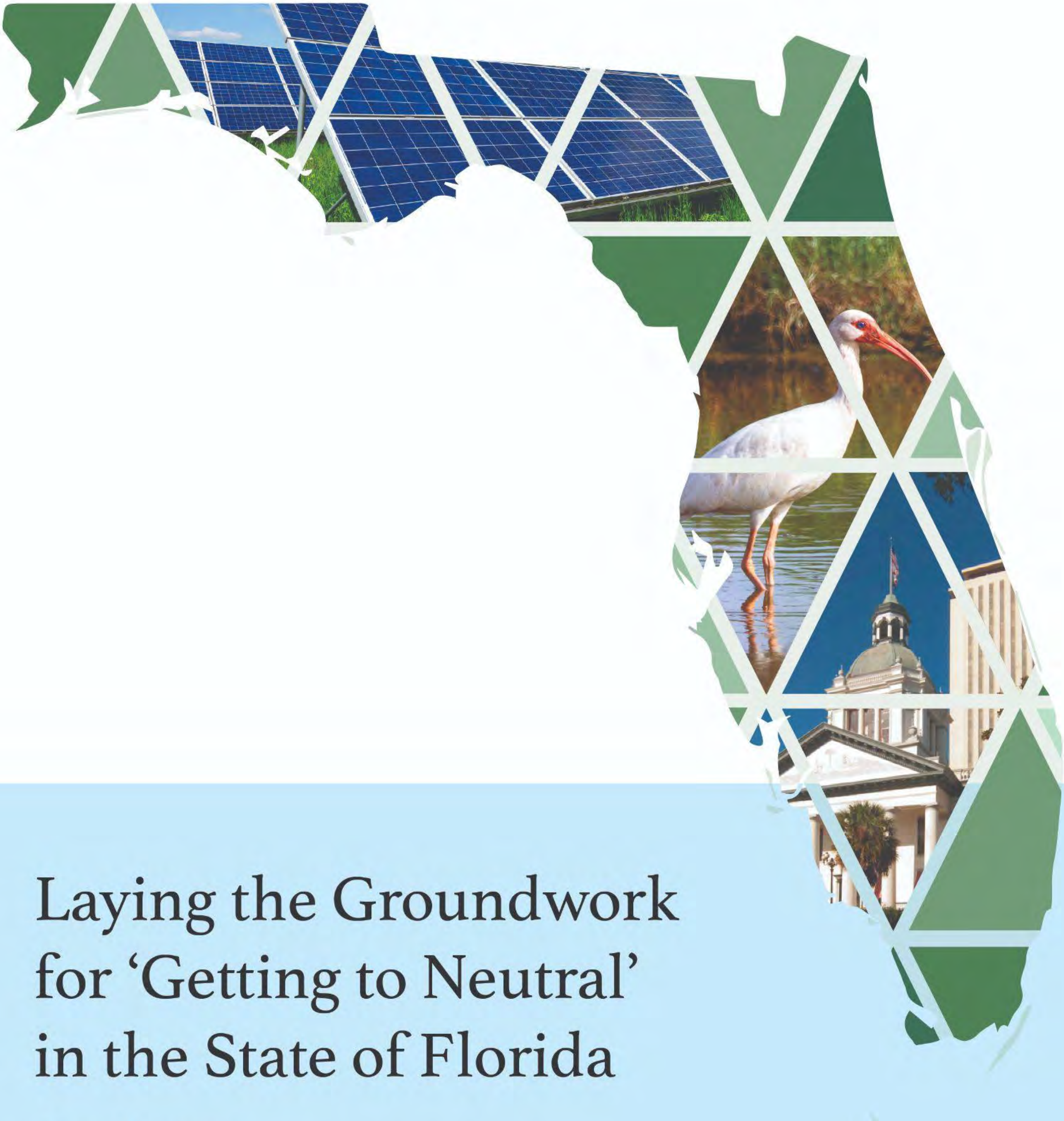

Laying the Groundwork for 'Getting to Neutral' in the State of Florida

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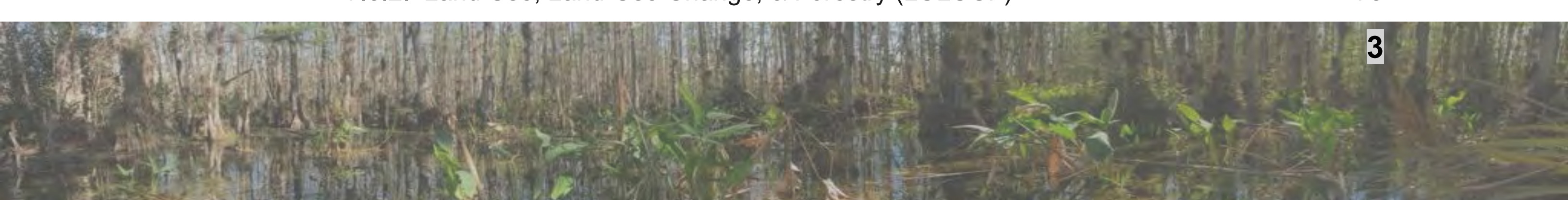

Laying the Groundwork for 'Getting to Neutral' in the State of Florida

EXECUTIVE SUMMARY

This report presents a state-level greenhouse gas (GHG) emissions inventory and lays the groundwork for a net-zero action planning effort for Florida. It has been prepared by a group of faculty and students from different member universities of the Florida Climate Institute (FCI). This special collaboration was initiated to conduct the project "*Laying the Groundwork for Getting to Neutral in the State of Florida*". The GHG emissions inventory and projections consider both emissions and removals across Intergovernmental Panel on Climate Change (IPCC) categories and subcategories. Calculations were conducted using the US Environmental Protection Agency's (EPA) State Inventory Tool (SIT) and the State Projection Tool, supplemented by information and IPCC methodologies not available in the EPA tools.

This report summarizes historical emissions from 1990 to 2018 and discusses emissions for the year 2018 in some detail, which is considered the current reference year and the starting year for projections. The net-zero action planning component of the report identifies multiple actions across GHG sectors, and their potential emissions reductions, to achieve clean electricity by 2035 and net-zero emissions by 2050.

In the GHG inventory, the year 2018 was selected as the reference year due to the fact that there is a nearly complete dataset in the various sources and in the SIT. The report also compares current emissions against 2005 baseline values that were estimated in a previous state-level inventory.

The emissions are estimated based on ten SIT modules that consider the various sources of emissions and removals (E/R), and a number of additional E/R categories that were not included in the SIT modules. These include:

- Energy generation within the state
    - Carbon dioxide (CO_2) emissions from fossil fuel combustion in all sectors
    - Methane (CH_4) and nitrous oxide (N_2O) emissions from stationary combustion at residential, commercial, industrial, and electric power facilities
    - CH_4 and N_2O emissions from transportation use (mobile combustion)
    - CH_4 emissions from coal extraction and processing activities
    - CH_4 and CO_2 emissions from natural gas and oil extraction and processing activities
- Industrial process – includes CO_2, N_2O, and fluorinated carbon emissions
- Agricultural activities – includes CO_2, N_2O, and CH_4 emissions
- Land-Use, Land-Use Change, and Forestry (LULUCF)
    - Forest management – includes CH_4 and N_2O emissions, and carbon removals
    - Coastal wetlands - includes CO_2 and CH_4 removals
- Solid and liquid waste management - includes CO_2, N_2O, and CH_4 emissions

1. Summary of Findings – Total and Net Emissions

Baseline Inventory (1990-2018)

Florida's total historical gross and net GHG emissions are shown in Figure ES-1. Total GHG emissions and removals of each sector, activity, and cumulative total, by 5-year intervals plus the baseline year of 2018, can be found in Table ES-1. A breakdown of these emissions by gas type and gas-specific unit are presented in Table ES-2.

The total *gross* GHG emissions for the state of Florida in 2018 were estimated to be 304.8 million metric tons of carbon dioxide equivalent (MMT CO_2e). The 2018 *net* emissions were estimated at 292.4 MMT CO_2e, with sinks being factored in. The corresponding emission estimates for 2005 were a *gross* of 297.6 and a *net* of 293.7 MMT CO_2e, respectively. The total gross GHG emissions in 2018 were higher compared to the 2005 baseline, however, the net emissions were similar. This is attributed to the higher GHG removals from forest management activities in 2018 (-12.4 MMT CO_2e) and from coastal wetlands (-2.4 MMT CO_2e).

Although the total GHG emissions showed an increasing trend from 2005 to 2018, GHG emissions intensity [emissions per capita and emissions per million USD ($) Gross State Product (GSP)] showed a general declining trend given the increase in population in that period (see Figure ES-2). Total per capita gross emissions in 2005 and 2018 were 16.8 and 14.4 MT CO_2e, respectively and the corresponding emissions per million $ GSP were 427.1 and 293.3 MT CO_2e.

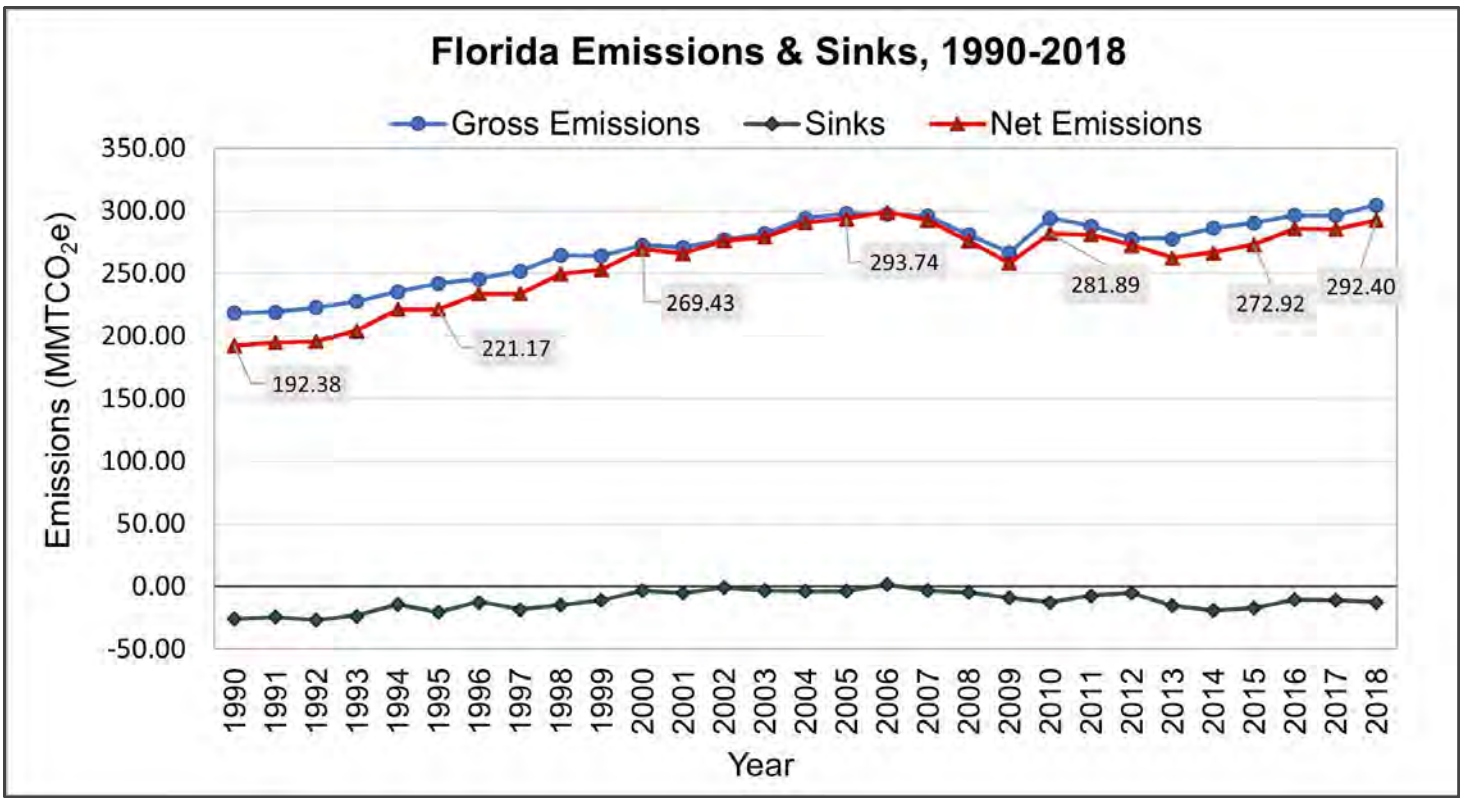

Figure ES-1: Total historical GHG gross emissions, sinks, and net emissions of Florida.

MMT CO_2e	Source of emissions	1990	1995	2000	2005	2010	2015	2018
Energy		**193.80**	**212.82**	**241.49**	**263.65**	**252.62**	**245.64**	**251.34**
Energy Combustion	CO_2 from Fossil Fuel Combustion (Appendix A)	188.64	207.81	236.63	258.27	248.26	242.01	247.72
	Stationary Combustion (Appendix B)	1.05	1.97	0.97	0.92	0.99	0.70	0.58
	Mobile Combustion (Transportation) (Appendix C)	2.63	3.15	3.22	2.72	1.59	1.15	1.09
Fossil Fuel Extraction & Distribution Industry	Coal Mining (Appendix D)	0	0	0	0	0	0	0
	Natural Gas & Oil Systems (Appendix E)	1.49	0.89	0.67	1.73	1.78	1.78	1.95
Industrial Processes & Product Use (Appendix F) (including emissions from Phosphoric acid production)		**5.36**	**7.16**	**10.15**	**12.60**	**17.95**	**19.4**	**27.05**
Agriculture (Appendix G)		**9.13**	**9.78**	**9.57**	**9.30**	**9.38**	**9.63**	**9.42**
	Enteric Fermentation	3.50	3.80	3.39	3.25	3.25	3.21	3.11
	Manure Management	0.96	0.98	1.00	0.89	0.77	0.83	0.75
	Agricultural Soil Management	4.09	4.52	4.74	4.84	4.97	5.23	5.30
	Rice Cultivation	0.08	0.15	0.12	0.07	0.08	0.09	0.09
	Liming	0.42	0.24	0.22	0.21	0.24	0.16	0.06
	Urea	0	0.01	0.01	0.01	0.01	0.01	0.01
	Burning of Agricultural Crop Waste	0.08	0.08	0.08	0.03	0.07	0.09	0.09
LULUCF* (Appendix H) (including wetlands)		**-25.81**	**-20.58**	**-3.19**	**-3.87**	**-12.59**	**-17.28**	**-12.37**
Waste		**9.89**	**11.98**	**11.42**	**12.09**	**14.53**	**15.54**	**16.97**
	Municipal Solid Waste (Appendix I)	8.36	10.26	9.46	9.99	12.36	13.23	14.56
	Wastewater (Appendix J)	1.53	1.72	1.95	2.07	2.16	2.31	2.40
Gross Emissions		**218.18**	**241.74**	**272.62**	**297.60**	**294.48**	**290.21**	**304.77**
Emission Sinks		**-25.81**	**-20.58**	**-3.19**	**-3.87**	**-12.59**	**-17.28**	**-12.37**
Net Emissions		**192.38**	**221.17**	**269.43**	**293.74**	**281.89**	**272.92**	**292.40**
Indirect CO_2 from Electricity Consumption**(Appendix K)		93.3	108.87	134.79	146.76	136.74	119.37	107.28

Table ES-1: Summary of emissions and carbon capture per sector, from 1990-2018 in MMT CO_2e.

** LULUCF: "Land-Use, Land-Use Change, and Forestry"*

****** *This is estimated as an alternative to emissions from fossil fuel combustion in the electric power sector. However, it is not included in the total emission to avoid double counting.*

EMISSIONS BY GAS TYPE	*1990*	*1995*	*2000*	*2005*	*2010*	*2015*	*2018*
Total (MMT CO_2e)	**192.38**	**221.17**	**269.43**	**293.74**	**281.89**	**272.92**	**292.40**
Total Carbon Dioxide (MMT **CO_2**)	194.40	214.75	242.82	265.09	254.05	248.57	255.81
Total Methane (MMT **CO_2e**)	16.05	21.90	21.14	22.97	26.58	27.17	27.27
Total Methane (MMT **CH_4**)	0.64	0.88	0.85	0.92	1.06	1.09	1.09
Total Nitrous Oxide (MMT **CO_2e**)	7.71	9.92	10.19	9.85	13.80	12.55	19.30
Total Nitrous Oxide (MMT **N_2O**)	0.026	0.033	0.034	0.033	0.046	0.042	0.065
Total HFC, PFC, SF_6, AND NF_3 (MMT **CO_2e**)	1.26	2.82	5.47	7.04	9.45	10.72	11.20

Table ES-2: Historical emissions for all sectors by gas type and gas-specific unit.

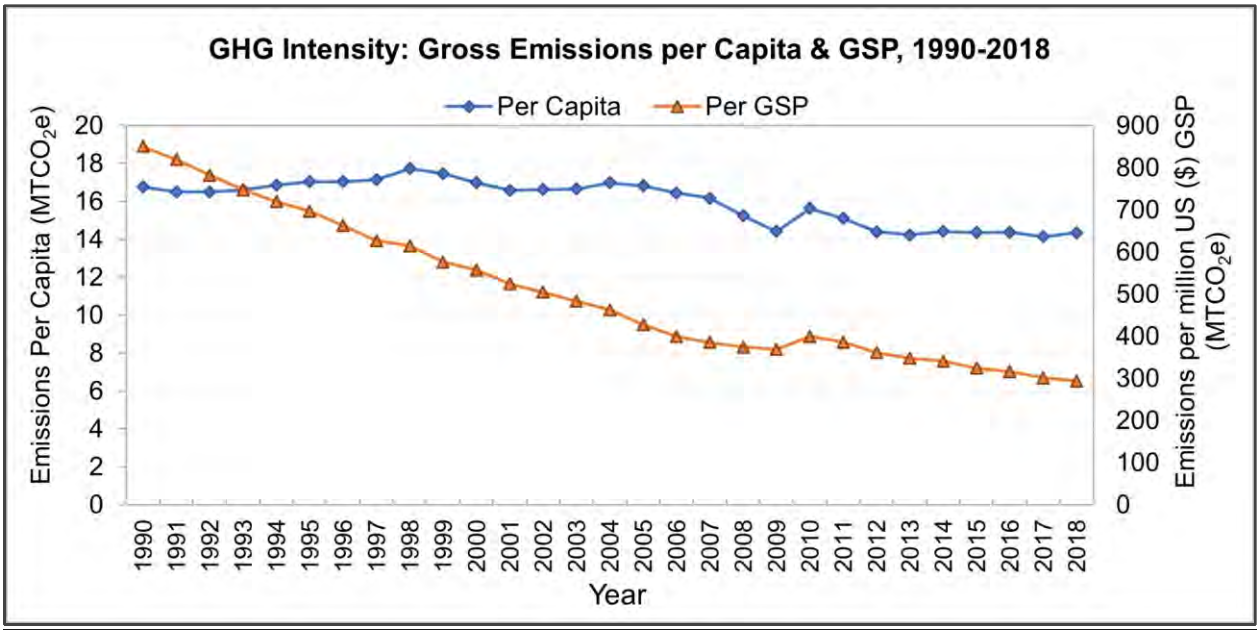

Figure ES-2: Historical GHG emissions intensity normalized with respect to per population and economic activity [emissions per capita and emissions per million USD ($) Gross State Product (GSP)].

In 2018, the highest GHG emissions came from the energy sector (see Figure ES-3), where transportation and electric power generation (at energy utilities as well as residential, commercial, and industrial facilities) are the largest contributors. Total GHG emissions from the energy sector for 2018 amounted to 251.3 MMT CO_2e, roughly 82.5% of the state's total gross emissions. The values for the transportation and electric power generation components of that 2018 sector total are 128.6 MMT CO_2e (~42% of state gross emissions) and 122.8 MMT CO_2e (~40%), respectively.

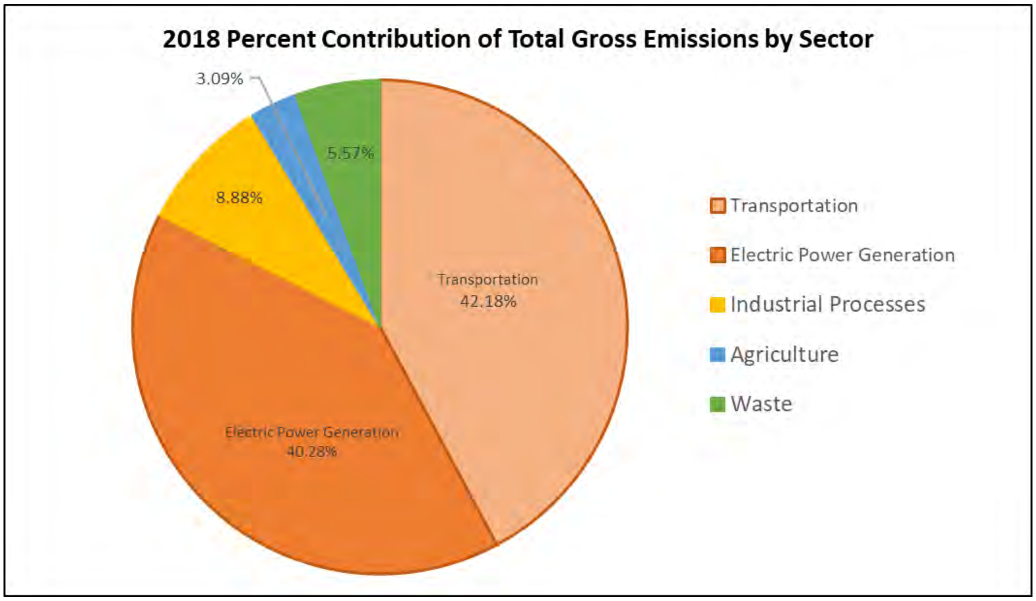

Figure ES-3: Sector-wise emission contributions of 2018 gross total. Total energy sector emissions is the sum of the transportation and electric power generation emissions, which accounts for 82.5% of the total GHG emissions for the state. *Note*: LULUCF values are not shown because they have a negative value representing the net removal of emissions.

The main fuel types for energy generation in Florida are petroleum, coal, and natural gas. As seen in Figure ES-4, the largest current and historical GHG emissions are generated from petroleum use, with emissions ranging from 110.2 to 153.9 MMT CO_2e across the entire time series. Coal was the second-largest emitter until 2010 when natural gas emissions surpassed those of coal. Petroleum is expected to be the largest contributor in the future although it has shown some decline.

In addition to estimating GHG emissions from fuel combustion for electric power generation, emissions from electricity consumption were also calculated. Total GHG emissions from electricity consumption in 2005 and 2018 were 146.8 and 107.3 MMT CO_2e, respectively. There was a reduction of about 27%, which may be attributed to the use of energy-efficient systems. This is quite encouraging and useful to identify additional strategies to reduce emissions based on practical actions on the consumer side.

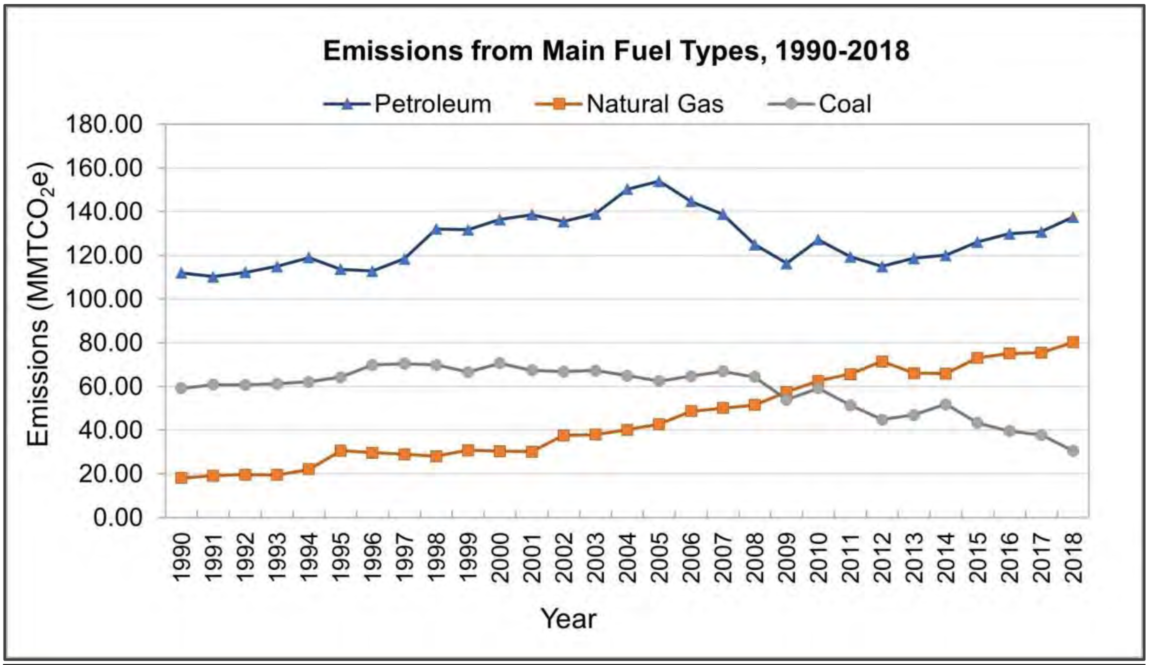

Figure ES-4: Historical GHG emissions of the main fuel types in Florida.

2. Emission Projections (2019-2050)

This section presents GHG emissions projections from 2019 to 2050. The GHG emissions are estimated using the EPA State Projection Tool. It uses data from the baseline inventory of 1990-2018. The projection considers three scenarios, described below.

I. *Business-As-Usual* scenario with current and planned State actions (Reference scenario). This scenario considers existing actions of the State such as reducing electric power generation by coal and other non-renewable sources, increasing EV cars.

II. *Clean Electricity Generation by 2035* where all the electric power for Florida comes from clean fuel sources (nuclear and renewable energy sources such as solar and wind). This scenario assumes the implementation of the Biden Administration's plan to achieve the generation of electricity using clean sources of energy by 2035. This assumes that all GHG emitting sources of energy for electric power generation will retire by 2035.

III. *Net-Zero Emissions by 2050* based on reductions of GHG emissions and increased GHG capture. This scenario includes GHG reduction actions in all sectors. It includes the actions considered for the clean electricity scenario, efficiency in electricity usage, incentivizing Electric Vehicle (EV) usage and transforming transportation with a State-wide network of solar EV charging stations, increasing the use of landfill gas (methane) for electric power generation, replacing carbon-intensive agriculture by less carbon-intensive practices, and other actions in transportation and industrial sectors. This scenario also includes actions that will increase carbon capture in urban lands through revegetation and afforestation and restoring coastal wetlands.

The GHG emissions projections under the three scenarios are presented in Table ES-3, ES-4, and ES-5. The results show that plans and actions that are already happening in the energy sector such as increasing renewable sources for power generation and electric vehicles will reduce future GHG emissions under the Business-As-Usual scenario (Scenario I). Additional measures in increasing renewable sources for the electric power generation under the clean electricity by 2035 scenario (Scenario II) will result in about 26% more GHG reduction compared to scenario 1. For the net-zero scenario (Scenario III), GHG emission reductions in all sectors (energy, industrial processes, agriculture, and waste), as well as measures for GHG removals in LULUCF, can help Florida go beyond net-zero by 2050.

MMT CO_2e	**1990**	**2000**	**2010**	**2020**	**2030**	**2035**	**2040**	**2050**
Energy	193.88	241.6	252.72	237.85	209.77	201.67	201.1	206.7
CO_2 from Fossil Fuel Combustion	188.64	236.63	248.26	230.65	202.36	194.3	193.73	199.32
Stationary Combustion	1.12	1.08	1.09	0.47	0.38	0.35	0.35	0.36
Mobile Combustion	2.63	3.22	1.59	1.63	1.56	1.56	1.56	1.56
Coal Mining & Abandoned Mines	-	-	-	-	-	-	-	-
Natural Gas and Oil Systems	1.49	0.67	1.78	5.1	5.47	5.47	5.47	5.47
Industrial Processes	4.09	9.04	17.2	27.27	39.49	41.62	43.59	47.26
Agriculture	4.21	4.12	3.72	6.78	6.36	6.18	6	5.66
Enteric Fermentation	-	-	-	2.78	2.63	2.56	2.48	2.33
Manure Management	-	-	-	0.59	0.6	0.6	0.61	0.62
Rice Cultivation	0.08	0.12	0.08	0.12	0.12	0.12	0.12	0.12
Agricultural Soil Management	3.63	3.68	3.32	3.13	2.92	2.82	2.71	2.5
Liming	0.42	0.22	0.24	0.07	-	-	-	-
Urea	0	0.01	0.01	0.01	0	0	0	0
Burning of Agricultural Crop Waste	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.08
Waste	9.83	10.85	14.09	16.28	19.17	20.52	21.64	23.35
Municipal Solid Waste	8.36	9.01	11.99	13.84	16.41	17.6	18.57	19.96
Wastewater	1.47	1.84	2.1	2.44	2.76	2.91	3.07	3.39
Total emissions	**212.01**	**265.62**	**287.73**	**288.18**	**274.78**	**269.99**	**272.33**	**282.98**
Total removals	**25.81**	**3.2**	**12.59**	**12.34**	**12.34**	**12.34**	**12.34**	**12.34**
Net emissions	**186.2**	**253.42**	**275.14**	**275.84**	**262.44**	**257.65**	**259.99**	**270.64**

Table ES-3: Summary of total and net GHG emissions from 1990-2050 for reference scenario I – Business-As-Usual.

MMTCO2e	1990	2000	2010	2020	2030	2035	2040	2050
Energy	193.88	241.6	252.72	232.9	155.49	131	130.48	135.69
CO_2 from Fossil Fuel Combustion	188.64	236.63	248.26	225.71	148.16	123.7	123.17	128.38
Stationary Combustion	1.12	1.08	1.09	0.46	0.3	0.27	0.28	0.29
Mobile Combustion	2.63	3.22	1.59	1.63	1.56	1.56	1.56	1.56
Coal Mining & Abandoned Mines	-	-	-	-	-	-	-	-
Natural Gas and Oil Systems	1.49	0.67	1.78	5.1	5.47	5.47	5.47	5.47
Industrial Processes	4.09	9.04	17.2	27.27	39.49	41.62	43.59	47.26
Agriculture	4.21	4.12	3.72	6.78	6.36	6.18	6	5.66
Enteric Fermentation	-	-	-	2.78	2.63	2.56	2.48	2.33
Manure Management	-	-	-	0.59	0.6	0.6	0.61	0.62
Rice Cultivation	0.08	0.12	0.08	0.12	0.12	0.12	0.12	0.12
Agricultural Soil Management	3.63	3.68	3.32	3.13	2.92	2.82	2.71	2.5
Liming	0.42	0.22	0.24	0.07	-	-	-	-
Urea	0	0.01	0.01	0.01	0	0	0	0
Burning of Agricultural Crop Waste	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.08
Waste	9.83	10.85	14.09	16.28	19.17	20.52	21.64	23.35
Municipal Solid Waste	8.36	9.01	11.99	13.84	16.41	17.6	18.57	19.96
Wastewater	1.47	1.84	2.1	2.44	2.76	2.91	3.07	3.39
Total emissions generation	**212.01**	**265.62**	**287.73**	**283.22**	**220.5**	**199.32**	**201.71**	**211.97**
Total removals	**25.81**	**3.2**	**12.59**	**12.34**	**12.34**	**12.34**	**12.34**	**12.34**
Net emissions	**186.2**	**253.42**	**275.14**	**270.88**	**208.16**	**186.98**	**189.37**	**199.63**

Table ES-4: Summary of total and net GHG emissions from 1990-2050 for scenario II – Clean Electricity by 2035.

MMT CO_2e	1990	2000	2010	2020	2030	2035	2040	2050
Energy	193.88	241.6	252.72	237.85	209.77	201.67	201.1	206.7
CO_2 from Fossil Fuel Combustion	188.64	236.63	248.26	230.65	202.36	194.3	193.73	199.32
Stationary Combustion	1.12	1.08	1.09	0.47	0.38	0.35	0.35	0.36
Mobile Combustion	2.63	3.22	1.59	1.63	1.56	1.56	1.56	1.56
Coal Mining & Abandoned Mines	-	-	-	-	-	-	-	-
Natural Gas and Oil Systems	1.49	0.67	1.78	5.1	5.47	5.47	5.47	5.47
Industrial Processes	4.09	9.04	17.2	27.27	39.49	41.62	43.59	47.26
Agriculture	4.21	4.12	3.72	6.78	6.36	6.18	6	5.66
Enteric Fermentation	-	-	-	2.78	2.63	2.56	2.48	2.33
Manure Management	-	-	-	0.59	0.6	0.6	0.61	0.62
Rice Cultivation	0.08	0.12	0.08	0.12	0.12	0.12	0.12	0.12
Agricultural Soil Management	3.63	3.68	3.32	3.13	2.92	2.82	2.71	2.5
Liming	0.42	0.22	0.24	0.07	-	-	-	-
Urea	0	0.01	0.01	0.01	0	0	0	0
Burning of Agricultural Crop Waste	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.08
Waste	9.83	10.85	14.09	16.28	19.17	20.52	21.64	23.35
Municipal Solid Waste	8.36	9.01	11.99	13.84	16.41	17.6	18.57	19.96
Wastewater	1.47	1.84	2.1	2.44	2.76	2.91	3.07	3.39
Total emissions	**212.01**	**265.62**	**287.73**	**288.18**	**274.78**	**269.99**	**272.33**	**282.98**
Total emission reductions and removals	**25.81**	**3.2**	**12.59**	**12.34**	**161.15**	**261.17**	**265.22**	**312.27**
GHG reductions	**-**	**-**	**-**	**-**	**141.32**	**236.06**	**253.5**	**282.96**
Removals	**25.81**	**3.2**	**12.59**	**12.34**	**19.83**	**25.14**	**28.84**	**29.32**
Net emissions	**186.2**	**253.42**	**275.14**	**270.88**	**113.63**	**8.82**	**-10.01**	**-29.29**

Table ES-5: Summary of total and net GHG emissions from 1990-2050 for scenario III – Net-Zero Emissions by 2050.

Trends of GHG reductions and removals are shown in Figure ES-5. It is assumed that the reductions and removals occur from 2023 onwards. The results show that with the proposed actions Florida can reduce in total about 312 MMT CO_2e by 2050 (reduction plus removal). Rough estimates indicate that this can be achieved at a cost of $5.27 Billion ($17 per MT CO_2e). This estimated cost is distributed across sectors and public, private, and government stakeholders. The estimated cost does not include any form of revenue nor does it include long-term cost savings from avoided damages or mitigated health impacts. About 86% (254 MMT CO_2e) of the potential emission reductions come from actions in the energy sector. GHG removals based on LULUCF account for 6% (16.9 MMT CO_2e) of the total emission reduction.

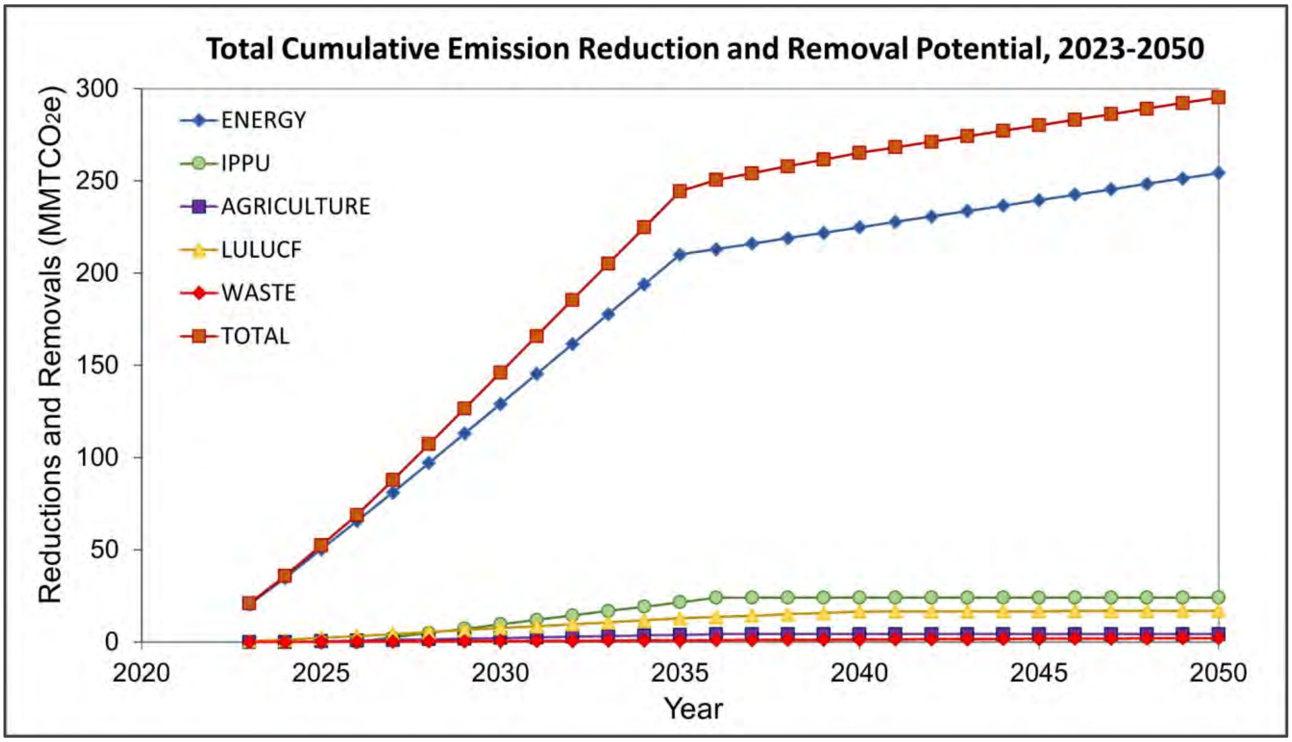

Figure ES-5: Total Cumulative Emission Reduction and Removal Potential (MMT CO_2e).

Net GHG emission trends for the three scenarios are shown in Figure ES-6. The net GHG emission in 2050 from scenarios I, II, and III are 253, 199, and -29 MMT CO_2e, respectively.

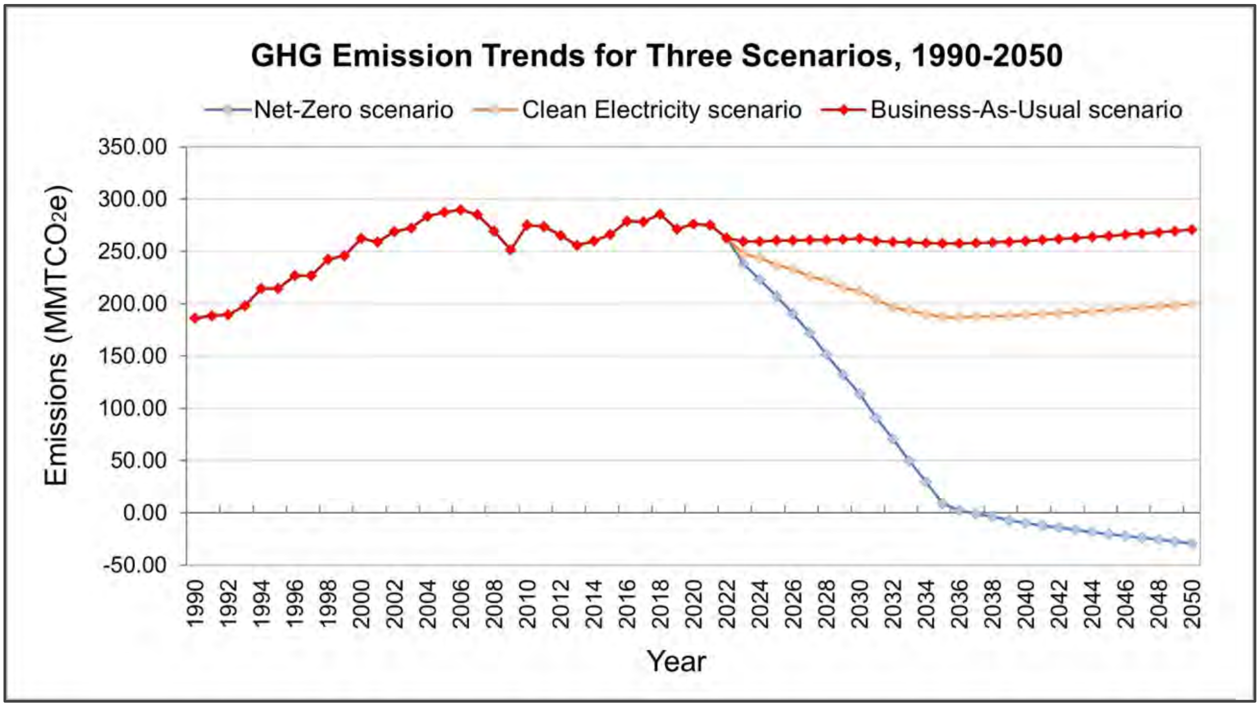

Figure ES-6: GHG emissions trends for the three scenarios considered in this report.

3. Key Recommendations for Net-Zero Action Planning

The research presented here is intended to lay the groundwork for more in-depth emissions reduction and cost analyses relative to the specific actions identified. A broad and diversified set of net-zero actions were identified across sectors of the GHG emissions inventory. For each action, we provide research to support potential emissions reduction estimates as well as general information on the feasibility and rough estimates of costs. The suite of recommended actions is not all-inclusive but lays the groundwork for immediate and achievable emissions reductions to achieve net-zero emissions by 2050 – a critically important endeavor if we are to avoid the most significant impacts of climate change.

The largest impact in reducing GHG emissions is clean electricity and net-zero actions within the Energy sector, primarily in electric power generation and transportation. For instance, over 50% of electric power sales come from residential electricity use and another 38% from commercial use. Thus, transforming electric power generation from fossil fuel to renewable energy (e.g., solar), from residential-scale to utility-scale, and increasing energy efficiency, both with modest rates of annual conversion, and continuing uptake of solar by the largest utilities, eliminates GHG emissions from direct electric power consumption by 2050. Another sub-sector within the Energy sector where large emission reductions can be made is in transportation. A diverse array of net-zero actions were identified with the largest emission reductions achievable by implementing solar charging at the State's expanding network of electric vehicle charging stations.

In the Land Use, Land-use Change, and Forestry (LULUCF) sector, flooding the largest areas of drained cropland organic soils, increasing revegetated and afforested uplands in developed areas, restoring coastal wetlands, and enhancing degraded seagrass meadows through water quality improvements were actions that both reduced emissions and increased carbon removal additional to existing natural systems. With additional upland areas potentially degraded, information about areas where coastal wetlands and seagrasses have been lost, and coastal management practices that facilitate transgression of healthy coastal ecosystems with sea-level rise, more opportunities for realizing additional natural carbon removal could be achieved within Florida.

Finally, substitution of distillate fuels and substances used for Industrial Processes and Product Use (IPPU), technologies to capture CO_2 emissions from heavy-duty vehicles, and generation of energy from landfill waste methane were among the additional actions for potential emission reductions that comprised a diverse portfolio to achieve net-zero by 2050.

Based on this groundwork, recommended next steps include more detailed emissions reduction and cost analyses relative to the specific actions identified that were not possible within the scope of this project.

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Acronyms & Key Terms

Acronym	*Description*	*Acronym*	*Description*
AAPFCO	Association of American Plant Food Control Officials	**GSP**	Gross State Product
ACP	Alternative Compliance Payment	**GWP**	Global Warming Potential
AFOLU	Agriculture, Forestry, and Other Land Use	**ICoNZ Team**	Inventory Compilation and Net-Zero Lead Team
AFV	Alternative Fuel Vehicles	**IFAS**	UF's Institute of Food and Agricultural Sciences
AISI	American Iron and Steel Institute	**IPCC**	Intergovernmental Panel on Climate Change
API	EIA's Application Programming Interface	**IPPU**	Industrial Processes and Product Use
APM	Ascend Performance Materials	**ITC**	Investment Tax Credit
BAU	Business-As-Usual	**LNG**	Liquified Natural Gas
$CaCO_3$	Calcium Carbonate	**LPG**	Liquified Petroleum Gas
CBECS	Commercial Buildings Energy Use Survey	**LULUCF**	Land Use, Land-Use Change, and Forestry
CDFA	California Department of Food and Agriculture	**MECS**	Manufacturing Energy Consumption Survey
CEMS	EPA's Continuous Emission Monitoring System	**MSW**	Municipal Solid Waste
CNG	Compressed Natural Gas	**NASS**	USDA's National Agricultural Statistics Service
CO_2FFC	Carbon Dioxide Fossil Fuel Combustion	**NOAA**	National Oceanic and Atmospheric Administration
CPI	Climate Policy Institute	**NREL**	National Renewable Energy Laboratory
DOE	United States Department of Energy	**NTD**	FTA's National Transit Database
E/R	Emissions and Removals	**ODS**	Ozone Depleting Substances
EAA	Everglades Agricultural Area	**PCA**	Portland Cement Association
EDF	Environmental Defense Fund	**PHMSA**	Pipeline and Hazardous

			Materials Safety Administration
EF	Emission Factor	**PPA**	Purchase Power Agreement
EV	Electric Vehicle	**PV**	Photovoltaic
eGRID	EPA's Emissions & Generation Resource Integrated Database	**RCA**	Recycled Concrete Aggregate
EIA	DOE's Energy Information Administration	**RCI**	Residential, Commercial and Industrial
EIIP	EPA's Emissions Inventory Improvement Program	**RCIT**	Residential, Commercial, Industrial and Transportation
EPA	United States' Environmental Protection Agency	**RGGI**	Regional Greenhouse Gas Initiative
ETS	Emission Trading System	**RPS**	Renewable Portfolio Standard
FAO	United Nations' Food and Agriculture Organization	**SEDS**	EIA's State Energy Data System
FCI	Florida Climate Institute	**SIT**	EPA's State Inventory Tool
FFC	Fossil Fuel Combustion	**TFI**	The Fertilizer Institute
FTA	Federal Transit Administration	**TNC**	The Nature Conservancy
FDACS	Florida Department of Agriculture and Consumer Service	**TVA**	Tennessee Valley Authority
FDEP	Florida Department of Environmental Protection	**UCF**	University of Central Florida
FDOT	Florida Department of Transportation	**UF**	University of Florida
FHWA	US DOT's Federal Highway Administration	**UGA**	University of Georgia
FIPRI	Florida Industrial and Phosphate Research Institute	**USDA**	United States Department of Agriculture
FIU	Florida International University	**USDOT**	United States Department of Transportation
FLIGHT	EPA's Facility Level Information on GreenHouse gases Tool	**USF**	University of South Florida
FPL	Florida Power & Light	**USGS**	United States Geological Survey
FRCC	Florida Reliability Coordinating Council	**WBCSD**	World Business Council for Sustainable Development
FSU	Florida State University	**WRI**	World Resources Institute

Units			
Btu **MBtu** **MMBtu** **BBtu** **TBtu**	British Thermal Units Thousand Btu Million Btu Billion Btu Trillion Btu	**lb**	Pound
Cf **Mcf** **MMcf** **Bcf**	Cubic feet Thousand cubic feet Million cubic feet Billion cubic feet	**MT** **MMT**	Metric Ton Million Metric Ton
ha	hectare	**VMT**	Vehicle Miles Traveled
Kg	Kilogram	**W** **kW** **kWh** **MW** **MWh** **GW** **GWh**	Watt Kilowatt Kilowatt hour Megawatt Megawatt hour Gigawatt Gigawatt hour
GHGs	***Greenhouse Gases***		
CO_2e	Carbon Dioxide Equivalent	**N_2O**	Nitrous Oxide
CO_2	Carbon Dioxide	**NF_3**	Nitrogen Trifluoride
CH_4	Methane	**PFC**	Perfluorocarbons
H_2S	Hydrogen Sulfide	**SF_6**	Sulfur Hexafluoride
HFC	Hydrofluorocarbons		

GREENHOUSE GAS
EMISSIONS INVENTORY
Florida: 1990-2018

1. Introduction

The first goal of this project "*Laying the Groundwork for Getting to Neutral in the State of Florida*" was to conduct a greenhouse gas (GHG) inventory of emissions and removals across Intergovernmental Panel on Climate Change (IPCC) categories and subcategories using the Environmental Protection Agency's (EPA) State Inventory Tool (SIT) for the state of Florida. Additionally, the project aimed to apply this inventory to produce GHG emissions projections under different future scenarios: 1) Business-As-Usual projection, considering relevant policies in Florida, 2) 100% clean electricity by 2035, and 3) net-zero emissions by 2050.

This report includes historical GHG emissions from 1990 to 2018 and discusses emissions for the year 2018 in some detail, considering the current reference year and the starting year for projections. The year 2018 was selected as the reference year due to the fact that there is a nearly complete dataset in the various sources and in the SIT.

2. Overview of Approach and Methodology

The GHG emissions inventory was conducted using the Excel-based EPA's State Inventory Tool (SIT). The tool has several modules that are organized around the various sectors and types of GHGs. The modules include emissions from combustion of fossil fuels, agriculture, forest management, solid waste, wastewater, and industrial processes and product use.

GHG estimates are reported in carbon dioxide equivalents (CO_2e), which represents the total greenhouse effectiveness of the different gases based on their global warming potential (GWP). The six major GHGs included in the inventory are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

It is important to note that emission results vary based on the GWPs that are applied during analysis. This report followed the methodology of the EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019 (EPA, 2021) for methane emissions, which uses the IPCC Fourth Assessment Report (AR4) (IPCC 2007) for the 100-year time horizon GWP of 25. The EPA and FCI acknowledge that later reports and studies, like the IPCC Fifth Assessment Report (AR5), use a 20-year time horizon GWP of 86 for methane. Although 100-year GWPs could underestimate emissions and near-term impacts, the authors of this report chose to be consistent with the IPCC AR4, which is in line with the UNFCCC's international reporting standards established in 2013 and applied to the EPA's SIT.

In the case of GHG emissions from electricity and transportation, two alternative approaches were utilized. Electricity GHG emissions were estimated based on both the production side and consumption side. In this report, only estimates based on production are considered in the total GHG emissions to avoid double counting. Estimates based on consumption are important to identify targets for emission reduction. Similarly, GHG emissions in

the transportation sector are estimated based on total fuel combustion and total vehicle miles traveled (VMT) of the different vehicle categories. In this report, only emissions based on fuel combustion have been included in the total GHG emissions to also avoid double counting. Estimates of emissions based on VMT are important to identify the largest emitting vehicle group and develop strategies to achieve reduction objectives.

In each module, data were obtained from national and state databases such as the EPA's Emissions & Generation Resource Integrated Database (eGRID) and US Energy Information Administration's (EIA) State Energy Data System (SEDS) tool, as well as information from state agencies such as Florida Department of Environmental Protection (FDEP) and Florida Department of Transportation (FDOT). Data from scientific publications were used in a few cases, as were personal communications with members of this project who have expertise in specific sectors. In other cases, data were obtained by reaching out to representatives of external entities like National Oceanic and Atmospheric Administration (NOAA) and the EPA. Two specific reports were referred to often: the EPA's 2020 Inventory of U.S. Greenhouse Gas Emissions and Sinks (1990-2018), and the Center for Climate Strategies' 2008 Final Florida Greenhouse Gas Inventory and Reference Case Projections (1990-2025).

In most cases, default values that are pre-populated with the SIT were utilized. In some cases where default values were not available or do not represent the actual situation, state data were used. These may include data in the various modules or emission factors that are relevant to Florida.

In this report, we have estimated emissions from sectors that were not included in the SIT. For example, GHG emissions from phosphorus production in Florida have been estimated separately. Also, the release and/or sequestration of GHGs from wetlands has been estimated outside of the SIT. All such external calculations have been included in the total emissions.

3. Summary of Findings

3.1. Energy Sector: Energy Consumption

3.1.1. CO_2 from Fossil Fuel Combustion

This section presents carbon dioxide (CO_2) emissions from fossil fuel combustion for energy use in the residential, commercial, industrial, transportation, and electric power sectors, as well as use in international bunker fuels[1]. Emissions are estimated based on the collection of data pertaining to combustion efficiency (percentage of carbon oxidized during combustion) and carbon content coefficients. The source activities considered are:

- Coal Consumption
- Petroleum Consumption
    - Including: Distillate Fuel, Residual Fuel, Motor Gasoline, Kerosene, Naphtha, Asphalt & Road Oil, Liquified Petroleum Gas (LPG)
- Natural Gas Consumption
    - Including: Hydrocarbon Gas Liquids

[1] International bunker fuels are activities related to international transportation, through both aviation and maritime transport; Emissions from international bunker fuels are the result of fuel combustion for these transport activities (EPA, 2021).

Figures 3-1 and 3-2 display the historical trends of emissions from 1990-2018 by fuel type and sector, respectively. As shown in Figure 3-1, emissions from petroleum combustion are the highest, while Figure 3-2 shows that transportation and electric power are the two main contributors of GHG emissions. Table 3-1 presents the total emissions from fossil fuel combustion in the baseline years of 2005 and 2018, which were estimated at 258.3 MMT CO_2e and 247.7 MMT CO_2e, respectively.

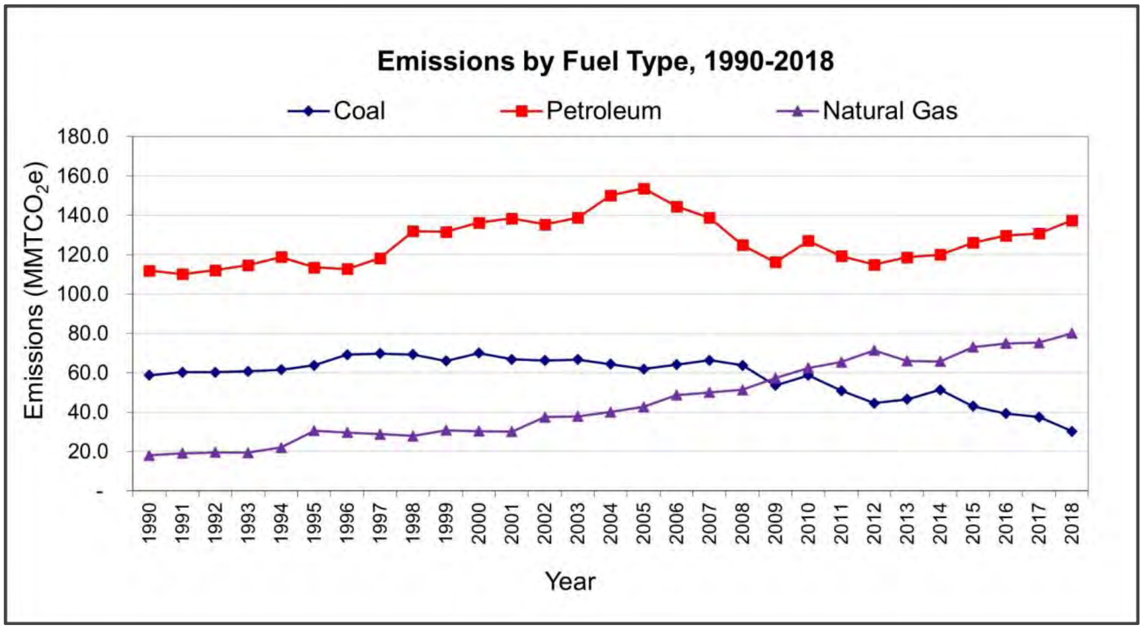

Figure 3-1: CO_2FFC - Historical emissions by fuel type in all sectors (residential, commercial, industrial, transportation, and electric power).

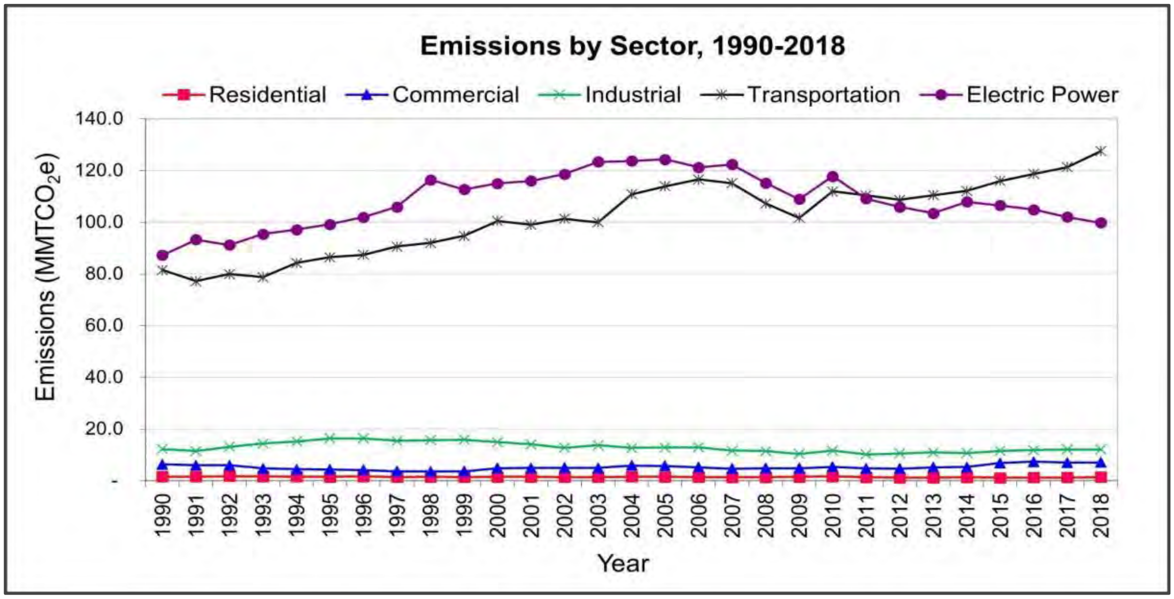

Figure 3-2: CO_2FFC - Historical emissions by sector.

Sector	1990	1995	2000	2005	2010	2015	2018
Residential	1.53	1.48	1.51	1.49	1.61	1.17	1.36
Commercial	6.25	4.33	4.80	5.66	5.31	6.83	7.09
Industrial	12.19	16.35	14.85	12.85	11.65	11.50	12.03
Transportation	81.48	86.47	100.45	113.92	111.89	115.98	127.47
Electric Power	87.19	99.18	115.00	124.35	117.80	106.54	99.77
Intl. Bunker Fuel	0.03	0.02	0.02	0.02	0.04	0.03	0.03
Total	**188.64**	**207.81**	**236.63**	**258.27**	**248.26**	**242.01**	**247.72**

Table 3-1: CO_2FFC - Emissions by sector (MMT CO_2e).

3.1.2. <u>Stationary Combustion</u>

The stationary combustion module estimates methane (CH_4) and nitrous oxide (N_2O) emissions from fuel combustion in the residential, commercial, industrial, and electric power sectors. The source activities considered are:

- Coal Consumption
- Petroleum Consumption
  - Including: Distillate Fuel, Residual Fuel, Motor Gasoline, Kerosene, Asphalt & Road Oil, Special Naphthas, Liquified Petroleum Gas (LPG)
- Natural Gas Consumption
  - Including: Hydrocarbon Gas Liquids
- Wood Consumption

Emissions of CH_4 and N_2O by sector are shown in Figures 3-3 and 3-4. Figure 3-5 displays the combined total non-CO_2 emissions, of both CH_4 and N_2O, by sector. As seen in the figures, the electric power sector is the largest source of both CH_4 and N_2O emissions. A summary of the emissions from stationary combustion by emissions type, sector, and year is provided in Table 3-2. Focusing on the baseline years of 2005 and 2018, combined CH_4 and N_2O emissions from stationary combustion were estimated at 0.9 MMT CO_2e and 0.6 MMT CO_2e, respectively.

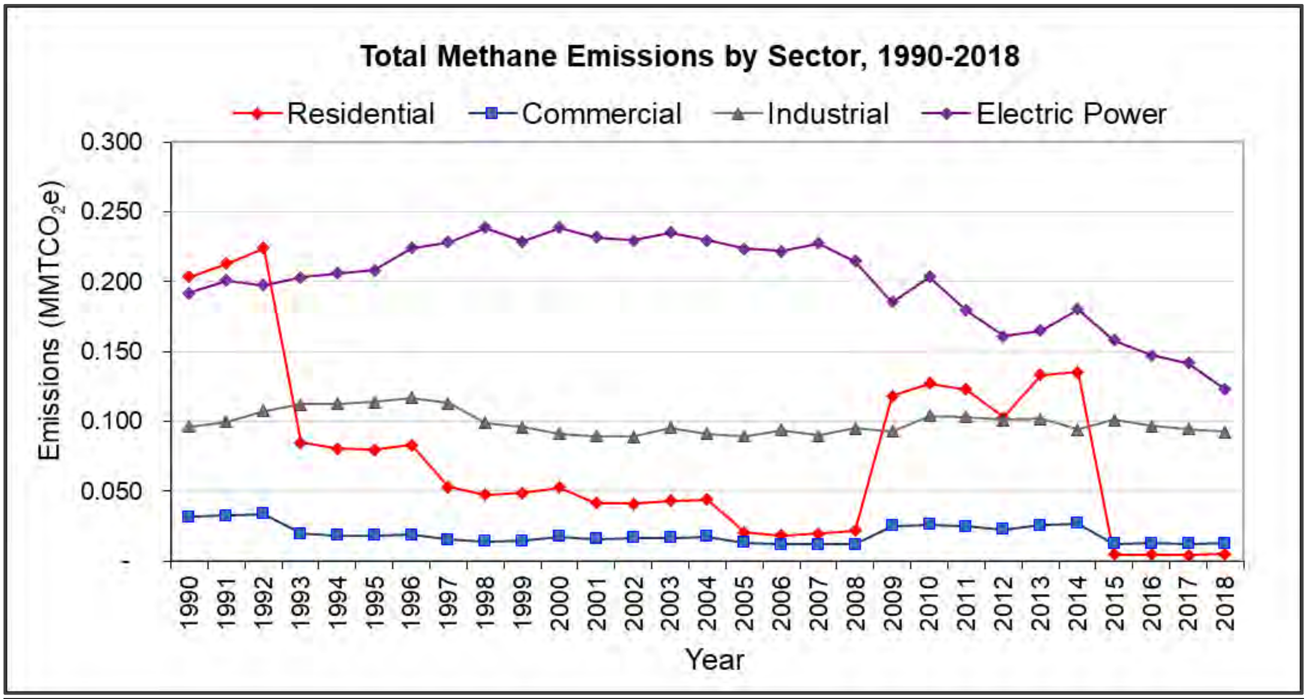

Figure 3-3: Stationary Combustion - Historical CH_4 emissions by sector.

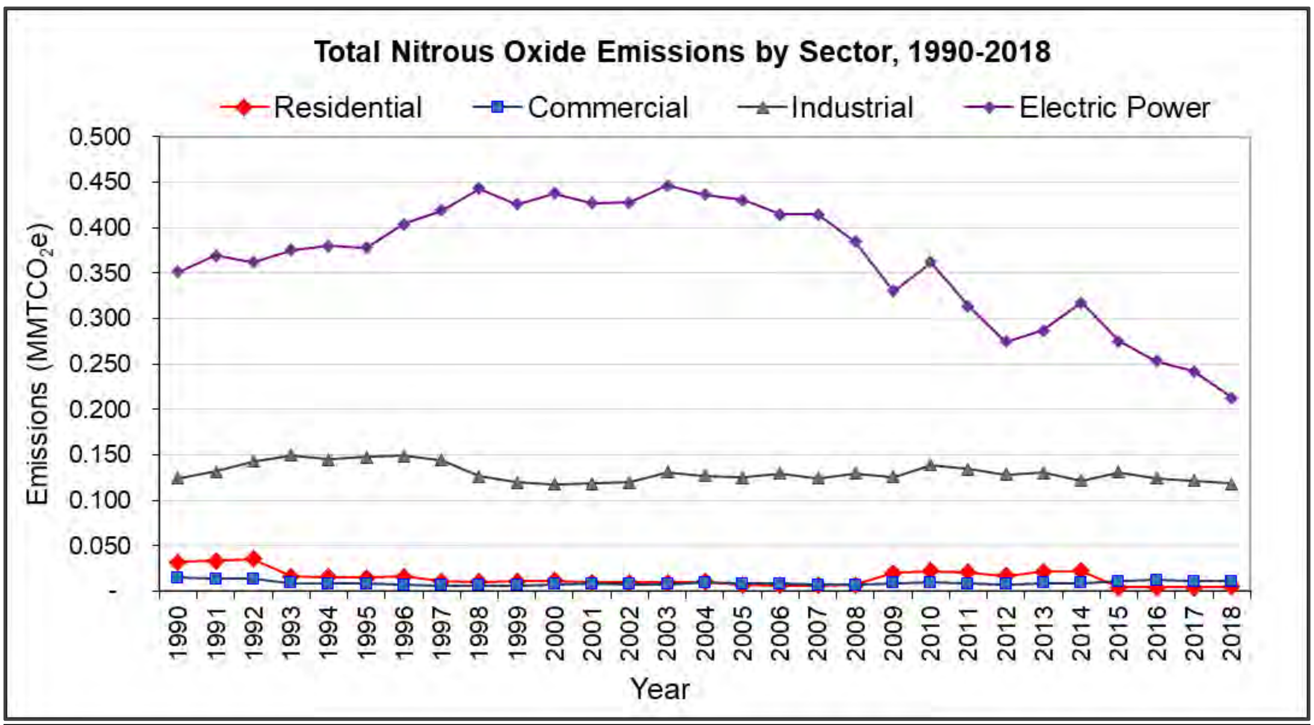

Figure 3-4: Stationary Combustion - Historical N_2O emissions by sector.

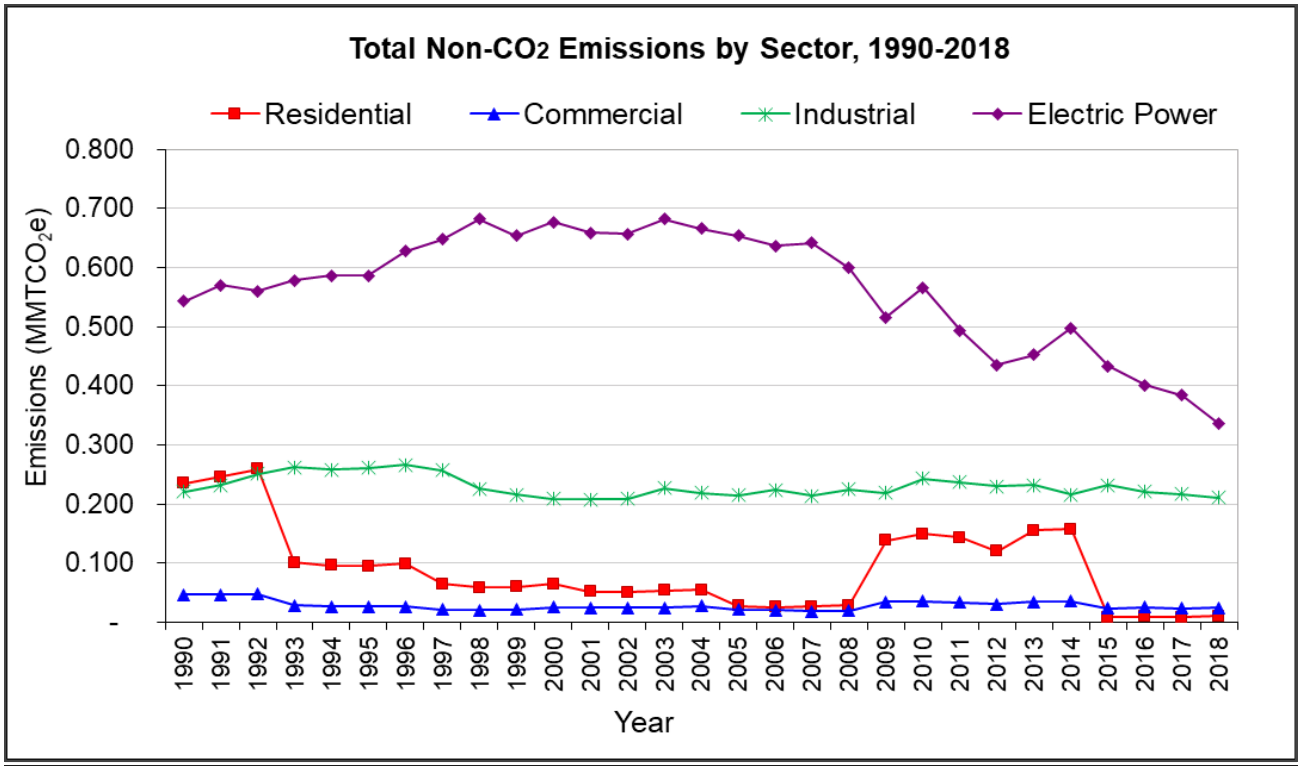

Figure 3-5: Stationary Combustion - Historical cumulative emissions of CH_4 and N_2O by sector.

MMT CO_2e	1990	1995	2000	2005	2010	2015	2018
Residential	**0.235**	**0.095**	**0.064**	**0.027**	**0.149**	**0.009**	**0.01**
N_2O	0.032	0.015	0.011	0.007	0.022	0.004	0.005
CH_4	0.203	0.08	0.053	0.02	0.127	0.005	0.005
Commercial	**0.046**	**0.026**	**0.025**	**0.022**	**0.036**	**0.023**	**0.024**
N_2O	0.015	0.008	0.008	0.008	0.01	0.011	0.011
CH_4	0.031	0.018	0.017	0.013	0.026	0.012	0.013
Industrial	**0.221**	**0.261**	**0.209**	**0.214**	**0.243**	**0.232**	**0.211**
N_2O	0.124	0.147	0.118	0.125	0.139	0.131	0.118
CH_4	0.096	0.114	0.091	0.09	0.104	0.101	0.093
Electric Power	**0.543**	**0.586**	**0.676**	**0.654**	**0.566**	**0.433**	**0.336**
N_2O	0.351	0.378	0.438	0.43	0.362	0.275	0.213
CH_4	0.192	0.208	0.238	0.224	0.204	0.158	0.123
TOTAL	**1.045**	**0.969**	**0.975**	**0.918**	**0.993**	**0.697**	**0.580**

Table 3-2: Stationary Combustion - Historical emission totals of CH_4 and N_2O by sector.

3.1.3. **Mobile Combustion**

Mobile combustion looks into carbon methane (CH_4) and nitrous oxide (N_2O) greenhouse gas emissions from vehicles. This module estimates these emissions from mobile sources using activity data, information on the combustion technologies used, and information on the type of emission control technologies employed during and after combustion. The source activities considered are:

- ➢ Highway vehicles
- ➢ Aviation (planes)
- ➢ Boats and vessels
- ➢ Locomotives
- ➢ Alternative fuel vehicles
- ➢ Other sources (non-highway vehicles, e.g. farming & industrial equipment)

Figure 3-6 shows CH_4 and N_2O historical emission totals for all mobile sources. Figure 3-7 shows CH_4 and N_2O historical emission totals specifically for non-highway mobile sources. Focusing on the baseline years of 2005 and 2018, combined CH_4 and N_2O emissions from mobile combustion were estimated at 2.7 MMT CO_2e and 1.1 MMT CO_2e, respectively.

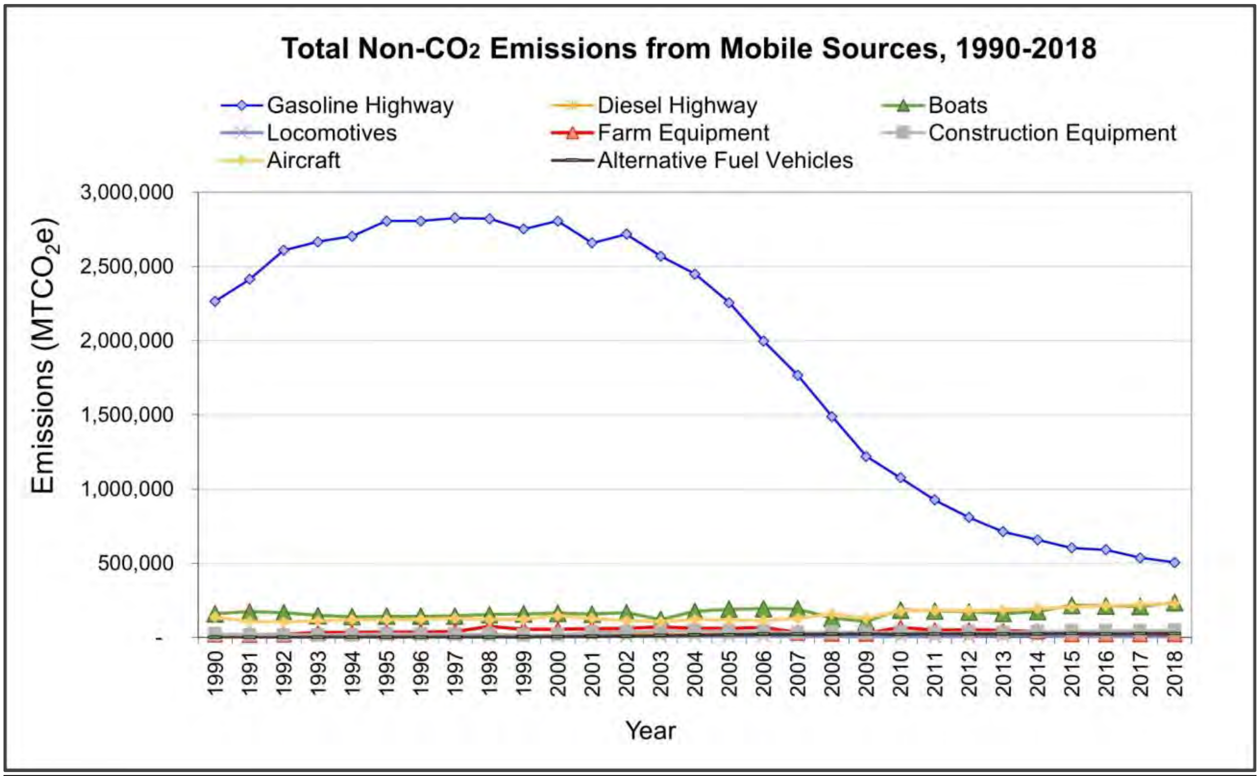

Figure 3-6: Mobile Combustion - Total CH_4 and N_2O emissions from mobile sources by transport mode/vehicle type.

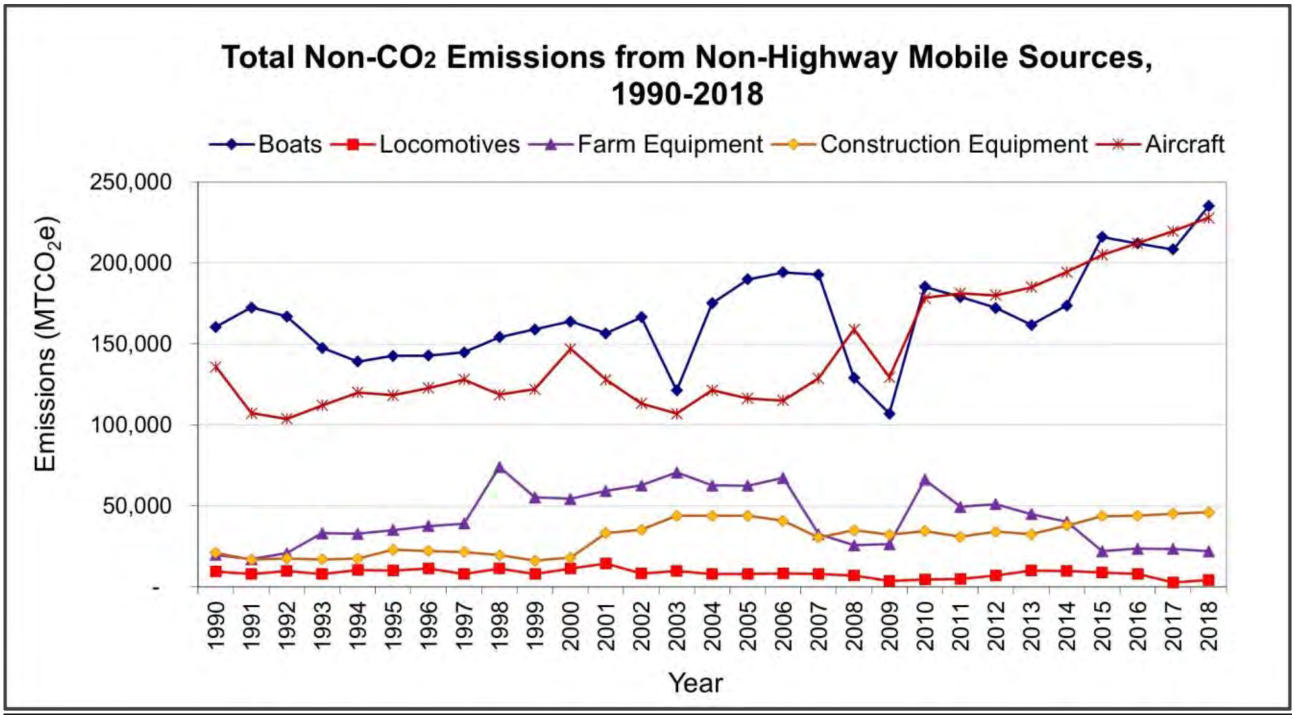

Figure 3-7: Mobile Combustion - Total CH_4 and N_2O emissions from non-highway mobile sources.

3.2. Energy Sector: Fossil Fuel Extraction & Distribution Industry

3.2.1. **Coal Mining**

This inventory includes methane (CH_4) emissions from coal mining activities associated with Surface Mining Activities, Surface Post-Mining Activities, Underground Mining Activities, Underground Post-Mining Activities, and Abandoned Coal Mines. However, the State of Florida does not partake in coal mining due to the absence of coal in the state. Therefore, methane emissions from coal mining are zero across the board.

3.2.2. **Natural Gas & Oil Systems**

This section includes fugitive methane (CH_4) and carbon dioxide (CO_2) emissions from the variety of components that make up the natural gas and petroleum systems present in the state of Florida. The source activities considered are:

- Natural Gas
  - Production
  - Transmission
  - Venting & Flaring
  - Distribution
- Oil
  - Production

- Refining
- Transportation

Figure 3-8 shows the total GHG emissions from natural gas and oil activities emitted from 1990 to 2018 in MMT CO_2e. The total methane emissions from natural gas and oil activities, including the production, transmission, and distribution of natural gas, are displayed in Figure 3-9 in MT CH_4. Table 3-3 displays the estimated emissions from natural gas and oil systems in Florida for all years between 2005 and 2018. Zooming into the baseline years of 2005 and 2018, emissions from natural gas and oil systems were estimated at 1.7 MMT CO_2e and 2.0 MMT CO_2e, respectively.

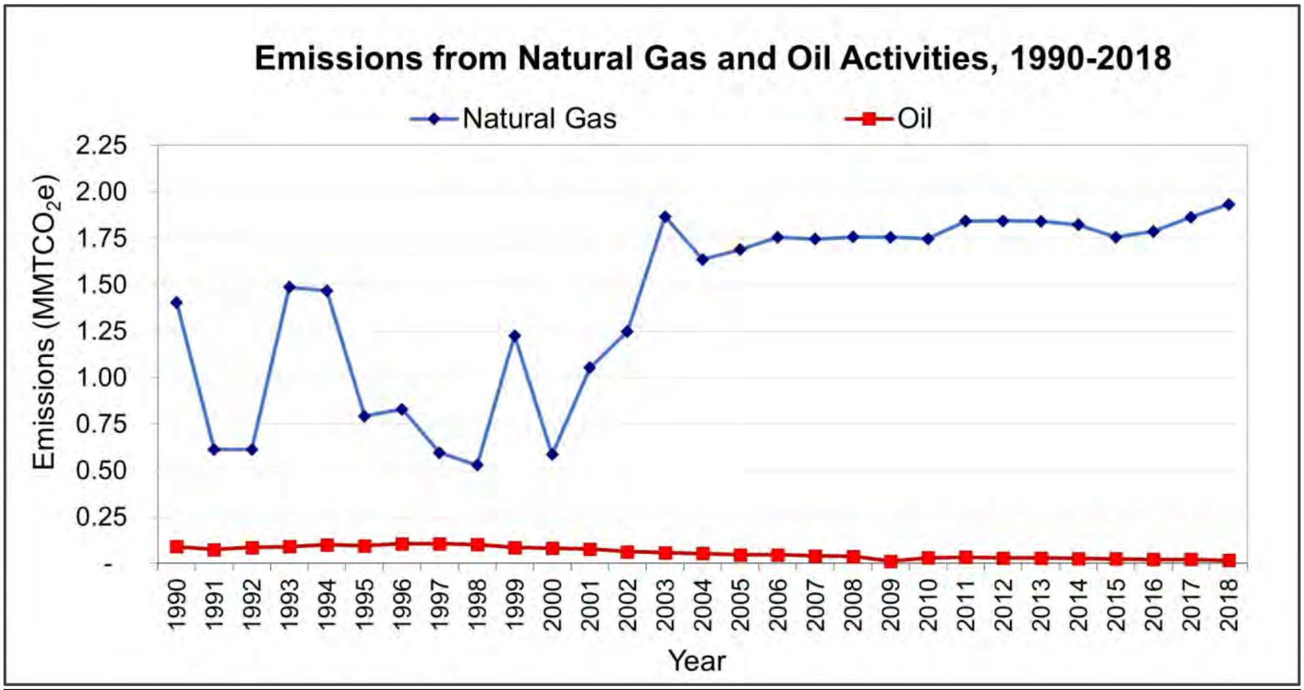

Figure 3-8: Natural Gas & Oil - Total emissions from all activities in MMT CO_2e.

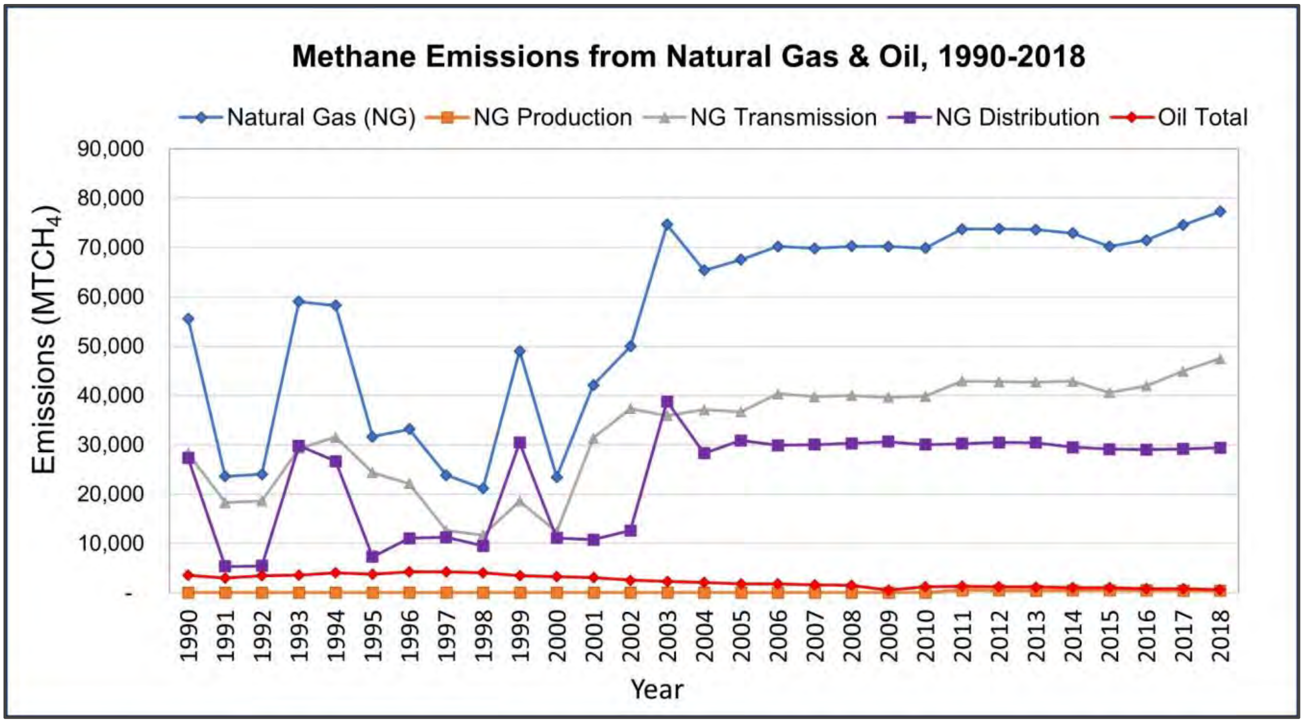

Figure 3-9: Natural Gas & Oil - Total CH_4 emissions from all activities in MT CH_4.

(MMT CO_2e)	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cumulative Total	**1.74**	**1.80**	**1.79**	**1.80**	**1.76**	**1.78**	**1.87**	**1.87**	**1.87**	**1.85**	**1.77**	**1.81**	**1.88**	**1.95**
Natural Gas Total	**1.69**	**1.75**	**1.75**	**1.76**	**1.75**	**1.75**	**1.84**	**1.84**	**1.84**	**1.82**	**1.75**	**1.79**	**1.86**	**1.93**
Production	0	0	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Transmission	0.92	1.01	0.99	1.00	0.99	1.0	1.07	1.07	1.07	1.07	1.01	1.05	1.12	1.19
Distribution	0.77	0.75	0.75	0.76	0.77	0.75	0.76	0.76	0.76	0.74	0.73	0.73	0.73	0.73
Flaring	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil Total	**0.05**	**0.05**	**0.04**	**0.04**	**0.01**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**	**0.02**	**0.02**	**0.02**

Table 3-3: Natural Gas & Oil - Total GHG emissions from 2005-2018.

The EPA SIT did not include post-meter CH_4 emissions in the Natural Gas and Petroleum analysis. These values were calculated separately and the total post-meter CH_4 emissions from these units from 2018 were about 0.66 MMT CO_2e. The post-meter CH_4 emissions from each sector were as follows: residential buildings (0.24 MMT CO_2e), commercial buildings (0.03 MMT CO_2e), industrial facilities (0.03 MMT CO_2e), electric power generation facilities (0.36 MMT CO_2e) and alternative fuel vehicles (~0 MMT CO_2e).

Emissions from the residential sector were calculated using information from the American Housing Survey (AHS) and the IPCC emission factor of 4 kg per appliance, with a consideration of 2.2 appliances per house that uses natural gas. For the commercial sector, estimates were

made based on the proportion to the national value. For industrial and electric power generation, natural gas consumption was obtained from the EIA database and the IPCC emission factor of 11,326.7 kg CH_4/BCF natural gas consumption was applied. The number of alternative fuel vehicles was extracted from EIA alternative fuel vehicle data and considered the IPCC emission factor of 0.33 kg per vehicle.

According to Alvarez et al. (2008), measurement-based estimates of methane emissions from natural gas and petroleum activities are roughly 50% higher than what has been presented through the latest GHG inventory, suggesting a probable underestimation of methane emissions in this report.

3.3. Industrial Processes & Product Use Sector

3.3.1. **Industrial Processes**

The inventory for the Industrial Processes and Product Use (IPPU) includes emissions from an array of industries and consists of non-combustion process emissions of various GHGs. Several GHGs are included within this module: carbon dioxide, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons. The source activities considered are:

- ➢ Clinker production in cement making
- ➢ Lime production
- ➢ Limestone & Dolomite consumption
- ➢ Soda Ash consumption
- ➢ Iron & Steel production
- ➢ Ammonia production
- ➢ Urea consumption
- ➢ Nitric Acid & Adipic Acid production
- ➢ Electric Power Transmission & Distribution Systems
- ➢ Consumption of Ozone Depleting Substances (ODS)
- ➢ Semiconductor Manufacturing
- ➢ Phosphoric Acid production *(estimated separately as it is not included in the SIT)*

Table 3-4 displays values per activity for all years between 2005 and 2018. Figure 3-10 shows the total emissions for all relevant activities within IPPU from 1990 to 2018. Focusing on the baseline years of 2005 and 2018, emissions from this sector were estimated at 12.6 MMT CO_2e and 27.1 MMT CO_2e, respectively.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cumulative Total (MMT CO_2e)	**12.60**	**13.07**	**13.32**	**13.20**	**12.33**	**17.95**	**23.75**	**19.18**	**18.80**	**19.83**	**19.40**	**23.34**	**23.72**	**27.05**
Total Emissions of CO_2	**5.56**	**5.63**	**5.48**	**4.86**	**3.40**	**3.92**	**3.74**	**4.11**	**4.74**	**4.93**	**5.02**	**5.23**	**5.30**	**5.40**
Cement	2.73	2.91	2.70	2.46	1.54	1.71	1.57	1.96	2.42	2.58	2.70	2.86	2.98	3.19
Lime	0.13	0.13	0.10	0.13	0.09	0.11	0.09	0.06	0.05	0.03	0.02	0.03	0.04	0.04
Limestone and Dolomite	0.55	0.61	0.64	0.43	0.41	0.48	0.45	0.49	0.63	0.74	0.72	0.75	0.71	0.68
Soda Ash	0.15	0.15	0.15	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13
Iron and Steel	1.03	1.02	1.05	0.92	0.56	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urea	.0007	.0006	.0008	.0003	.0006	.0007	.0004	.0005	.0008	.0007	.0005	.0009	.0010	.0010
Phosphoric Acid	0.96	0.80	0.83	0.77	0.68	0.75	0.76	0.73	0.77	0.71	0.70	0.71	0.70	0.62
Total Emissions of N_2O	**0**	**0**	**0**	**0**	**0**	**4.57**	**10.33**	**5.25**	**4.08**	**4.54**	**3.66**	**7.14**	**7.36**	**10.45**
Nitric Acid	0	0	0	0	0	0.71	0.62	0.64	0.67	0.60	0.62	0.70	0.62	0.60
Adipic Acid	0	0	0	0	0	3.86	9.71	4.61	3.41	3.94	3.04	6.44	6.75	9.85
Total Emissions of HFC, PFC, NF_3, and SF_6	**7.04**	**7.44**	**7.84**	**8.35**	**8.92**	**9.45**	**9.68**	**9.82**	**9.98**	**10.36**	**10.72**	**10.97**	**11.06**	**11.20**
ODS Substitutes	6.50	6.99	7.46	7.97	8.55	9.09	9.30	9.50	9.68	10.04	10.45	10.68	10.77	10.92
Semiconductor Manufacturing	0.03	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Electric Power Transmission & Distribution Systems	0.51	0.44	0.38	0.37	0.37	0.35	0.35	0.29	0.27	0.29	0.24	0.26	0.26	0.25

Table 3-4: IPPU - Total and specific GHG (CO_2, N_2O, HFC, PFC, NF_3, and SF_6) emissions.

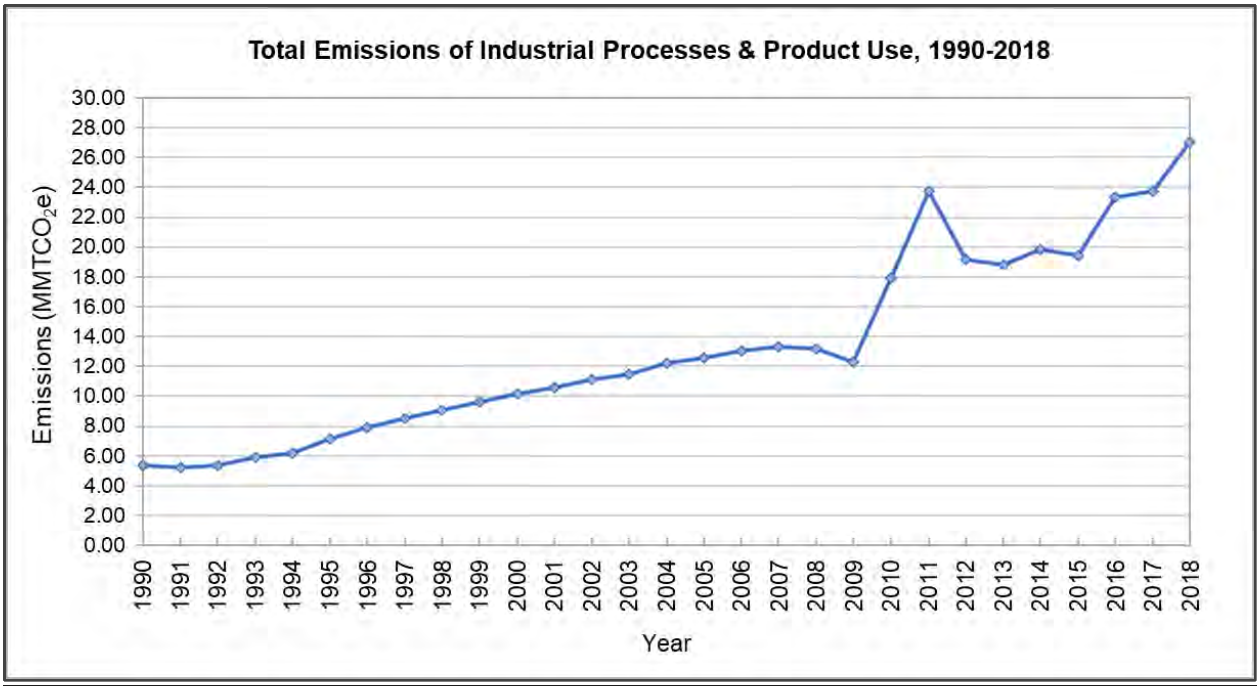

Figure 3-10: IPPU - Total emissions from all activities in MMT CO_2e.

3.4. Agriculture, Forestry, and Other Land Use (AFOLU) Sector

3.4.1. **Agriculture**

The agriculture module estimates CO_2, CH_4, and N_2O emissions within the agricultural industry. The source activities considered include:

- Enteric Fermentation
- Manure Management
- Agriculture Soils
- Liming Agricultural Soil
- Rice Cultivation
- Urea Fertilizer
- Agricultural Residue Burning

Figure 3-11 shows the proportions of average annual emissions from agriculture by gas type between 1990 and 2018 in MMT CO_2e. The largest component of GHGs produced by agriculture activities was CH_4, followed by N_2O and CO_2. Figure 3-12 shows the historical trends by agricultural activity types across the entire time series. Table 3-5 lays out the total annual CO_2e emissions from the agriculture sector from 2005 to 2018. The activities with the largest average emissions were agricultural soils and enteric fermentation, with 1990-2018 emission totals averaging to 4.8 MMT CO_2e and 3.4 MMT CO_2e, respectively. Zooming into the baseline years of 2005 and 2018, emissions from the agriculture sector were estimated at 9.3 MMT CO_2e and 9.4 MMT CO_2e, respectively.

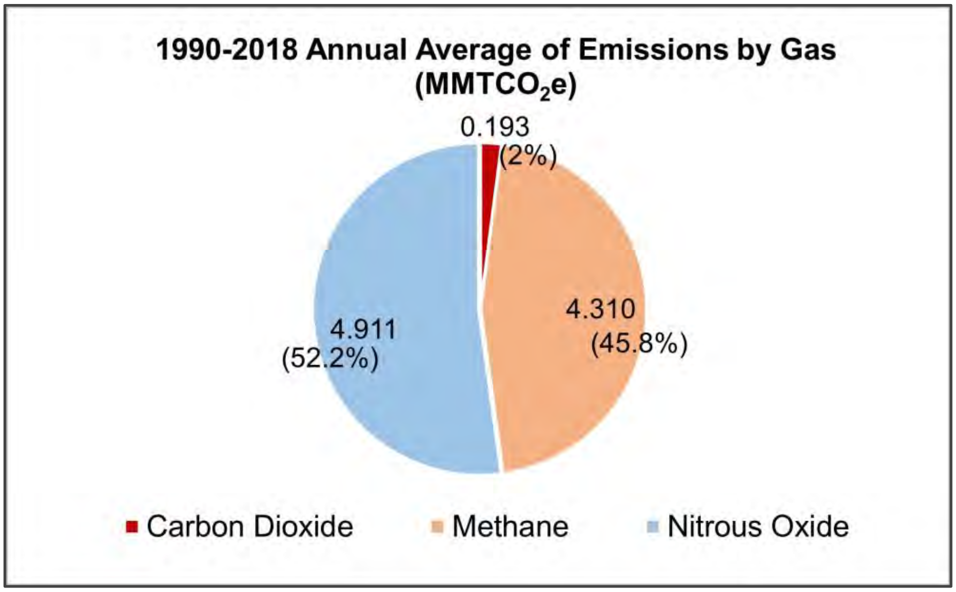

Figure 3-11: Agriculture - Annual average emission (MMT CO_2e) from 1990 to 2018, by gas type.

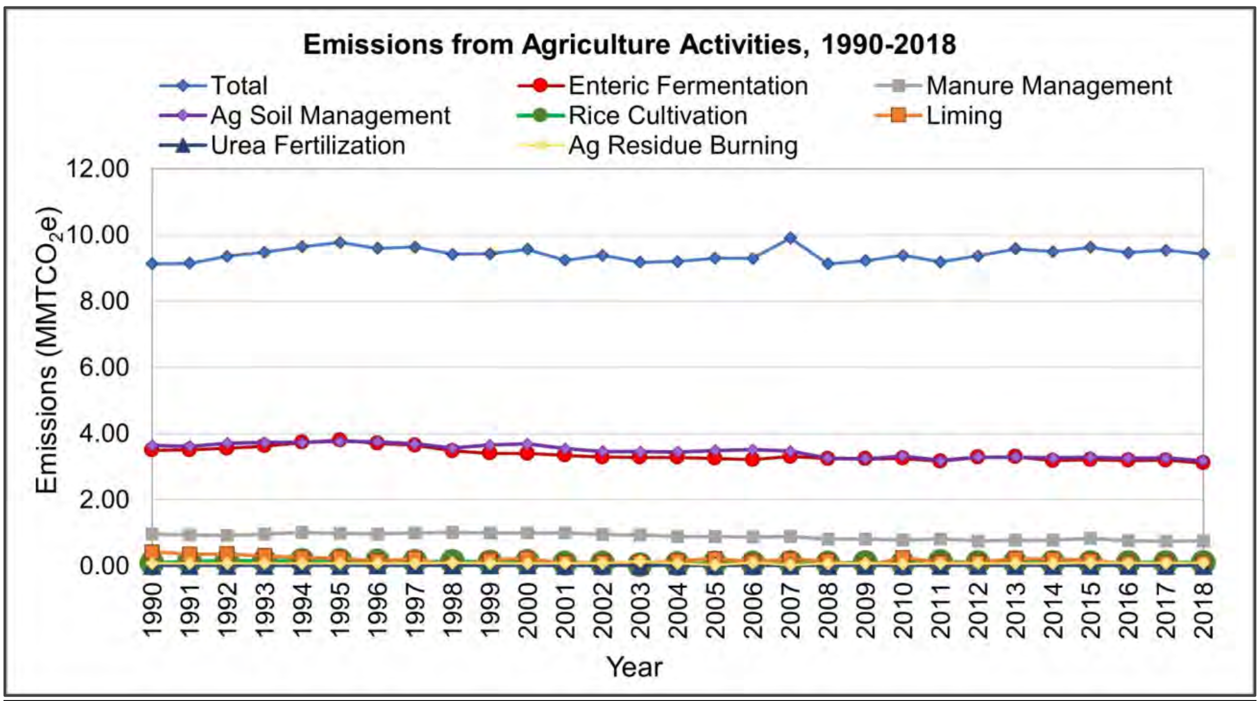

Figure 3-12: Agriculture - Historical emissions (MMT CO_2e) from agricultural activity types.

MMTCO₂e	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Enteric Fermentation	3.25	3.21	3.30	3.24	3.23	3.25	3.16	3.28	3.29	3.18	3.21	3.18	3.19	3.11
Manure Management	0.89	0.87	0.89	0.81	0.80	0.77	0.81	0.75	0.78	0.78	0.83	0.77	0.74	0.75
Ag Soil Management	4.84	4.92	5.37	4.78	4.83	4.97	4.89	5.05	5.11	5.15	5.23	5.26	5.35	5.30
Rice Cultivation	0.07	0.07	0.10	0.08	0.09	0.08	0.13	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Liming	0.21	0.12	0.20	0.14	0.19	0.24	0.11	0.10	0.22	0.20	0.16	0.06	0.06	0.06
Urea Fertilization	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Ag Residue Burning	0.03	0.09	0.04	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09
TOTAL	**9.30**	**9.29**	**9.91**	**9.13**	**9.22**	**9.38**	**9.18**	**9.37**	**9.58**	**9.49**	**9.63**	**9.46**	**9.54**	**9.42**

Table 3-5: Agriculture - Total annual emissions (MMT CO_2e) from the agriculture sector.

3.4.2. Land Use, Land-Use Change, & Forestry

The Land Use, Land-Use Change, and Forestry module, more commonly referred to by its acronym "LULUCF", is responsible for monitoring Florida's net carbon dioxide flux (CO_2) emanated from forest byproducts. Other quantifiable GHG emissions gathered from the state's forestry section include methane (CH_4) and nitrous oxide (N_2O). The activities considered are:

- Forest Carbon Flux
    - Forest Land Remaining Forest Land
    - Land Converted to Forest Land
    - Forest Land Converted to Other Land Uses
- Urban Trees
- Non-CO_2 Emissions from Forest Fires/Settlement Soils
- Landfilled, Yard Trimmings, and Food Scraps
- Agricultural Soil Carbon Flux

In addition to the activities presented by the SIT's LULUCF module, external calculations were conducted to determine the net removal of emissions from wetlands.

Figure 3-13 displays carbon emissions and sequestration from forest management and land-use change by activity type. Figure 3-14 presents the net removal of GHG emissions in MMT CO_2e by wetlands from 1990-2018. Figure 3-15 shows the emissions from forest fires, also measured in MMT CO_2e, with individual historical trends for both CH_4 and N_2O emissions, as well as the combined total. Net forest carbon flux generated the greatest output in terms of CO_2 removal, of about -24.1 MMT CO_2e in 2018 as sequestered amount, followed by agricultural soil carbon flux (-16.1), Urban Trees (-9.8), landfilled yard trimmings and food scraps (-0.6), and N_2O from settlement soils (-0.1). Zooming into the baseline years of 2005 and 2018, emission removals from LULUCF were estimated at -3.9 MMT CO_2e and -12.4 MMT CO_2e, respectively.

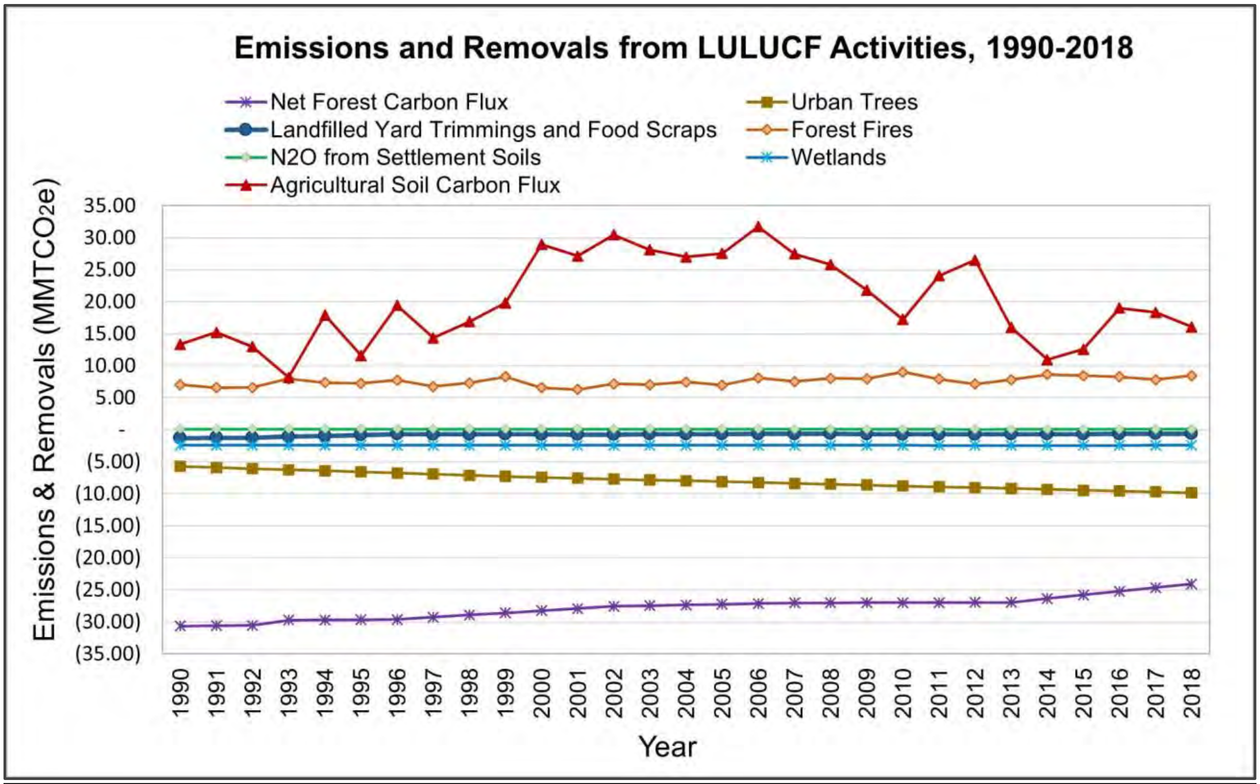

Figure 3-13: LULUCF - Carbon E/R from forest management and land-use change (MMT CO_2e).

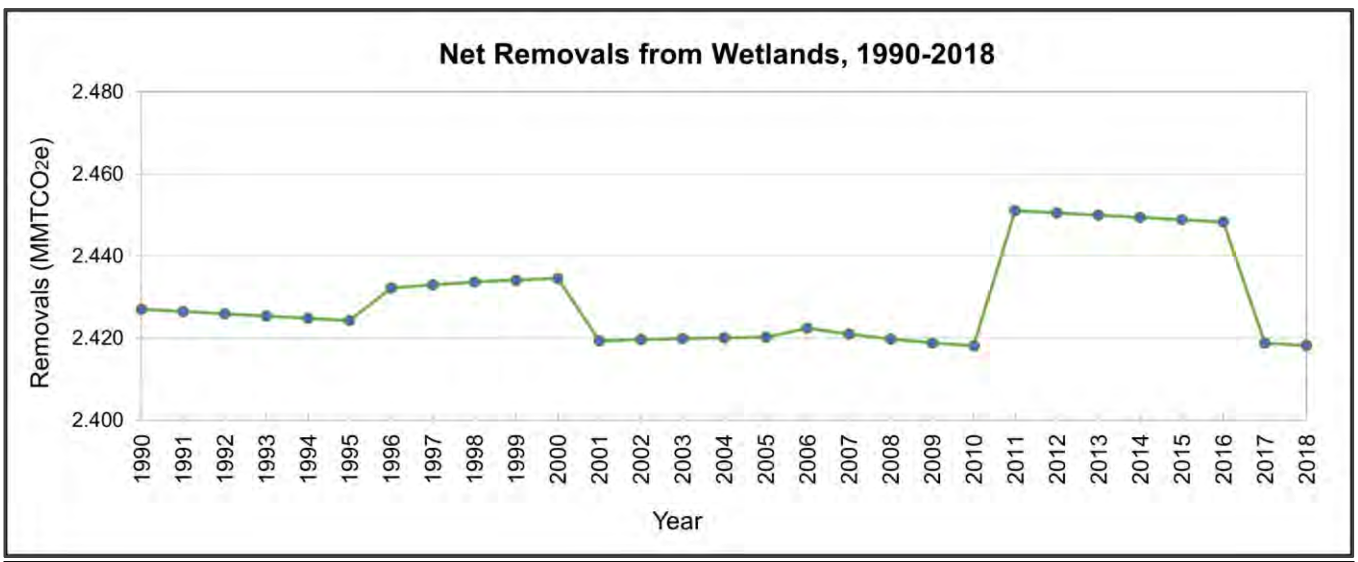

Figure 3-14: LULUCF - Net removal of GHGs by wetlands (MMT CO_2e).

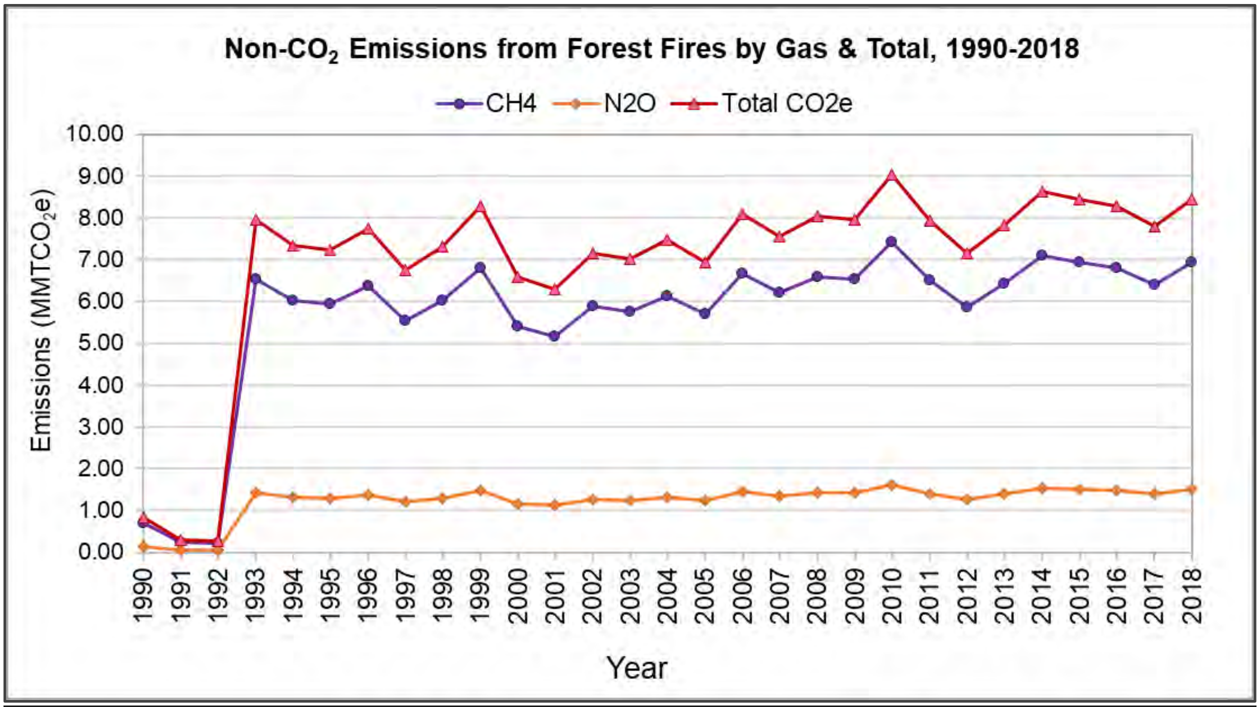

Figure 3-15: LULUCF - CH_4 and N_2O emissions from forest fires, both individual and cumulative total.

3.5. Waste Sector

3.5.1. <u>**Solid Waste**</u>

The Municipal Solid Waste module calculates methane (CH_4) emissions from landfilling of municipal solid waste (MSW) and carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions from the combustion of MSW. The activities considered are:

- Municipal Solid Waste Combusted
- Municipal Solid Waste Landfilled
- Municipal Solid Waste Discarded
- Municipal Solid Waste Generated
- Municipal Solid Waste Flared
- Combustion of Plastic
- Combustion of Synthetic Rubber
- Combustion of Synthetic Fibers

Figure 3-16 shows the GHG emissions resulting from both landfills and waste combustion by gas type (MMT CO_2e). Results show that CH_4 emissions have increased steadily over the years due to the rise in the amount of solid waste generated. Figure 3-17 presents GHG emissions from waste combustion, by both gas and activity type (MT CO_2e). The majority of CO_2 emissions from waste combustion resulted from the burning of plastics and synthetic fiber. Focusing on the baseline years of 2005 and 2018, combined emissions from landfills and waste combustion were estimated at 10.0 MMT CO_2e and 14.6 MMT CO_2e, respectively.

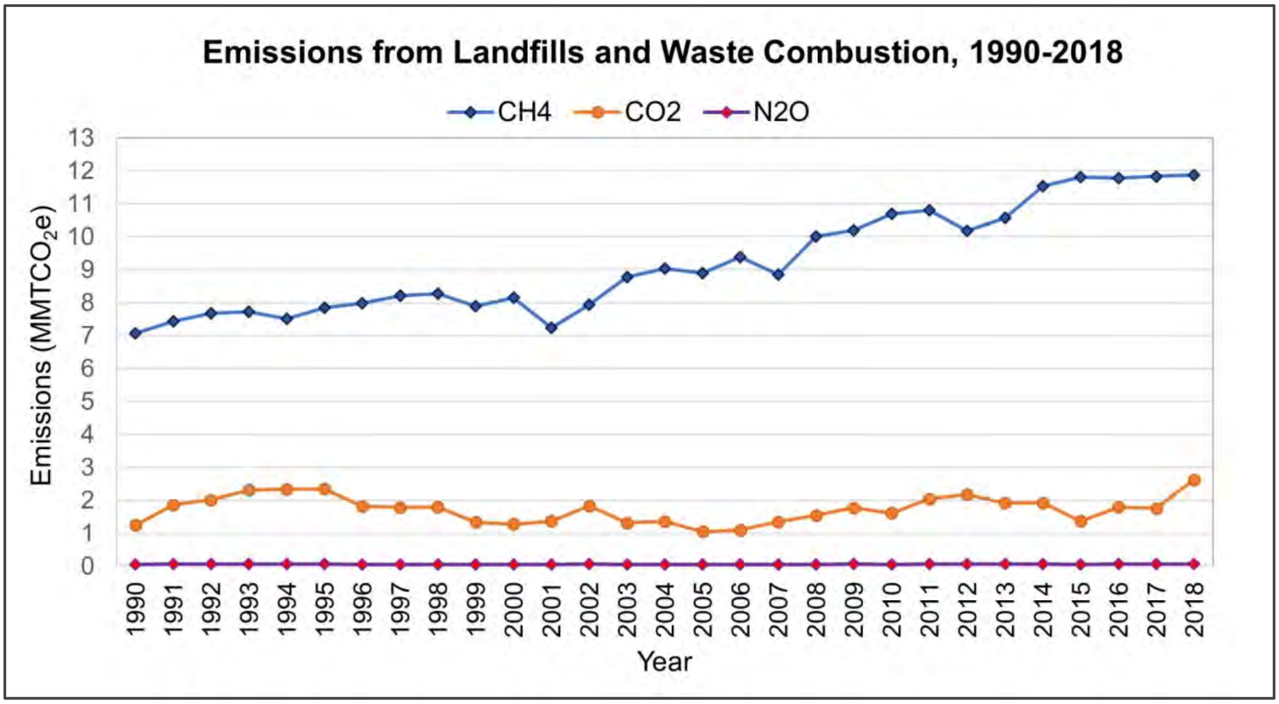

Figure 3-16: GHG emissions from landfills and waste combustion, by gas type (MMT CO_2e). Note that N_2O values are not equal to zero, but range between 0.045 and 0.073.

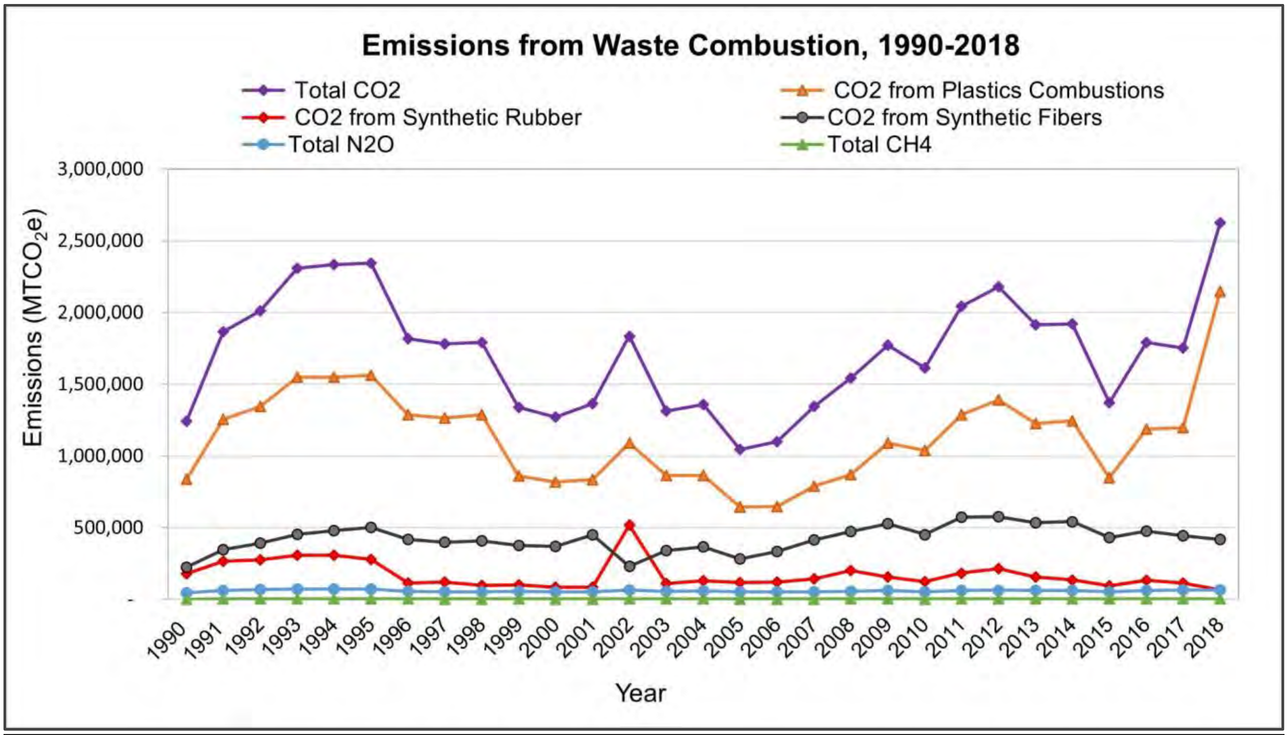

Figure 3-17: GHG emissions from waste combustion, by gas and activity type (MT CO_2e).

3.5.2. Wastewater

The Wastewater module calculates methane (CH_4) and nitrous oxide (N_2O) emissions from the treatment of municipal and industrial wastewater. To calculate the GHG emissions from wastewater, municipal and industrial categories are analyzed. The source activities considered include:

- ➢ Municipal Wastewater Treatment
- ➢ Biosolids Treatment
- ➢ Industrial Wastewater from:
    - ○ Fruits & Vegetables
    - ○ Poultry
    - ○ Red meat

Figure 3-18 represents the total wastewater emissions from years 1990-2018 by gas and sector. Figure 3-19 presents the overall total emissions produced by wastewater in MMT CO_2e. Figure 3-20 shows CH_4 emissions from wastewater produced during the processing of fruits and vegetables, red meat, and poultry from the years 1990-2018. Focusing on the baseline years of 2005 and 2018, emissions from wastewater were estimated at 2.1 MMT CO_2e and 2.4 MMT CO_2e, respectively.

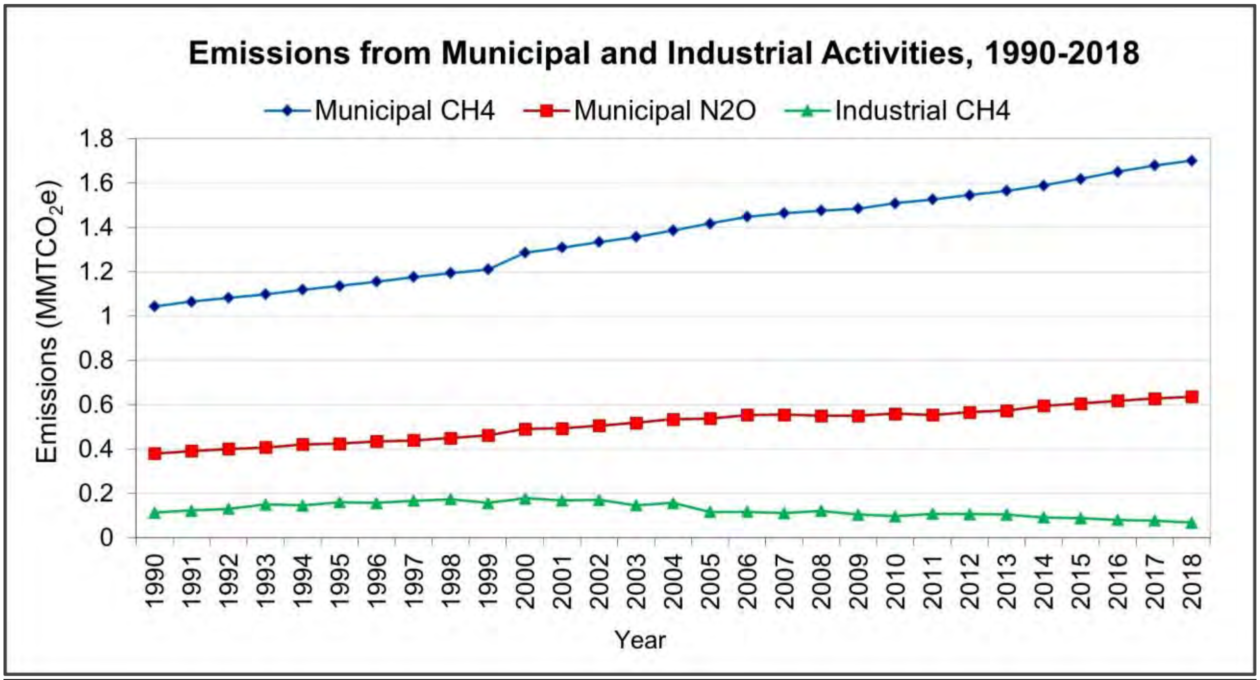

Figure 3-18: Wastewater - Historical total GHG emissions by gas and sector.

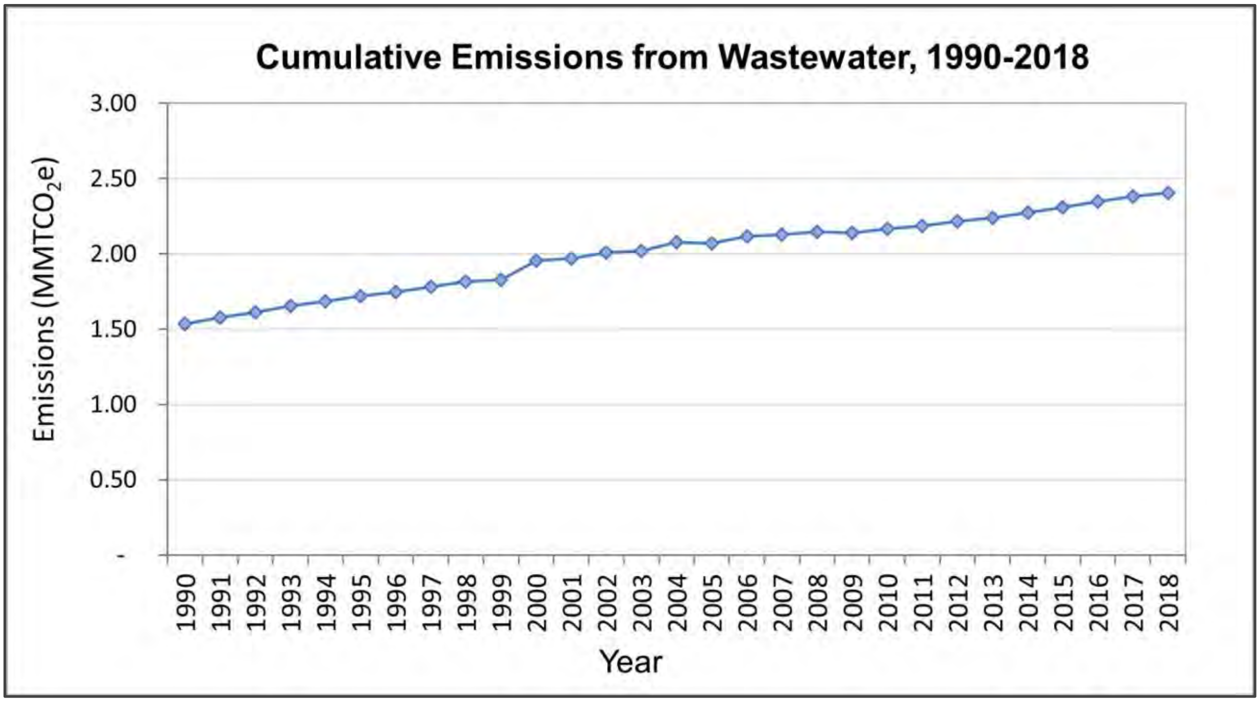

Figure 3-19: Wastewater - Historical cumulative emissions in MMT CO_2e.

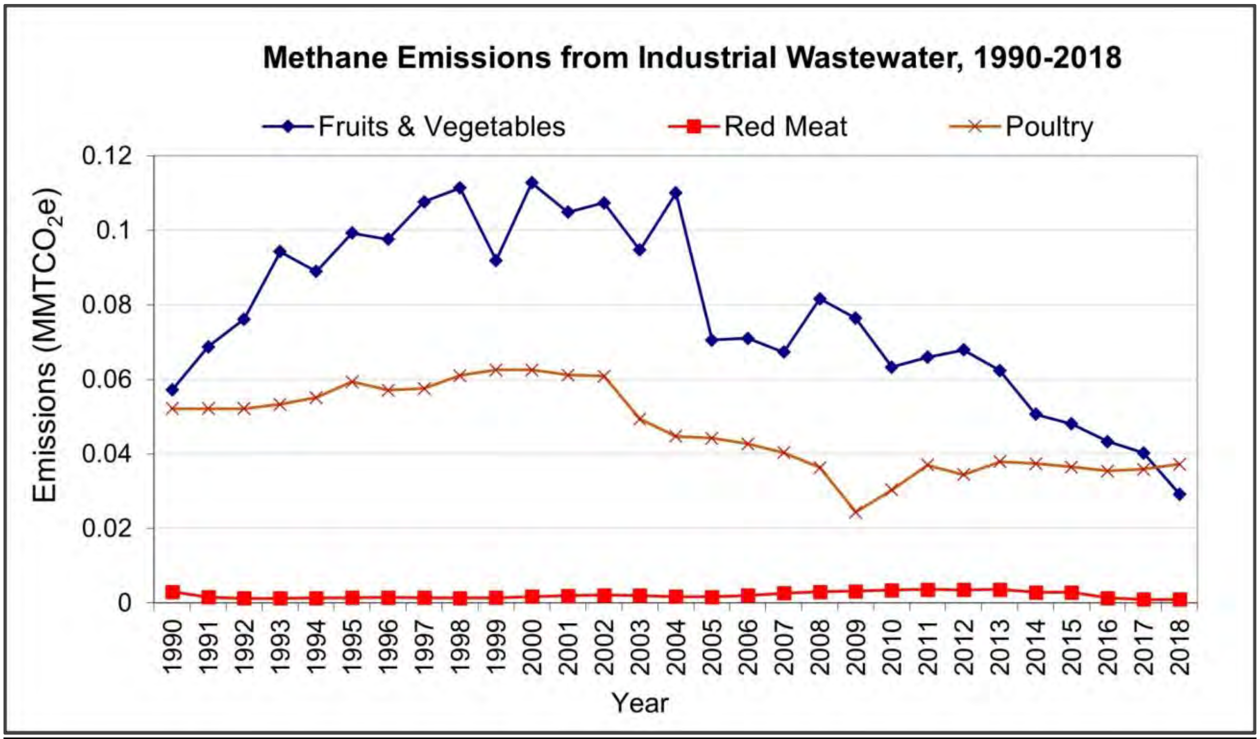

Figure 3-20: Wastewater - CH_4 emissions produced during the processing of fruits and vegetables, red meat, and poultry.

4. Total and Net Emissions

Florida's total historical GHG emissions and removals, both gross and net, are shown in Figure 4-1 and Table 4-1. A breakdown of these emissions by gas type and gas-specific unit are presented in Table 4-2. The total *gross* GHG emissions for the state of Florida in 2018 were estimated to be 304.8 million metric tons of carbon dioxide equivalent (MMT CO_2e). The 2018 *net* emissions were estimated at 292.4 MMT CO_2e, with sinks being factored in. The corresponding emission estimates for 2005 were a *gross* of 297.6 and a *net* of 293.7 MMT CO_2e, respectively. The total gross GHG emissions in 2018 were higher compared to the 2005 baseline, however, the net emissions were similar. This is attributed to the higher GHG removals from forest management activities in 2018 (-12.4 MMT CO_2e) and from coastal wetlands (-2.4 MMT CO_2e).

Although the total GHG emissions showed an increasing trend from 2005 to 2018, GHG emissions intensity [emissions per capita and emissions per million USD ($) Gross State Product (GSP)] showed a general declining trend given the increase in population in that period (see Figure 4-2). Total per capita gross emissions in 2005 and 2018 were 16.8 and 14.4 MT CO_2e, respectively and the corresponding emissions per million $ GSP were 427.1 and 293.3 MT CO_2e.

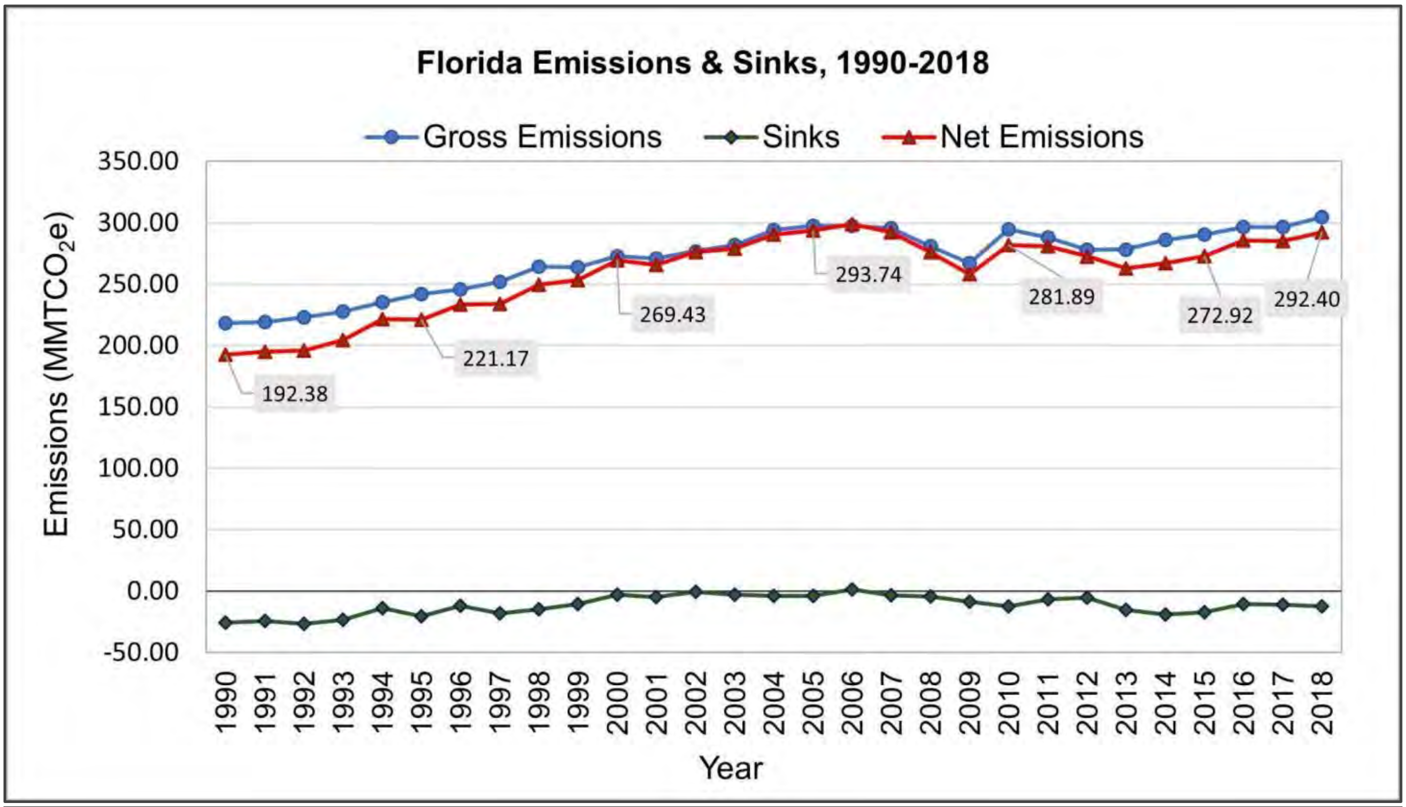

Figure 4-1: Total historical GHG gross emissions, sinks, and net emissions of Florida.

MMT CO_2e	Source of emissions	1990	1995	2000	2005	2010	2015	2018
Energy		**193.80**	**212.82**	**241.49**	**263.65**	**252.62**	**245.64**	**251.34**
Energy Combustion	CO_2 from Fossil Fuel Combustion (Appendix A)	188.64	207.81	236.63	258.27	248.26	242.01	247.72
	Stationary Combustion (Appendix B)	1.05	1.97	0.97	0.92	0.99	0.70	0.58
	Mobile Combustion (Transportation) (Appendix c)	2.63	3.15	3.22	2.72	1.59	1.15	1.09
Fossil Fuel Extraction & Distribution Industry	Coal Mining (Appendix D)	0	0	0	0	0	0	0
	Natural Gas & Oil Systems (Appendix E)	1.49	0.89	0.67	1.73	1.78	1.78	1.95
Industrial Processes & Product Use (Appendix F) (including emissions from Phosphoric acid production)		**5.36**	**7.16**	**10.15**	**12.60**	**17.95**	**19.4**	**27.05**
Agriculture (Appendix G)		**9.13**	**9.78**	**9.57**	**9.30**	**9.38**	**9.63**	**9.42**
	Enteric Fermentation	3.50	3.80	3.39	3.25	3.25	3.21	3.11
	Manure Management	0.96	0.98	1.00	0.89	0.77	0.83	0.75
	Agricultural Soil Management	4.09	4.52	4.74	4.84	4.97	5.23	5.30
	Rice Cultivation	0.08	0.15	0.12	0.07	0.08	0.09	0.09
	Liming	0.42	0.24	0.22	0.21	0.24	0.16	0.06
	Urea	0	0.01	0.01	0.01	0.01	0.01	0.01
	Burning of Agricultural Crop Waste	0.08	0.08	0.08	0.03	0.07	0.09	0.09
LULUCF* (Appendix H) (including wetlands)		**-25.81**	**-20.58**	**-3.19**	**-3.87**	**-12.59**	**-17.28**	**-12.37**
Waste		**9.89**	**11.98**	**11.42**	**12.09**	**14.53**	**15.54**	**16.97**
	Municipal Solid Waste (Appendix I)	8.36	10.26	9.46	9.99	12.36	13.23	14.56
	Wastewater (Appendix J)	1.53	1.72	1.95	2.07	2.16	2.31	2.40
Gross Emissions		**218.18**	**241.74**	**272.62**	**297.60**	**294.48**	**290.21**	**304.77**
Emission Sinks		**-25.81**	**-20.58**	**-3.19**	**-3.87**	**-12.59**	**-17.28**	**-12.37**
Net Emissions		**192.38**	**221.17**	**269.43**	**293.74**	**281.89**	**272.92**	**292.40**
Indirect CO_2 from Electricity Consumption** (Appendix K)		93.3	108.87	134.79	146.76	136.74	119.37	107.28

Table 4-1: Summary of emissions and carbon capture per sector, from 1990-2018 in MMT CO_2e.

** LULUCF: "Land-Use, Land-Use Change, and Forestry"*

****** *This is estimated as an alternative to emissions from fossil fuel combustion in the electric power sector. However, it is not included in the total emission to avoid double counting.*

EMISSIONS BY GAS TYPE	***1990***	***1995***	***2000***	***2005***	***2010***	***2015***	***2018***
Total (MMT CO_2e)	**192.38**	**221.17**	**269.43**	**293.74**	**281.89**	**272.92**	**292.40**
Total Carbon Dioxide (MMT **CO_2**)	194.40	214.75	242.82	265.09	254.05	248.57	255.81
Total Methane (MMT **CO_2e**)	16.05	21.90	21.14	22.97	26.58	27.17	27.27
Total Methane (MMT **CH_4**)	0.64	0.88	0.85	0.92	1.06	1.09	1.09
Total Nitrous Oxide (MMT **CO_2e**)	7.71	9.92	10.19	9.85	13.80	12.55	19.30
Total Nitrous Oxide (MMT **N_2O**)	0.026	0.033	0.034	0.033	0.046	0.042	0.065
Total HFC, PFC, SF_6, AND NF_3 (MMT **CO_2e**)	1.26	2.82	5.47	7.04	9.45	10.72	11.20

Table 4-2: Historical emissions for all sectors by gas type and gas-specific unit.

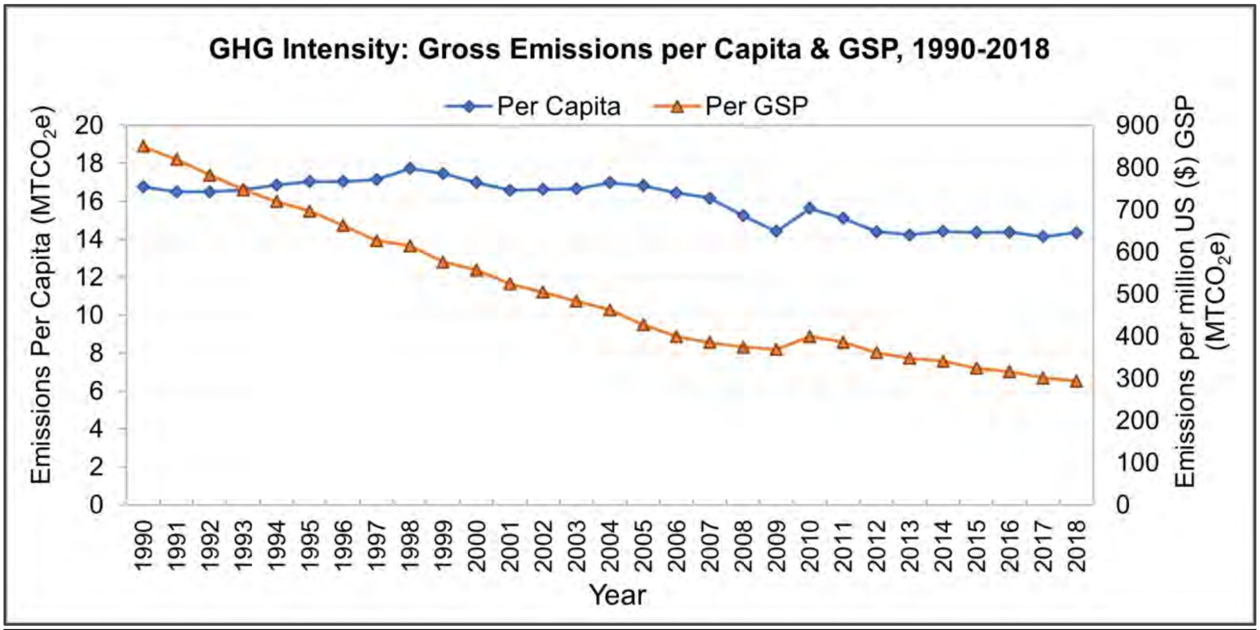

Figure 4-2: Historical GHG emissions intensity normalized with respect to per population and economic activity (emissions per capita and emissions per Gross State Product).

In 2018, the highest GHG emissions came from the energy sector (see Figure 4-3), where transportation and electric power generation (at energy utilities as well as residential, commercial, and industrial facilities) were the largest contributors. Total GHG emissions from the energy sector for 2018 amounted to 251.3 MMT CO_2e, roughly 82.5% of the state's total gross emissions. The values for the transportation and electric power generation components of that 2018 sector total are 128.6 MMT CO_2e (~42% of state gross emissions) and 122.8 MMT CO_2e (~40%), respectively.

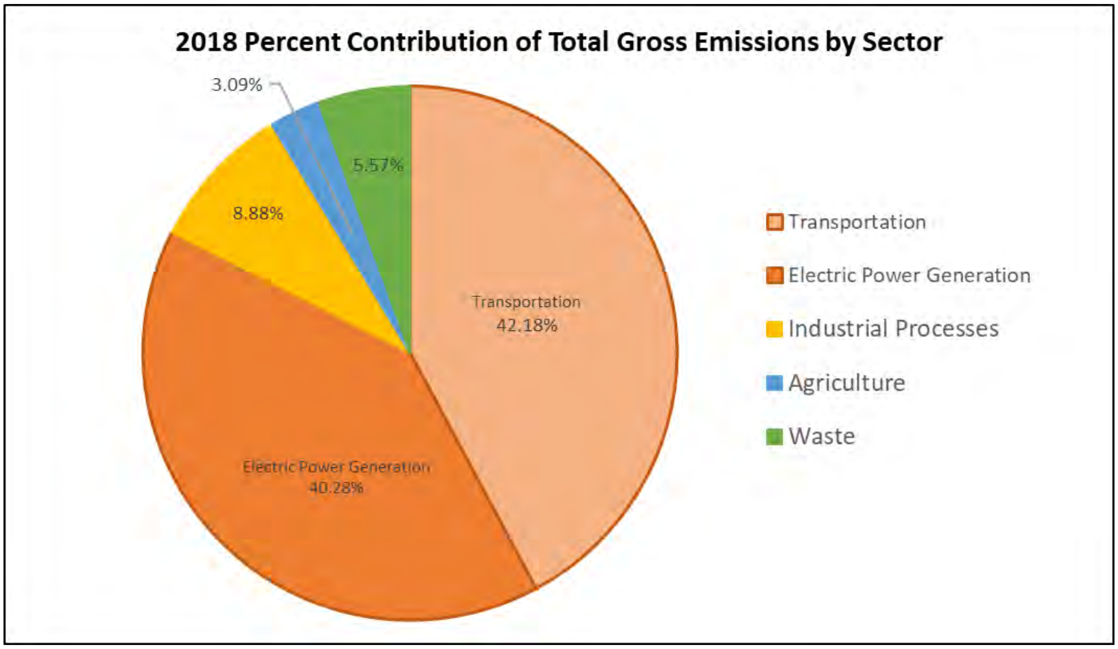

Figure 4-3: Sector-wise emission contributions of 2018 gross total. Total energy sector emissions is the sum of the transportation and electric power generation emissions, which accounts for 82.5% of the total GHG emissions for the state. *Note*: LULUCF values are not shown because they have a negative value representing the net removal of emissions.

The main fuel types for energy generation in Florida are petroleum, coal, and natural gas. As seen in Figure 4-4, the largest current and historical GHG emissions are generated from petroleum use, with emissions ranging from 110.2 to 153.9 MMT CO_2e across the entire time series. Coal was the second-largest emitter until 2009 when natural gas emissions surpassed those of coal. Petroleum is expected to be the largest contributor in the future although it has shown some decline.

In addition to estimating GHG emissions from fuel combustion for electric power generation, emissions from electricity consumption were calculated. Total GHG emissions from electricity consumption in 2005 and 2018 were 146.8 and 107.3 MMT CO_2e, respectively. There was a reduction of about 27%, which may be attributed to the use of energy-efficient systems. This is quite encouraging and useful to identify additional strategies to reduce emissions based on practical actions on the consumer side.

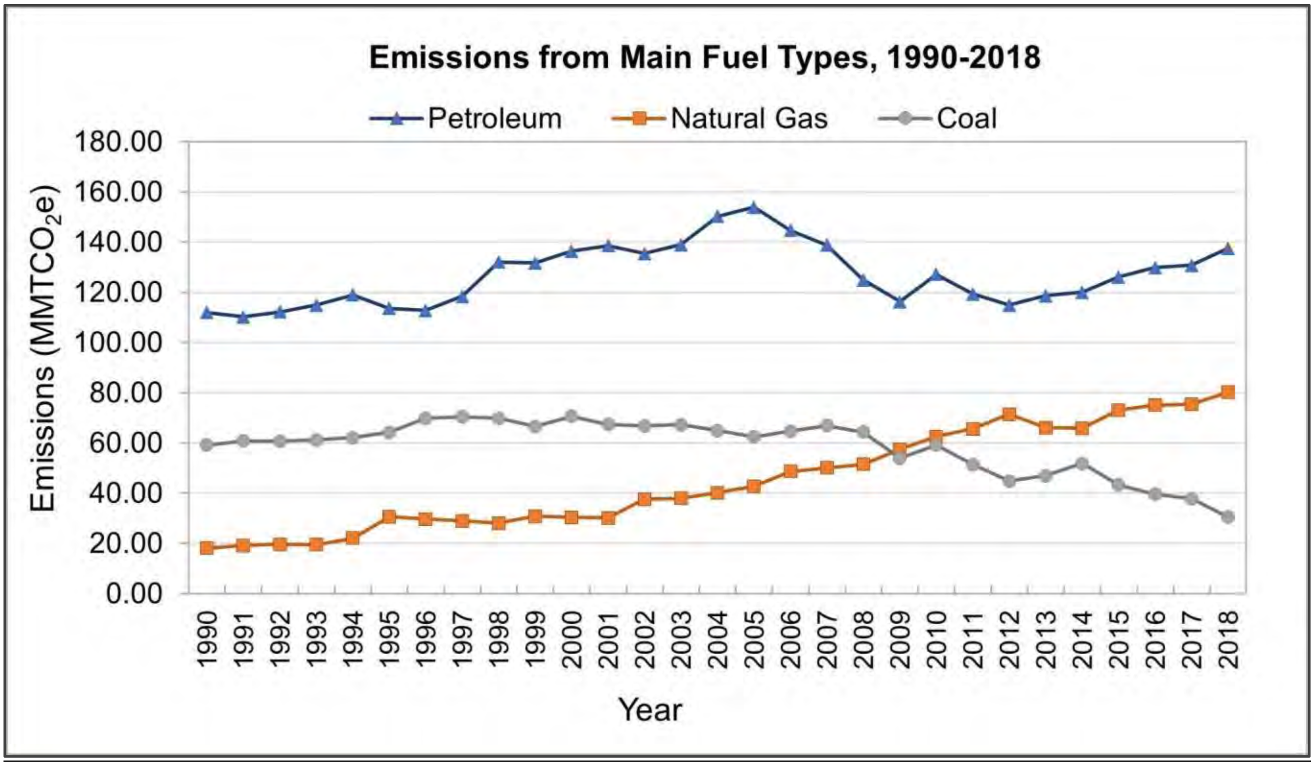

Figure 4-4: Historical GHG emissions of the main fuel types in Florida.

The EPA's Greenhouse Gas Reporting Program (GHGRP) annually requires roughly 8,000 large facilities across the United States to report information related to their activities and emissions. This information is then made publicly available and can be accessed using the EPA's Facility Level Information on Greenhouse Gases Tool (FLIGHT), which offers state-specific breakdowns for facilities and emissions. The FLIGHT tool states that in 2018, Florida's total reported emissions from reporting facilities was estimated to be 133 MMT CO_2e. Although a reliable source, the FLIGHT tool only accounts for emissions from the large facilities that are required to report information. Such facilities are classified as "large emitters" that produce more than 25,000 MT CO_2e of emissions per year. The tool clearly states that the datasets it presents do not reflect the total GHG emissions for the states for which they are estimated. Therefore, the reported value of 133 MMT CO_2e is solely the result of activities from Florida's 182 facilities required to participate in the GHGRP and does not account for any other statewide emissions. For comparison, this report estimates that total statewide gross emissions in 2018 was 304.77 MMT CO_2e, which is higher than the reported value in FLIGHT.

GREENHOUSE GAS EMISSIONS PROJECTIONS

5. Introduction

5.1. Overview

This section presents the GHG emissions projection for the state of Florida from 2019 to 2050. It extends from the GHG emissions inventory that was established for the years 1990-2018.

The sectors that contribute to sources of GHG emissions include: energy sector (electric power, transportation, residential, commercial, and industrial), industrial processes and product use (IPPU), agriculture, and waste (solid waste and wastewater). The net GHG emissions include carbon removals based on natural sequestration (such as forests and wetlands). Carbon removals can also occur by technologies that trap carbon before it is emitted into the atmosphere. We did not consider engineered technologies that remove carbon from the atmosphere (e.g., Direct Air Carbon Capture and Storage. This section also discusses actions and policy recommendations that will help achieve net-zero emissions by 2050.

In the baseline GHG inventory, about 80% of the total emissions in Florida came from the energy sector (transportation and electric power). Therefore, the main actions and strategies of the State should focus on the energy sector. Recommended actions from the other sectors are also required but to a lesser extent.

Different scenarios have been considered that represent the various pathways based on current actions and plans of the State and the Federal Government.

The scenarios considered in this report include:

i. Business-As-Usual scenario with current and planned State actions (Reference scenario)
ii. Clean electricity generation by 2035 where all the electric power for Florida comes from clean fuel sources (nuclear and renewable energy sources such as solar and wind)
iii. Net-zero emissions by 2050 based on reductions of GHG emissions and increased GHG removals. This scenario includes the clean electricity scenario.

The GHGs considered in this report include: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and perfluorinated compounds (PFCs) which includes sulfur hexafluoride (SF_6). And the total GHG emissions are reported as million metric tons of carbon dioxide equivalent (CO_2e), or MMT CO_2e.

5.2. Approach and Methodology

The GHG emissions projections were estimated using the EPA's GHG State Projection Tool. The tool has default values for most of the parameters and uses historical data that can be imported from the State Inventory Tool (SIT). The default values are mostly estimated based on national data that are distributed to State values in proportion to consumption, population, or other parameters.

The main input data for the projection tool include population, livestock, and fuel consumption. Data for agriculture, industry, and waste were also used either as default values or imported from the SIT. Population data was obtained from the Florida Office of Economic and

Demographic Research's (EDR) Florida Product data site (EDR, n.d.). Data from EDR was available until 2045 and the population from 2045 to 2050 was estimated using linear extrapolation.

Energy data mainly included fuel consumption for electric power and transportation. Fuel consumption for electric power generation was obtained from the Florida Reliability Coordinating Council's (FRCC) 2021 Regional Load & Resource Plan (FRCC, 2021). FRCC collects fuel consumption data from all power utilities in Florida. The projection data from FRCC extend up to 2030 and the data from 2030-2050 was extrapolated assuming linear growth. Fuel consumption for transportation was estimated based on EIA reports for the Southern Atlantic region where Florida is located. For the Business-As-Usual scenario fuel consumption for electric power generation is considered to decline according to the projections from FRCC. Their data show that utilities will diversify their portfolio of renewable fuel sources. Similarly, fuel consumption for transportation is expected to decrease as more electric vehicles are expected to increase in the State. According to a study by the Center for Urban Transportation Research (CUTR) for the FDOT, by 2048 about 14.6% of Florida's vehicle market will be represented by electric vehicles (Concas et al., 2019).

Since the projection tool estimates only GHG emissions from the different sources/sectors, reductions as well removals of GHG emissions based on different actions were estimated separately. Total reductions come from actions related to retiring non-renewable sources of electric power generation (primarily solar), increasing electric vehicle usage, improving energy efficiency in buildings, and other measures in the agriculture, industry, and waste sectors. Actions for GHG removals include measures in revegetation, afforestation, and coastal wetland regeneration. This report presents the gross emissions and net emissions that account for GHG reductions/removals. The net GHG emissions for the State are calculated as the difference between the gross emissions and the total reductions and removals.

6. Trends in GHG Emissions Under Different Scenarios

This section presents the GHG emissions projections up to 2050 for the three main scenarios described earlier and compares the emissions under the different scenarios.

GHG emissions trends for each scenario based on sectors, gas type, and sources of emissions are presented below.

6.1. Emissions Projection for Scenario I: BAU with existing and planned State actions

The trends in GHG emissions (1990-2050) for the reference scenario (Business-As-Usual scenario with State actions) are shown in Figure 6-1. In this scenario, the percentage of GHG emissions in 2050 from the energy, industry, agriculture, and waste sectors will be 73%, 17%, 2%, and 8%, respectively. The energy sector is the dominant GHG emission source. However, the amount of emissions declines over the years. In 2018, the GHG emissions from the energy sector were close to 80%. The decline from 2018-2050 could be attributed to the use of renewable energy sources that are coming into action by power utilities and increasing fuel efficiency in the transportation sector. In this scenario, electric power generation from coal and residual fuel will retire by 2036 and 2039, respectively.

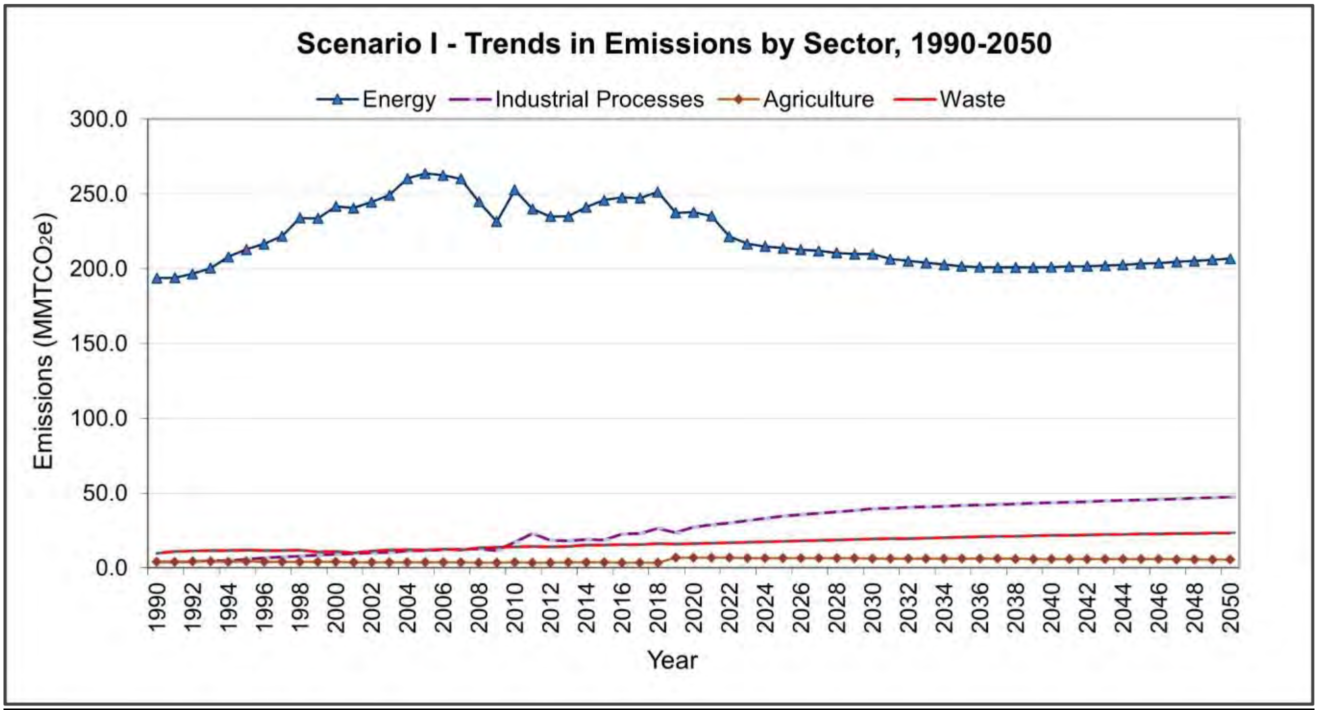

Figure 6-1: Trends in GHG emissions for the reference Scenario I (Business-As-Usual with state actions) 1990-2050.

As shown in Table 6-1, natural gas accounts for the majority of the emissions from electric power generation and it remains stable until 2050. Use of coal and residual fuel declines and both will retire before 2040.

Fuel type (BBtu)	2019	2020	2025	2030	2035	2040	2045	2050
Coal	279,653	226,498	86,587	76,480	2,522	-	-	-
Natural Gas	1,327,762	1,418,983	1,322,081	1,324,925	1,323,420	1,326,324	1,329,229	1,332,133
Distillate Fuel	18,166	17,637	692	1,082	1,973	2,496	3,020	3,543
Residual Fuel	20,056	19,465	289	182	79	-	-	-
Total	**1,645,638**	**1,682,583**	**1,409,649**	**1,402,669**	**1,327,994**	**1,328,821**	**1,332,248**	**1,335,676**

Table 6-1: Electricity generated in Florida by fuel type in BBtu.

As shown in Figure 6-2, the trend for GHG emissions intensity (emissions per capita and per million $ GSP show a declining trend.

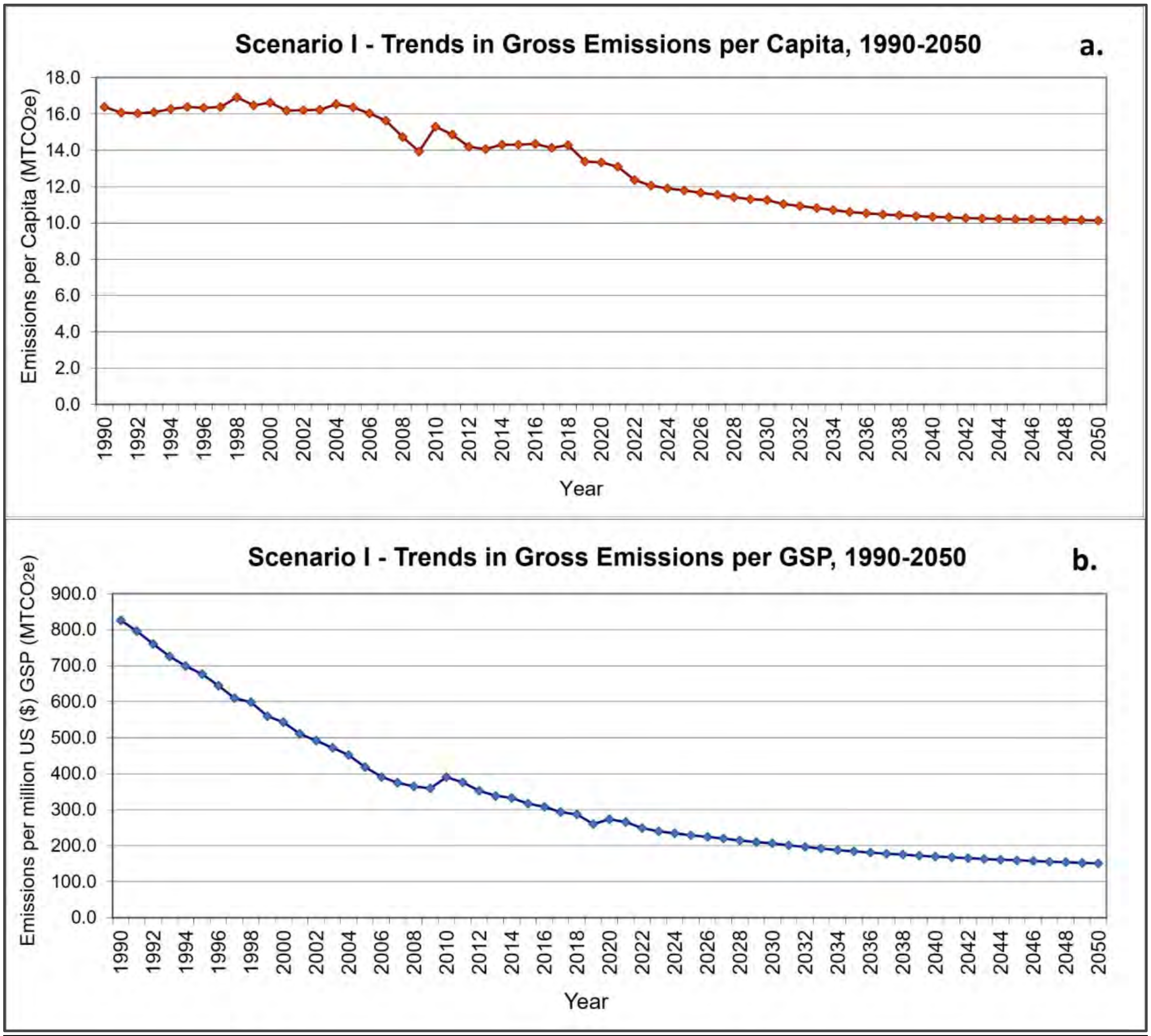

Figure 6-2: GHG emissions intensity for reference Scenario I – Business-As-Usual, 1990-2050, a) emissions per capita, b) emissions per million $ GSP.

As shown in Figures 6-3, the majority of GHG from fuel combustion is due to petroleum, and actions to reduce petroleum combustion would be important to reduce GHG emissions in the State. There are some initiatives in this regard. According to FDOT strategic plan, Florida will "Deploy surface transportation infrastructure to support automated, connected, electric, and shared vehicles (ACES) and other emerging technologies, such as the deployment of roadside sensors and communication systems, electric vehicle charging stations, electronic payment, and positive train control technologies." These plans are expected to increase the electric vehicles (EV) numbers that will reduce GHG emissions.

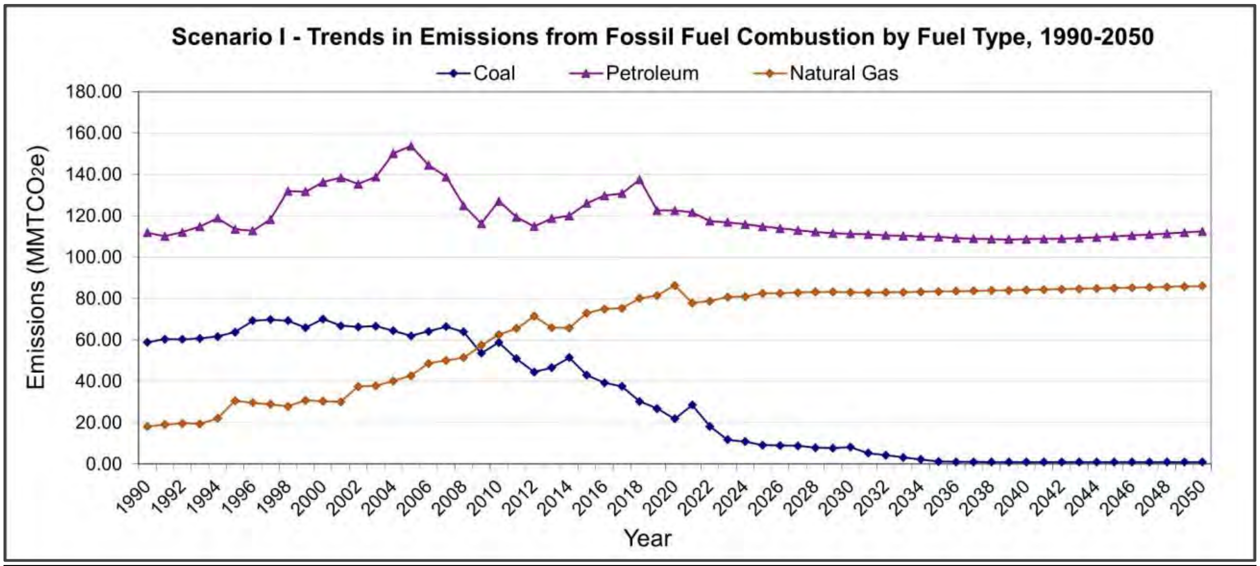

Figure 6-3: Projected GHG emissions by fuel type for Scenario I – Business-As-Usual, 2019-2050.

6.2. Emissions Projection for Scenario II: Clean Electricity by 2035

This scenario was considered in accordance with the Biden Administration's plan to achieve the generation of electricity using clean sources of energy by 2035. This implies the retirement of GHG emitting fuels such as coal, natural gas, distillate fuel, and residual fuel for electric power generation and replacing them with clean sources of energy including renewable sources (such as solar, wind, geothermal, hydropower, biomass, and waste) and nuclear. In the case of Florida, feasible main sources of clean energy include solar, nuclear, and wind. Based on the EIA's *Annual Energy Outlook (AEO) 2021*[2] report for the Southeast region (that includes Florida), the renewable capacity constitutes mainly solar (at the electric power sector and end-user), offshore wind, and stand-alone energy storage. In this report, the majority of the clean energy is considered to come from solar power at utility level and end-user (rooftops). Measures that include energy efficiency, as well as other non-GHG emitting sources such as offshore wind and nuclear, are also included. In 2021, electric power generation from renewable sources in Florida was estimated to be about 5% (EIA, 2021).

For the Clean electricity scenario, it was assumed that the non-renewable energy sources such as (coal, natural gas, distillate, and residual fuels) will gradually retire and be replaced by clean energy sources. Based on some existing plans for renewable energy by the state and aggressive measures that need to be taken to achieve the clean electricity objective, emissions were estimated by applying a percentage reduction of the non-renewable sources starting in 2023. Cumulative percent reductions were used to reach 100% clean electricity by 2035.

Figure 6-4 shows the GHG emissions from the different sectors in Florida for this scenario. The results show that the emissions from the energy sector account for about 64% of the total State emissions. This shows a drop of about 46% compared to the baseline value in 2018. This is also about 34% lower compared to emissions under the reference scenario.

[2] www.eia.gov/aeo

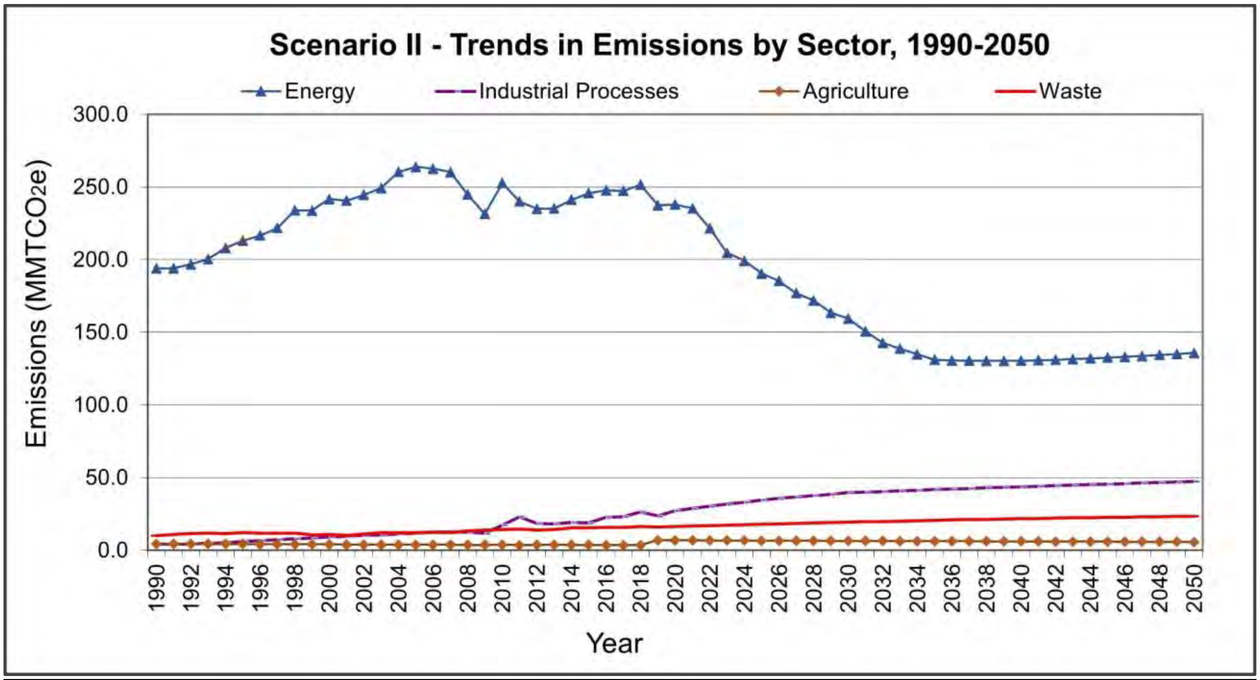

Figure 6-4: Trends in GHG emissions for Scenario II: Clean Electricity by 2035, 1990-2050.

A summary of fuel consumption (non-renewable sources) in each sector is shown in Table 6-2. In this scenario, fuel consumption from electric power generation reaches zero by 2035. The largest fuel consumption is in the transportation sector. In this scenario, fuel consumption in sectors other than electric power are based on the conditions for reference scenarios that consider current and planned State actions.

Fuel Consumption by sector	2020	2025	2030	2035	2040	2045	2050
Residential	23,074	22,796	22,551	22,670	22,816	23,030	23,332
Commercial	118,821	123,045	125,731	129,315	132,592	136,071	139,749
Industrial	215,871	236,411	245,982	257,149	269,436	285,615	304,405
Transportation*	1,557,618	1,489,388	1,437,048	1,410,889	1,394,133	1,409,532	1,439,466
Electric Power	1,682,583	986,754	490,934	-	-	-	-

Table 6-2: Fuel consumption in each sector from 2020-2050 for Scenario II – Clean Electricity.

6.3. Emissions Projection for Scenario III: Net-Zero by 2050

In this scenario, several actions have been identified that would lead to net-zero emissions by 2050. While some of the actions are based on reductions of GHG emissions, other actions are based on additional carbon removal that include sequestration by restored and enhanced natural systems. This scenario considers additional measures on top of the reductions based on clean electricity.

The main actions under this scenario include:

- Improving efficiency in electricity usage. This includes increased efficiency in residential, commercial, industrial, and public buildings.
- Support, incentivize and adopt clean electricity generation. This implies electricity generation without GHG emissions by employing renewable sources primarily from solar supported by electricity storage to also increase grid resilience. This includes residential, commercial, and industrial rooftop solar as well as small, medium, and large-scale utility solar. In order to make sure electricity is available other low-carbon energy sources can also be utilized including wind, geothermal, hydropower and biomass, and other non-GHG emitting energy sources such as nuclear.
- Transform transportation with a State-wide network of solar electric vehicle charging stations and incentivize electric vehicles in residential, commercial, industrial, and public sectors. This includes increasing transportation modes (e.g., last-mile services like Freebee, transit buses, and commercial single-unit trucks) that utilize electricity. Florida is second only to California in the number of registered electric vehicles. There are more than 2,300 public-access electric vehicle charging stations in the state (EIA n.d.). This strategy provides significant reduction potential in GHG emissions when the vehicles are charged with clean electricity supply.
- Replace a proportion of non-renewable energy consumption in the commercial and industrial sections with methane regenerated from landfilled municipal solid waste.
- Adopt highway heavy-duty diesel vehicle engine carbon capture approach applying recent advancements in carbon capture technologies.
- Substitute distillate fuels for biodiesel in non-highway HDVD including locomotives, tractors, and construction trucks.
- Accelerate the phase-out of GHG emissions from the production of adipic acid and cement and products with fluorinated gases.
- Reduce and eliminate GHG emissions from enteric fermentation and manure management with farm-scale lagoon digesters and other forms of methane and nitrous oxide capture, and supplemental feeds.
- Eliminate GHG emissions from carbon-intensive cultivation of drained organic soils by flooding drained organic soils and shift to less carbon-intensive agricultural products like those from land-based aquaculture production and effective fisheries management.
- Increase uptake of carbon in urban lands through revegetation and afforestation on relevant proportions of open space and barren lands, and low to high density developed lands. This action will also have additional benefits in terms of improving air and water quality in populated areas.
- Restore coastal wetlands lost since 1990 and increase carbon uptake from degraded seagrass meadows with water quality improvements.
- Additional coastal wetland and seagrass meadow management actions, like managing wetland transgression with increasing sea-level rise, and restoring seagrass meadows where they have been lost to targeted historical coverages. Carbon gains from these

additional management actions were not included in this scenario and represent additional opportunities for nature-based approaches to C removal.

- Additional opportunities to increase uptake of carbon by natural lands. While not included in this scenario at this time, additional carbon gain can be achieved by activities that include improved forest management to increase forest health, restoration of proportions of degraded woodlands, cultivated lands, pasturelands, grasslands (e.g., ~10,000 square miles of total land area in cultivated lands, pasturelands, grasslands alone) and wetlands, and certain agricultural practices including soil biochar amendments could also be included to increase the carbon stored in trees and soils on natural lands. This action will also have additional benefits in terms of improving air and water quality and soil health.
- Potential GHG emissions reductions from Waste sector residential and community-scale composting were not included in this scenario and represent additional opportunities for diverting municipal solid waste where regeneration as fuel is not possible, and brings with it other benefits when conducted in conjunction with the building of community-scale food gardens and generating organic resources for local farms.

Trends of net GHG emissions from the major sectors for Scenario 3 are shown in Figure 6-5.

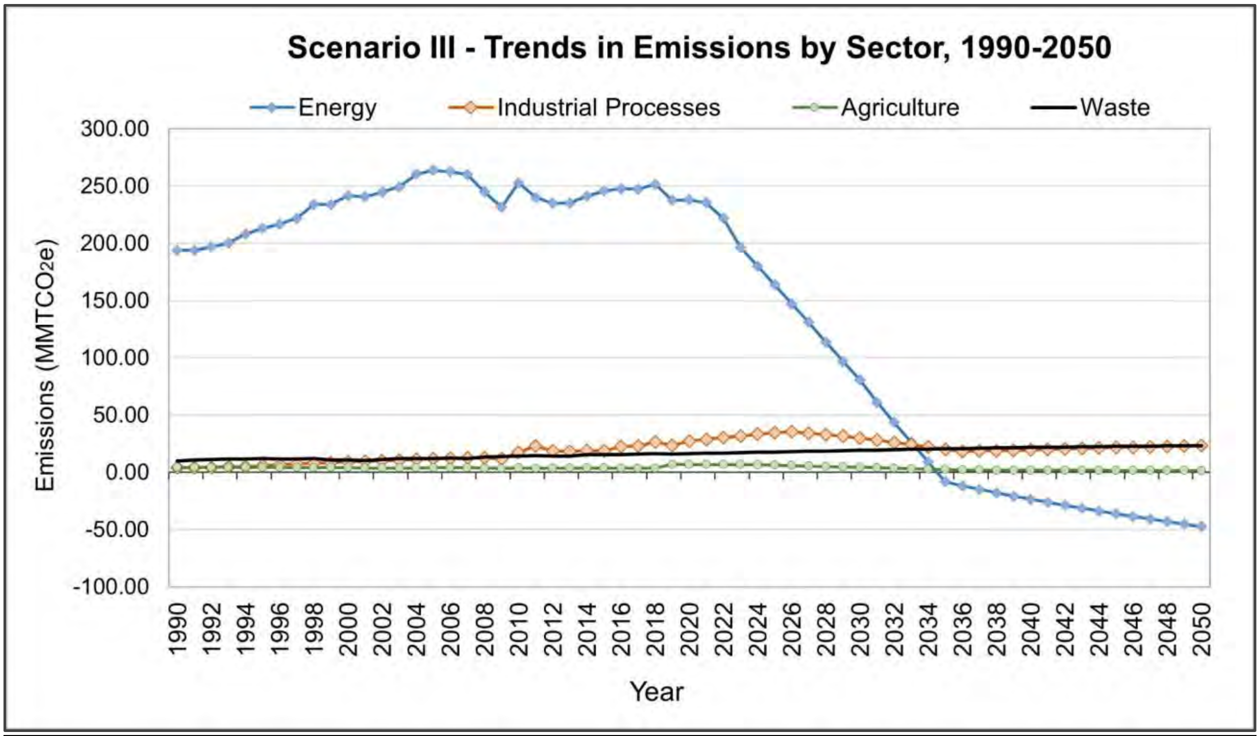

Figure 6-5: Trends in GHG emissions for Scenario III: Net-Zero by 2050, 1990-2050.

Considering the recommended actions above, the State can achieve net-zero GHG emissions by 2050. Figure 6-6 shows the net GHG emission that takes into account reduction and removal actions starting in 2023.

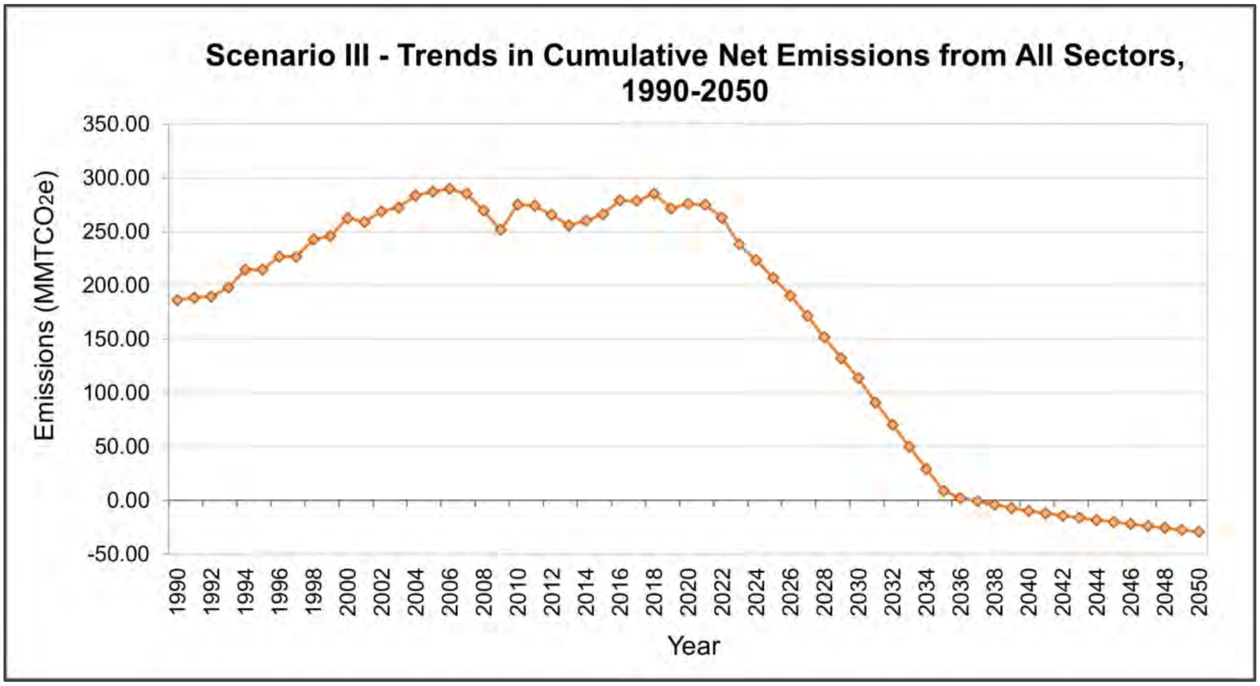

Figure 6-6: Net GHG emissions from all sectors for Scenario III – Net-Zero by 2050.

NET-ZERO ACTION PLANNING

As of 2021, the United States has officially rejoined the Paris Agreement on climate change to reduce global warming and its harmful effects. The Paris Agreement's main objective is to strengthen the global response to the threat of climate change by limiting global temperature increase to below 2 degrees Celsius above pre-industrial levels, while pursuing efforts to limit the increase to 1.5 degrees. In conjunction with the Paris Agreement, President Biden has established two overarching goals regarding U.S. climate action: ensure that the U.S. (1) achieves 100% clean electricity by 2035 and (2) achieves net-zero emissions by 2050.

As the U.S. attempts to combat climate change and reach these goals, the implementation of policies and actions at the state level become increasingly important. Given that Florida is the second-largest producer of electricity in the nation, proactive climate mitigation will have a national impact.

Within this section of the report, we will offer and describe a diverse set of potential emission reduction actions that could be undertaken in the state of Florida to reach clean electricity by 2035 and net-zero emissions by 2050. These recommendations are based on research across sectors, focusing the greatest number of actions in the largest emitting sectors, notably, electric power and transportation in the Energy sector. The suite of recommended actions are not all inclusive, but lay the groundwork for immediate and achievable emissions reductions. For each action, we provide research to support potential emissions reduction estimates as well as general information on feasibility and rough estimates of costs. The research presented here is intended to lay the groundwork for more detailed emissions reduction and cost analyses relative to the specific actions identified that were not possible within the scope of this project. Actions within each sector of the GHG emissions inventory were identified.

7. GHG Emission Reduction Potential of Specific Actions to Achieve Net-Zero by 2050

Across sectors, we identified various actions to support net-zero planning in the State of Florida. These actions support the path to clean electricity by 2035 and net-zero emissions by 2050. Specifically, Implementation across sectors is anticipated in the 2023-2025 time frame, depending on sector and action. Notably, small levels of actions launched within the next 1-3 years increase the potential for successful implementation toward net-zero emissions by 2050. Potential emission reductions are summarized across sectors, with a portion of LULUCF actions contributing to GHG removal and storage.

7.1. Energy Sector

7.1.1. Electric Power Generation and Use

Introduction

Electrical power generated through the combustion of fossil fuels generates substantial GHG emissions. In 2018, the United States' energy sector contributed 83.1% to the national total of GHG emissions, with the sector's fossil fuel combustion activities composing 92.8% of all national CO_2 emissions (EPA, 2020). From Florida's fossil fuel combustion activities alone, 247.72 million metric tons of carbon dioxide (MMT CO_2) were emitted in 2018, making it the third-leading US state in CO_2 emissions from the energy sector (EIA, 2021). In addition to CO_2, Florida's 2018 methane (CH_4) and nitrous oxide (N_2O) emissions totaled 2.44 and 1.17 MMT CO_2e, respectively. These CH_4 and N_2O emissions result from activities of stationary combustion, mobile combustion, and natural gas/oil systems. Nationally, 50% of 2018 emissions came from the US energy sector's release of both CH_4 and N_2O (EPA, 2020). The extraction, transportation, and processing of coal, natural gas, and oil for electricity generation are not only a significant source of GHGs but also expose humans to toxic air pollutants resulting in severe diseases and chronic illnesses. To combat increasing GHG emissions, we propose the implementation of solar energy initiatives in residential, commercial, and government sectors. This would significantly improve the availability of alternative renewable energy sources. In a residential setting, solar panels installed on the rooftops of homes can effectively convert the sun's energy into a clean, emission-free energy source.

The Solar Energy Industries Association stated that there have been 107,271 installations of solar systems in Florida, generating enough energy to power 1,028,589 homes. In 2020, residential solar accounted for only 4% of the state's electricity generation, which therefore presents an opportunity for a large potential reduction of GHG with new residential solar installations (Solar Energy Industries Association, 2021). Other states, such as California, have developed a policy to encourage homeowners to meet some of their electricity needs through the use of solar power. In an effort to reach 100% renewable power by 2045, the California Energy Commission introduced the California Solar Mandate. This mandate requires all new homes (with minor exceptions[3]) built after December 31st, 2019, to be equipped with solar photovoltaic systems on their roofs (Chuong, 2021). Given Florida's growing population and associated energy needs, widespread adoption of solar power would help the state reach its net-zero emission targets. Developing policies similar to the California Solar Mandate would help reduce emissions while meeting increased energy demand.

Some U.S. cities have demonstrated a commitment to sustainability and climate responsibility by implementing policies and initiatives that encourage the development of renewable solar energy. For example, Boulder, Colorado developed the Generation Solar project (City of Boulder, n.d.). The project installed solar energy systems on the roofs of 14 different facilities throughout the city. These different structures included parking garages, water resource facilities, community centers, fire stations, recreation centers, and even public safety buildings. The Generation Solar project was successful in mitigating GHG emissions while also inspiring the surrounding community to take steps towards investing in clean energy.

Incorporating solar energy into the urban design, such as street lighting can provide an effective emission-free energy source. Urban centers have a myriad of street lights illuminating sidewalks, parks, roads, and residential and commercial neighborhoods. Many initiatives have been developed throughout the U.S. to incorporate solar power within a city's energy grid, and replace electricity-powered street lighting with solar. A statewide effort would help bolster these initiatives and design a systematic framework used to replace traditional energy sources with renewable sources such as solar.

The desire to transition to renewable solar energy sources has gained momentum in recent years. Residents of urban, suburban, and rural areas have begun to understand the significance of using clean energy sources that maintain the health and well-being of human

[3] Exceptions include properties located in often-shaded areas, with too small roof space, and/or rebuilt in areas where Governor Gavin Newsom has declared a state of emergency.

communities and ecosystems. As solar photovoltaic systems become more affordable, opportunities arise for innovative designs of solar installations. For example, an initiative known as floating photovoltaics, or floatovoltaics, has been introduced that consists of solar energy systems mounted on floating expansions and placed on existing bodies of water. The Orlando Utilities Commission worked alongside developer company, D3Energy, to build a floating array over a stormwater reservoir set between waterways at the Orlando International Airport (Pickerel, 2017). Scaling this type of design at the regional and state level can provide promising benefits. Among these benefits are: reduced installation costs (as open water bodies are much more abundant than land), increased energy efficiency and yield (as water bodies create a cooling effect in warmer regions), and reduced algal growth (as solar panels provide shade for water). Therefore, the development of new technologies and innovative engineering solutions can bolster the widespread availability and use of solar energy across the state.

A recent study, conducted by researchers at the University of Central Florida and Ohio University, created multiple economic and environmental impact models to show the effects of adding new solar energy to Florida's grid[4] (Stevens et al., 2020). The team modeled three scenarios: a "low" scenario of 1.2 gigawatts (GW), a "moderate" scenario of 1.6 GW, and a "high" scenario of 2 GW. Through these models, the study outlined numerous benefits that purchase power agreements (PPAs) could bring to Florida including job creation, economic boost, and a decrease in GHG emissions.

The study found that 1.2 GW of solar energy via Florida PPAs would bring a total of 15,480 construction jobs and 138 annual O&M jobs to the state, 1.6 GW would bring 20,639 construction jobs and 184 O&M jobs, and 2 GW would bring 25,799 construction jobs and 230 O&M jobs (Stevens et al., 2020). Moreover, the researchers calculated 1.2 GW of solar energy via Florida PPAs would bring $2.3B of economic impacts to the construction phase and $15.9M of annual O&M, 1.6 GW would bring $3.1B of economic impacts to the construction phase and $21.1M of annual O&M, and 2 GW would bring $3.8B of economic impacts to the construction phase and $26.5M of annual O&M (Stevens et al., 2020). Finally, if PPAs were legalized in Florida, solar energy installations would produce millions of MWh annually, equivalent to powering 95,000 to 160,000 homes, depending on the scenario (Stevens et al., 2020).

7.1.1.1. Consumer (Residential/Commercial/Industrial) and Utility-Scale Solar

Emission Reduction Potential

Numerous states within the U.S. have developed programs and initiatives to incentivize the use of solar energy and reduce GHG emissions. For example, the California Solar Mandate aims to reduce the emission equivalent of 2.2 million cars over a time period of 30 years (approximately 10,000,000 MT CO_2e) (Penn, 2021). Another example is Boulder, Colorado. This city, located in the mid-western part of the country, developed the Generation Solar project in 2016. As mentioned in the newspaper Daily Camera, this project resulted in 2.1 megawatts of solar energy generated from rooftop and ground-based solar panel installations. In addition to this, over the next 20 years, the city expects to produce 80 million kilowatts of solar energy,

[4] Find the details and methods of their economic models at https://www.solarunitedneighbors.org/wp-content/uploads/2020/10/Impact-Analysis-of-Power-Purchase-Agreements-in-Florida.pdf

helping the city achieve its goal of operating on 100% renewable energy by 2030 (Swearingen, 2021).

In large metropolitan areas and urban settings, there are numerous opportunities to substitute some of the daily energy uses with solar energy. For example, streetlights in the U.S. annually consume as much electricity as approximately 1.9 million households and generate GHG emissions as much as 2.6 million cars just in one year (roughly 12,000,000 MT CO_2e) (Smalley, 2012). Therefore, switching to a renewable energy source such as solar allows for a significant decrease in total emissions.

Consumer-scale Solar

Across Florida, there are over 9.5M residential customers with a monthly and annual average consumption of 1,142 and 13,704 kWh (EIA, 2020). Gagnon et al. (2016) report that approximately small (less than 5000 sq ft) and medium to large (greater than 5,000 sq ft) buildings provide 343.4 Millions of m^2 and 213.6 Mm^2 of suitable roof area for rooftop solar. They estimated photovoltaic potential of 67.3B and 35.9B kWh for small and medium to large buildings, respectively, corresponding to 55% and 33% of residential and commercial/industrial consumption. At full deployment, this is equivalent to a reduction of 28 and 15 MMT CO_2 of residential and commercial/industrial electric power industry use (based on 2020 EIA data on annual sales). Deployment at a rate of 7.7% per year through 2035 achieves approximately 3 MMT CO_2e reduction per year and contributes to clean energy by 2035.

Utility-scale Solar

Across Florida, there are 44 small-to-medium scale utilities that sold 56,353 GWh of energy to Florida's consumers in 2018. Converting these utilities to solar power would reduce annual emissions by 1.8 MMT CO_2e. Deployment at a rate of 7.7% per year contributes to clean energy by 2035. The large-scale utility Florida Power and Light has made a commitment to installing 30 million solar panels or 11,700MW by 2030. The utility indicates in promotional materials on their website about the 30-30 plan that as of 2021 they've reached 40% attainment in their goal. This contribution to clean energy represents a reduction of about 7 MMT CO_2e by 2023 with a commitment that approximates another 1 MMT CO_2e per year through 2030. With an increase per year of 760MW renewable capacity, the balance in GHG emissions from electric power can be addressed through increased energy efficiency (see section 'Energy Efficiency' below).

<u>Feasibility & Financial Costs</u>

Based on the US Energy Information Administration's (EIA) Annual Energy Outlook for 2021, the 2020's renewable energy generation of solar equated to 6.35 BkWh, and its trajectory was estimated at 79.1 BkWh for the year 2050. In 2020, the solar energy consumption was approximately 0.06 quads Btu, and its trajectory estimated 0.62 quads Btu for the year 2050 (EIA, n.d.). With a population of approximately 21,500,000 people and an estimated 2.65 people per household in 2019, Florida has numerous opportunities to expand its solar energy potential. These opportunities span across the residential, commercial, and governmental sectors. Miami-Dade County has set a target for itself to produce 61,725 kW of solar energy by 2030 on County buildings, land, and water. With the help of communities and local municipalities, the County also plans to generate 794,000 kW of the same energy (Miami-Dade County, 2021). Numerous actions are already in place to help contribute to a state-level reduction of total GHG emissions from the electric energy sector. However, these actions must be implemented at a wider scale and through every possible avenue to reach these clean energy goals.

Numerous examples throughout different states showcase the different costs and numerous benefits of adopting widespread use of solar energy. In California for example, the Solar Mandate introduces flat grid access fees that could cost customers an additional $50 to $86 per month while reducing legacy rates for current consumers (Anderson, 2021). The article, "Why California's new solar mandate could cost new homeowners up to an extra $10,000," explains that mortgage payments are expected to see an increase in average monthly amounts of $40, but this cost becomes neutralized by the average monthly savings of $80 on lighting, cooling, and heating. Although monthly costs at the start of this sustainable process may seem high, the calculations of benefits in energy savings can reach $200 a month for a long-term period (Gillies, 2019).

There are multiple opportunities for incorporating solar energy throughout the urban landscape. Innovative designs and applications can be created to use solar energy to meet our energy needs while mitigating GHG emissions. For example, the use of solar power for street lighting has promising potential. Although an aggregated estimate of energy and maintenance costs for streetlights in the U.S. amounts to about $2 billion annually (Smalley, 2012), industry professionals suggest that $1,500 in energy costs can be saved on one singular streetlight over a span of 10 years (Tenkoo, 2021). When considering the initial cost necessary for the installation of an all-in-one solar street light several costs need to be included. These costs are associated with the materials required, such as batteries and LED lights, along with the body lamp (which ranges in average cost from $90-200) and the installation cost (Solar Feeds, 2021).

In addition to this, innovating ways to effectively capture solar energy can lead to new opportunities. Some solar installations may incur less installation and maintenance costs compared to others. For instance, a floating photovoltaic system on either an artificial or natural water body, has associated expenses related to the structural balance of the system (floats, anchoring, mooring, etc.), site staging, electrical components, and other soft costs (permitting, inspection, tax, engineering, etc.). After a rough calculation of operations and maintenance from necessary costs, a benchmark model assumption of the total would be $1.29/WDC, which is about 25% higher than the cost of a ground-mounted system benchmark assumption (Ramasamy and Margolis, 2021). Therefore, choosing the right method of incorporating solar energy into the energy budget of a city is intrinsically tied to the city's financial resources, urban design, and leadership.

While the cost of consumer-scale solar is born by the consumer, funds to assist consumers with loan assistance, financial assessments, and solar system technical support that help build consumer confidence by reducing upfront installation costs to the minimum and packaging energy cost savings into near-term low-interest loan payments could accelerate the adoption of consumer-scale solar. Assuming loan, financial and technical assistance was based on 3 hours of staff support for each consumer at a deployment rate of 7.7% and a staff salary of $50K + 30% fringe benefits, would approximate $54M per year.

For utility-scale solar, applying a cost of $2.31M/MW through 2029 and $1.73M/MW from 2030-2035 with a scaling factor of 5%, 10%, and 20% cost savings for systems 30MW-300MW, 301MW-2.5GW, and 4GW in size, respectively. The cost includes materials, installation including battery storage, and other costs (Quinn, 2019). Using the estimated number of customers for each utility and an average bill of $128/month, applying 20% of the bill and investing the proposed FPL approximate cost increase (~$16/month) into solar system transformation of these small to medium scale utilities, would offset any additional costs to consumers and payoff the utilities' investments in approximately 20 or fewer years after which revenues to these utilities would likely increase significantly.

7.1.1.2. Energy Efficiency

Introduction

In the process of transitioning to clean energy, energy efficiency is a key consideration. In the southeastern region of the US, the Tennessee Valley Authority (TVA) and Florida Power & Light (FPL) are among the largest in the area. However, to date, there is limited oversight of utility-administered energy efficiency programs in Florida (Bradley-Wright et al., 2022). Preliminary assessments estimate that FPL is spending as much as three times more per kilowatt-hour of savings compared to other facilities, yet the exact values are difficult to assess since Florida utilities do not conduct industry-standard program evaluations (Bradley-Wright et al., 2022).

Numerous opportunities exist to increase energy efficiency in the generation, transmission, distribution, and sale of electric energy. FPL remains the largest energy provider in the State and could offer millions of families the opportunity to eliminate energy waste and lower their electric bills, while also reducing associated emissions. Yet, the current regulatory framework excludes the most cost-effective efficiency measures, and FPL remains resistant to implementing modernization procedures that would increase energy efficiency (Bradley-Wright et al., 2022).

FPL is owned by NextEra Energy, Inc., a company that prides itself to be leading the field in a leading clean generation. However, having FPL as a subsidiary, much of its energy is still reliant on fossil fuels, and consequently, it was removed from the S&P Global Clean Energy Index (Bradley-Wright et al., 2022). NextEra claims to decarbonize and has announced short-term targets such as reducing its emissions rate (CO_2/MWh) by 67% from its 2005 levels by 2025. While this is a promising start, given the company's projected growth over the next decade, the total annual emissions could increase even though the company claims to have reduced its emission rate (Bradley-Wright et al., 2022).

Emission Reduction Potential

Wilson et al., (2017) estimated that economic potential electricity savings from energy efficiency upgrades using available technology that meet cost-effectiveness criteria for a US residential and single-family detached households were 21.9% and 17.4%, respectively. Through 2035, we estimated emission reduction potential from the percent uptake of energy efficiency measures as 18% reduction (kWh) of 50% of the number of residential consumers in single-family detached households. We estimate a 12% reduction in 25% of those total consumers (estimated as multifamily). Another 10% of the total consumers received an ECOkit which is estimated to reduce up to 206 kWh per year per household. We also estimated a 12% reduction in kWh of 75% commercial buildings and a 25% reduction in kWh of 75% industrial buildings through 2035. The cumulative emission reduction by 2035 approximated 11 MMT CO_2e and about 0.8 MMT

CO_2e/yr. By 2050, we estimated a cumulative reduction of 24 MMT CO_2e Greater uptake of energy efficiency measures would further increase the potential emissions reductions.

<u>Feasibility & Financial Costs</u>

Costs for energy efficiency upgrades were included in the estimated costs of services to help home and business owners identify rebates and other forms of financial support and package financial assistance as loans that were paid back using the cost savings from monthly electricity expenditures.

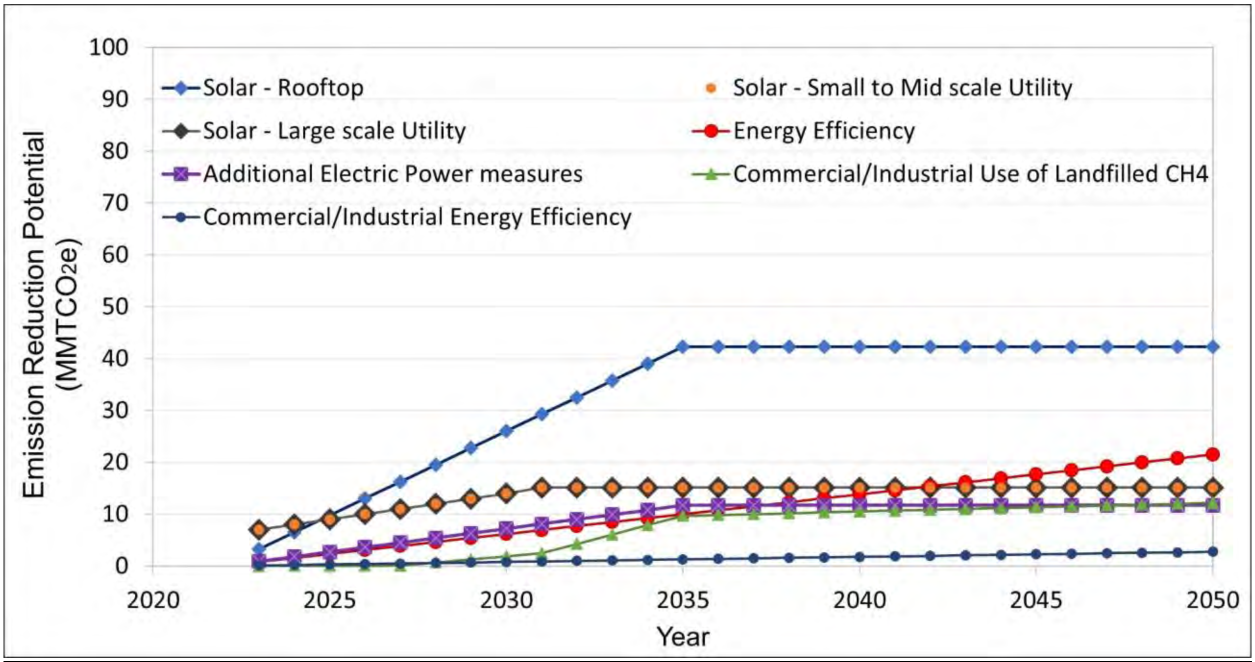

Figure 7-1: Cumulative emission reduction potential for electric power generation and energy consumption (in residential, commercial, and industrial sectors from other sources) (MMT CO_2e).

7.1.2. Transportation

7.1.2.1. Electric Vehicle Charging Infrastructure

<u>Introduction</u>

Emissions from the internal combustion engine of cars are a significant contributor to overall GHG emissions. The use of cars, trucks, and other automobiles is central to everyday life for most Floridians and will continue to be for the foreseeable future. However, innovations have paved the way for the mass production of battery-powered electric vehicles that do not produce tailpipe GHG emissions, but the source of energy used to generate electricity more than likely does electric vehicles (EVs) have increased in popularity throughout the country, with their rate of adoption is projected to continue to grow exponentially from one year to another.

Projection estimates show that by 2030, 1.16 million EVs could occupy Florida's roadways (FDACS, 2020). Florida Power and Light projects 8.25M EVs in the FPL and Gulf Power Service

Territories of Florida, including passenger, commercial, and bus EVs by 2040 (Cox, 2020). Therefore, it is critical that the proper infrastructure is developed to support the growing interest and the adoption of electric transportation alternatives. Not only should residents be able to easily access charging stations during their daily commute, but also be able to efficiently charge their vehicles during emergencies, such as storm evacuations. Estimates show that in 2018, the average car occupancy was 1.5 persons per vehicle (Davis & Boundy, 2020). Using that value along with the projected 1.16 million EVs in 2030, roughly 1.74 million lives could be at risk during a state-of-emergency evacuation, because of limited charging infrastructure to support the use of electric vehicles. Notably, the economic and social value of battery electric vehicles (BEVs) is significant. For instance, BEVs promote GHG emissions reductions in the transportation sector by fuel switching from gasoline and diesel to the fuel mix of the Florida grid with increasing contributions of solar energy over time. Further, BEVs are more resilient (as electricity is an energy carrier and not an energy source and it can be generated from a wide diversity of sources) and create profound opportunities in the ancillary grid services of battery storage. Since vehicles only spend about 5% of their lifespan in transit providing mobility services, the shift to BEVs opens up the other 95% of their potential value in backing up the electric grid.

Emission Reduction Potential

Increases in solar EV charging station infrastructure further offset GHG emissions from the energy sector by transitioning the energy source from fossil fuels used to power electrical utility energy production and supports grid resilience when utilities need to be shut down in advance of an approaching hurricane and grid disruptions including power outages incapacitate both gas and EV charging stations, stranding passengers in unsafe conditions. Transforming and expanding EV charging with solar infrastructure and battery storage not only confers resilience to the energy infrastructure but also optimizes EV climate mitigation capacity by shifting the power source from fossil fuels at the utility plant to solar. We estimated GHG emissions reductions by approximating the number of solar EV charging stations that could service approximately 1.1M vehicles per year (8 highway stations with 2 DCFC plugs and 4 Level 2 plugs at a charging rate of 35 mins per vehicle and 16 local stations with 1 DCFC plug and 2 Level 2 plugs at a charging rate of 20 mins per vehicle) or powering approximately 14B vehicle miles traveled per year. A deployment rate of about 7.7% a year would achieve about a 5.7 MT CO_2e reduction in emissions per year, with a cumulative annual reduction of 74 MMT CO_2e at full deployment by 2035.

Feasibility & Financial Costs

Other states have successfully implemented incentives and programs to support the development of EV charging infrastructure. In Florida, some local municipalities have developed their own incentives to encourage local charging station installation. More so, the state has entered into public-private partnerships with large companies to install charging stations along major roadways. While these projects have the potential of increasing EV charging infrastructure over time, a state-led initiative would catalyze a statewide market expansion and significantly improve widespread access to emission-free methods of transportation.

Transforming and expanding the network of electric vehicle charging stations with solar charging infrastructure has become feasible with recently appropriated federal infrastructure funding. We estimated that a highway station would require a 1.5MW system, which includes a

500kW solar system and 1MW battery storage (and approximately 3 hectares of land (e.g., parking lot) or roof area) while a local station would require a 500kW system. Due to rapidly decreasing costs for solar technology and batteries, the 2026 cost for a 1.5MW is estimated at $3.46M per highway station and $1.15M per local station while the 2030 cost for a 1.5MW is estimated at $2.59M per highway station and $0.86M per local station (Thalia, 2019). We estimated full deployment could be achieved with an annual investment of $46M through 2029 and $34.6M from 2030-2035. The costs estimated do not include revenues from selling solar electricity at EV charging stations.

Another opportunity to reduce transportation emissions that complements solar EV charging stations for passenger vehicles focuses on increasing solar charging infrastructure stations as heavy-duty single truck and bus fleets transition to hybrid and electric vehicles, and substituting biodiesel for distillate fuels in heavy-duty non-highway vehicles. The Federal Highway Association reported in their highway statistics that in 2018 gasoline and diesel fuel oil consumption from construction activities was the highest in Florida of any other state (45.9 Mgal and 746.5 Mgal, respectively), overtaking California and Texas in 2015. Diesel fuel oil consumption in Florida is 12% of the national 2018 total. Diesel fuel oil consumed by locomotives overtook California in 2016 and second only to Texas in 2018 at 314.2 million gallons.

We applied the total US fuel consumption by heavy-duty highway vehicles including trucks and buses to estimate the fraction of bus, single-unit truck, and combination truck distillate fuel emissions (CO_2e) in Florida. Based on the fact that most HDV trucks were reported to use distillate fuel in 2018 (with the notable exception of buses due to the lack of a source showing the fraction of fuel type for FL buses at the moment), we found that approximately 16.7, 9.6 and 1.5 MMT CO_2e for combination trucks, single-unit trucks and buses, respectively, were emitted by distillate fuel consumption. The FHWA also reports that in 2018, the average miles traveled per gallon of fuel consumed was 6.1, 7.5 and 7.3 for each HD vehicle type, respectively. Thus, given the increasing adoption of alternative fuel types for buses, single-unit trucks are a new opportunity for reducing emissions and lowering costs in transportation emissions. For non-highway heavy-duty vehicles, locomotives, tractors, and construction trucks primarily rely on distillate fuels (e.g., diesel) and emit nearly 3 MMT CO_2e per year.

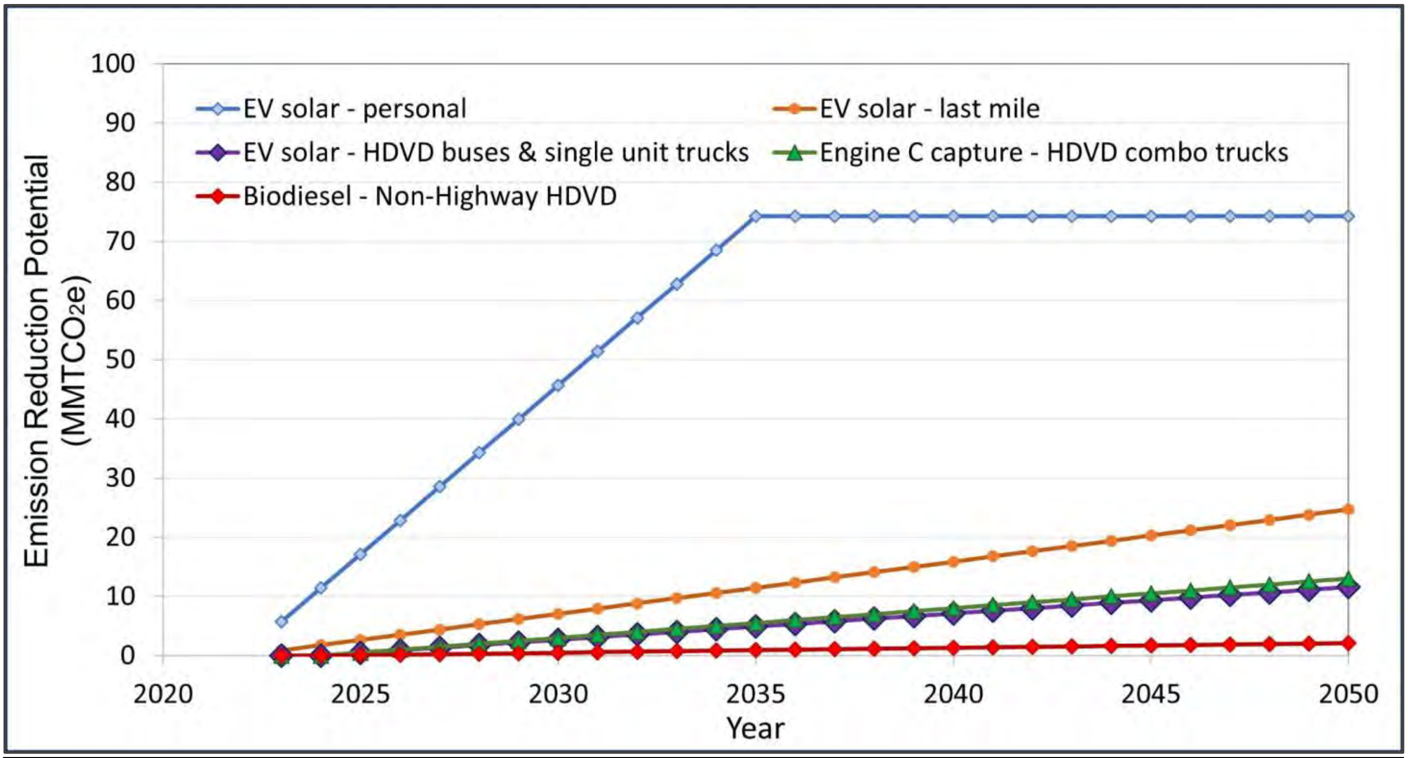

Figure 7-2: Cumulative emission reduction potential from transportation activities within the Energy sector (MMT CO_2e).

7.2. Industrial Processes & Product Use Sector

7.2.1. Concrete & Cement

Introduction

Concrete is a widely-used building material. It is used to construct foundations, floors, trusses, and other compressive stressed structural components. Most commonly, concrete is composed of three elements: water, aggregate, and portland or blended cement, though emerging alternatives integrate other components into the mixture. Applications for concrete range from small to large, and from personal to commercial to industrial uses. The most common applications are for large-scale commercial, industrial, and civil infrastructure construction projects. Over the last 30 years, the production value for ready-mix concrete manufacturing in the United States has grown from approximately $12 billion in 1990 to over $32 billion in 2018 (FRED, 2021).

Production of concrete is relatively low-tech, and the materials are abundant, which helps to make concrete an affordable material. Its affordability and versatility have helped make it one of the most important and widely used building materials worldwide. According to Solidia Tech (a green cement and concrete technology start-up), cement and concrete are generally used within a 250-mile radius of their production from locally-sourced raw materials. Their collective demand is second only to water itself from a human consumption standpoint (Solidia, n.d.). While early forms of concrete were first used over 6,000 years ago, the industrial revolution brought the aggregate binding power of portland and blended cement to modern concrete (which has generally stayed the same for the last 200 years) (Solidia, n.d.; Barber, 1995). Despite the profound importance and benefits of portland cement concrete to human society, its production process has made it one of the world's most energy-intensive and environmentally destructive building materials.

The importance of portland and blended cement concrete in the state's built environment cannot be understated as Florida is one of the largest producers and consumers of building materials in the U.S. According to the Mineral Industry Survey for Cement in January 2021, Florida was the fourth leading state producer of portland and blended cement (behind Texas, California, and Missouri) (USGS, 2021). It was also the third leading cement-consuming state (behind Texas and California), the leading masonry-cement-consuming state, and the fourth leading clinker-producing state (behind California, Texas, and Missouri). In Florida, portland and blended cement concrete is a common building material used at all scales of construction, including a significant part of large-scale commercial, industrial, and civil sectors.

Emission Reduction Potential

To counter current and future levels of GHGs, this reduction proposal aims to provide several decarbonization strategies, including (1) methods to replace and reduce the amount of portland cement used to produce concrete; (2) use of alternative aggregate in concrete production; (3) approaches to promote more efficient concrete usage in construction projects; (4) carbon sequestration through carbon capture and carbon injection technologies, (5) adopting an act to reduce embodied carbon in public procurement; and (6) developing a tradable low carbon cement standard (Table 7-1).

Decarbonization Strategy	Description
Cement Reducing Measures	Use pozzolan or chemically bonded phosphate ceramics (CBPCs) materials to some or all portions of cement in concrete
Alternative Aggregate	Use calcium aggregate extracted from demolished or unused concrete to trap CO_2 as an alternative to traditional aggregate
Efficient Concrete Usage	Investment in digital concrete solutions
Carbon in Concrete	Use carbon injection technology to place CO_2 gas directly into a concrete mixture
Regulate Large-Scale Public Projects	Pass an act to require the use of low embodied carbon technologies on large-scale public projects
Create Carbon Credits Marketplace	Develop a tradable carbon credits marketplace for cement producers and importers

Table 7-1: Decarbonization strategies for concrete production.

Feasibility & Financial Costs

Reducing the amount of cement used in concrete production should theoretically reduce the energy needed and environmental damage created in the concrete producing process. Currently, materials are used to replace some cement in the concrete mix, including fly ash, slag cement, and silica fume. Although these admixtures benefitted the concrete industry for decades, each additive is a hazardous byproduct of their respective industrial processes. Each of these industries worldwide is taking measures to reduce their toxic byproducts, reducing the availability of these admixtures. As a result, the cement industry has turned to alternative methods/technologies to improve its product's workability and reduce its carbon footprint. In other words, it is neither possible nor appropriate to continue to rely on these more diminishing byproducts as additives. Rather, this scenario is highly feasible as cement producers are beginning to look at various alternatives to differentiate their products.

Some aggregate producers and suppliers in Florida carry recycled aggregate as an alternative to virgin crushed stone. The Environmental Protection Agency (EPA) recently approved the use of phosphogypsum, a radioactive waste product of phosphate mining, as a synthetic aggregate alternative for roadways (Sampson, 2020; Florida Polytechnic University, 2020). Unlike phosphogypsum, Blue Planet Systems developed their synthetic aggregate for carbon sequestration. However, the current scale of production and plant location make Blue Planet Systems' aggregate unfeasible as a large-scale aggregate alternative. The company has recently seen investments from a number of companies, including Knife River, a top 10 aggregate producer in the United States (MDU, 2020).

To add carbon to the concrete mixture, companies first capture the carbon and then inject it. The companies acquire CO_2 by different means, including carbon capture technology on cement and coal plants and purchasing CO_2 from local industrial gas supply companies. These companies (CarbonCure and Solidia primarily) have been used in, or have connections to, Florida. Their ability to scale up and use the existing ready-mix concrete infrastructure for their product makes its use in Florida highly feasible.

Artificial intelligence (AI) and machine learning (ML), Computer-Aided Design (CAD), and Building Information Modeling (BIM) are some of the technologies already in existence, and to a varying degree, in use in the construction industry to implement concrete construction more efficiently. The results include a few benefits to safety, quality, cost reduction, build time reduction, and new design options. (Nyugen et al., 2021; Taffese & Sistonen 2017; De Schutter et al., 2018). Digital concrete applications have allowed for the development of structurally engineered shapes that focus load-deflection while providing strength comparable to traditional concrete elements. As computation, mechanization, automation, and virtual design and construction (VDC) technologies continue to expand into the processes for creating our built environment, innovations such as 3D printed building envelopes give an age-old building material a new approach through additive construction of novel concrete mixes and properties (ICON, n.d.).

Low embodied carbon concrete products are currently being used by governmental entities in various applications, including large-scale public projects. Therefore, using new technologies that reduce the carbon footprint associated with cement production is feasible. A growing list of strategies/technologies are reducing the carbon emissions associated with concrete, and government procurement principles to reward the most sustainable strategies in the concrete industry would further push companies toward sustainable solutions (Adaloudis & Bonnin Roca, 2021).

The Portland Cement Association (PCA), a policy, research, and education organization for America's cement manufacturers, supports a cap-and-trade mechanism for American cement manufacturers (Portland Cement Association, 2021). PCA is supported by some of the largest cement manufacturers in the U.S. Additionally, other states have implemented a Cap and Trade Program. As described by the Climate Policy Institute (CPI), there are barriers for cement manufacturers to implement greenhouse gas abatement options into their manufacturing process (Zuckermen et al., 2014). However, the feasibility lies within the implementation and policymakers' decision-making to help address some of those barriers.

Cement alternatives have traditionally cost less than the production of cement. Pozzolans are cheap and effective. Pozzolans are estimated to be 40-80% of portland cement cost (Adams, 2018). Different products have different cost estimates. For example, the cost of Blue Planet aggregate is between $70 and $100 per ton (approximately $63 to $90 per metric ton) (Kim, 2017). According to the U.S. Geological Survey (2021), the price for crushed stone per metric ton in 2020 was approximately $12 per ton. In addition to this, it has been suggested that 3D concrete printers can effectively reduce costs, whether onsite or in a warehouse. Researchers at the University of Nantes stated they built a home with a 3DCP at 20% less cost than traditional methods (Vihaan, 2022). Cost reduction comes from reduced labor and build times. Researchers at ETH Zurich estimate a 70% cost reduction when compared to traditional concrete approaches with their FoamWork (Hahn,2022; Hobson, 2021). However, the cost of implementing legislation for large-scale public projects or a cap-and-trade mechanism is virtually zero. We estimated a 10% annual reduction in cement production emissions starting in 2027.

7.2.2. Adipic Acid

Introduction

Hexanedioic acid, commonly known as adipic acid, is a solid crystalline monomer used to create materials like nylon and other polymers (ACS, 2015). In the entire United States, there are only two active plants for adipic acid production, one located in Texas and the other in Florida. Florida's facility, Ascend Performance Materials (APM), is the largest adipic acid plant in the country (McKenna, 2022). The typical process to artificially produce adipic acid is by oxidizing the ketone-alcohol oil mixture, also known as KA oil, with the use of nitric acid (ACS, 2015).

Nitrous oxide (N_2O) is the greenhouse gas (GHG) emitted from adipic acid production, which once emitted, is said to linger for over 100 years in Earth's atmosphere (ACS, 2015; EPA, n.d.). This GHG is defined as having a 100-year global warming potential (GWP) somewhere between 265 and 295 times more than carbon dioxide (CO_2) (EPA, n.d.). Reductions of N_2O emissions from the production of adipic acid is an effective and well-studied process. There are four main mechanisms that production plants can implement into their operations to achieve emission reductions: 1) Catalytic destruction; 2)Thermal destruction; 3) Recycling to produce other chemicals, such as phenol and benzene; and 4) Recycling to produce nitric acid (Climate Action Reserve, Adipic Acid Protocol 2020).

Both plants in the United States already employ these GHG reduction mechanisms and reduce a majority of emissions. Additionally, Florida's APM plant is part of the Climate Action Reserve's carbon credit program to reduce national N_2O emissions and participates in their Adipic Acid Production Protocol. This is a system designed to help entities reduce emissions through financial incentives such as trading carbon credits.

Emission Reduction Potential

The Texas facility, Invista, regularly reduces an estimated 97% of all emissions annually, which satisfies the Texas state regulators' requirement of reducing emissions by 95%. The APM plant in Florida reduced its emissions by an estimated 70% in 2020. This facility has pledged on reducing total emissions to 95% by February 2022 with the implementation of more reduction mechanisms. Unfortunately, progress on these efforts has slowed and emissions are variable.

In addition, requirements similar to the one implemented in Texas are not enforced upon Florida's facility. While APM abates a vast majority of emissions, it still releases a large amount of GHGs due to its size. For comparison, the Texas plant reduces 97% of emissions and therefore emits about 0.6 MMT CO_2e, while the Florida plant reduces roughly 70% and emits an estimated 7.7 MMT CO_2e. However, taking into account the pledge that APM made, a near-term percent reduction of 95% is achievable for Florida's plant. We estimated a more conservative 10% annual reduction in cement production emissions starting in 2027.

Feasibility and Financial Costs

Although Florida's adipic acid plant has reduction efforts in place and pledges to achieve a higher reduction percentage, there is little momentum as well as little oversight. Considering APM is the largest adipic acid plant globally, and has definite potential for emission reduction improvements, it is feasible for Florida to use this avenue to further reduce N_2O emissions. If state legislation were to mandate a certain percent reduction for this single plant, as Texas did, improvements in total emissions can be achieved. The plant could also be encouraged to implement more effective reduction methods if given incentives from the state for reaching specific emission goals. Similarly, providing financial assistance for the implementation, enhancement, operation, and maintenance of reduction mechanisms may increase the likelihood of the plant striving towards more aggressive emission goals.

7.2.3. Fluorinated Gases

Introduction

Fluorinated gases are used in a number of industrial processes and products. The use of fluorinated gases can be reduced, and thus their GHG emissions with substitutes for different gasses and better industry practices. The use of more climate-friendly alternatives through gradual phasing out of fluorinated gases can reduce emissions in the IPPU sector.

Emission Reduction Potential

We estimated the contribution of the gradual phase-out of fluorinated gases in IPPU with a 10% reduction beginning in 2027 through 2035. A more modest annual reduction can still be adopted to achieve net-zero emissions by 2050.

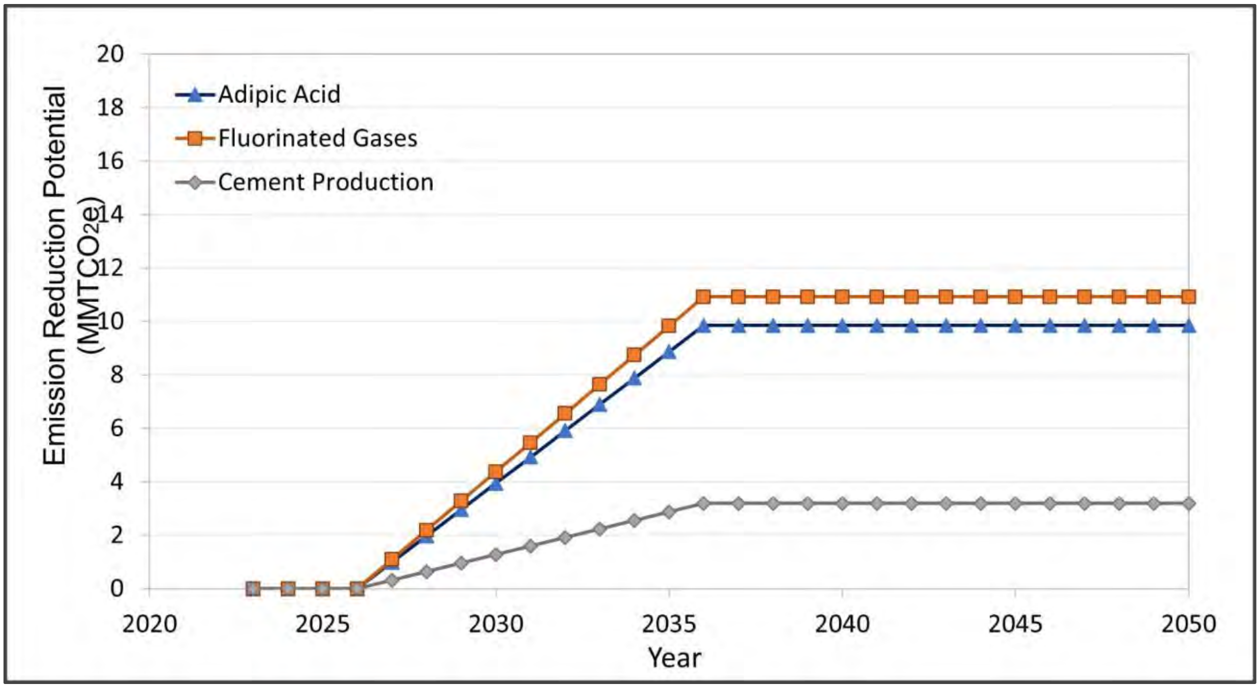

Figure 7-3: Cumulative emission reduction potential from the IPPU sector, focusing on the largest emission sources: adipic acid production, fluorinated gases, and cement production.

7.3. Agriculture, Forestry, & Other Land Use (AFOLU) Sector

7.3.1. Agriculture

7.3.1.1. Management of Livestock Manure in Anaerobic Covered Lagoon Digesters

Introduction

Manure management is one of the greatest challenges facing dairy and meat farms in the agricultural industry today. This is due to the difficulties associated with waste disposal produced predominantly by cattle. The primary gases of concern released through livestock manure are: ammonia (NH_3), methane (CH_4), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). All of these gases threaten human health and greatly contribute to the greenhouse effect (EPA, 2021). Although livestock waste has proven beneficial to the fertilization process (through its provision of both macro-and micronutrients, in addition to the enrichment of soil properties), this practice demands a proper system in place.

Composting and vermicomposting, lime stabilization, aerobic and anaerobic digestion, and heat drying, are all viable approaches to livestock waste management. However, based on the information gathered from studies and active operations throughout the United States, the suitable response we propose for farms across the State of Florida is the installment of livestock anaerobic covered lagoon digesters. The cattle waste that fills this basin vessel undergoes the process of anaerobic digestion - the breakdown of material without oxygen. This process produces renewable biogas energy that can be used as an alternative fuel source or as an electricity generator.

The Philip Verwey Dairy Farms, located in Hanford, California serves as an example of an agricultural operation that considered the environmental impacts associated with cattle farming. The farm, through its California Department of Food and Agriculture (CDFA)-funded Dairy Digester Research and Development Program, implemented the use of a large covered lagoon digester as a methane production mechanism to generate about 7.6 million kWh of electricity per year (California Climate Investments, 2017). Executing a similar plan in Florida has great potential to reduce the State's annual GHG emissions associated with manure management.

Emission Reduction Potential

During the planning stages of Philip Verwey Farm's anaerobic digester installation, the CDFA estimated the annual GHG emissions reduction at approximately 53,577 MT CO_2e and increasing to a reduction potential of 535,770 MT CO_2e during a 10-year period (California Department of Food and Agriculture, 2021). This is equivalent to removing approximately 106,515 passenger cars off the roads. The Environmental Protection Agency (EPA)'s AgSTAR Livestock Anaerobic Digester Database displays the most current estimates of total emission reductions for this particular Verwey Farm project to amount to 136,999 MT CO_2e per year. This number is double the original estimate and supports the claim that this is an effective emission reduction solution. Efforts to reduce emissions associated with livestock production have already been implemented. According to the Livestock Anaerobic Digester Database, a fixed film/attached media and two mixed plug-flow digesters have been established in Florida in 2000, 2009, and 2012 (generating electricity upwards of 12,000,000 kWh/yr). The success of these operational digesters suggests a strong probability that future digester systems will have similar, if not better, results, and a mechanism to offset farm energy requirements.

We estimated a 9% reduction in GHG emissions beginning in 2025 through 2035. In addition to anaerobic lagoon digesters, other approaches include composting and vermicomposting, lime stabilization, aerobic digestion, and heat drying. The offset energy use was not included in the emission reduction potential. A more modest annual reduction can still be adopted to achieve net-zero emissions by 2050.

Feasibility & Financial Costs

According to a 2020 report developed by the U.S. Department of Agriculture's National Agricultural Statistics Service, Florida ranks 13th in the country in terms of the number of cattle raised (1,020,000 cattle). Given the large number of cattle, it comes as no surprise that Florida is also a large emitter of GHGs. Assuming the state continues on the same trajectory through the following decade, a reduction in GHG emissions associated with manure management will contribute to the goal of net-zero emissions in 2050.

Other states have also developed projects and funding mechanisms to address emissions associated with livestock production. For example, the California Department of Food and Agriculture (CDFA) Report of Funded Projects, updated in 2018, showed that $6,179,861 was the estimated total cost to support the Verwey-Hanford dairy operations project. This amount accounted for the $3,000,000 in CDFA funds used to provide financial assistance for the establishment of dairy digesters on farms across California. An additional $4,000,000 in matching funds has since been allocated towards this goal, amounting to a total sum of $7,003,176 (CDFA, 2016).

Analyzing the estimated costs of installing anaerobic digesters in farms across the United States shows a significantly lower cost than that of the Verwey-Hanford project due to potential differences in size and livestock range. Costs can range between $95,200 and $289,474 due to varying expenses associated with the price of specific operational components such as: piping, excavation, engineering, covers, storage, and generators (Moser et al., 2014). Depending on the circumstances surrounding the location, space, and available cattle, the installation of anaerobic digesters in Florida could be a cost-effective operation and a viable emission mitigation strategy.

7.3.1.2. Reduction in Enteric Fermentation Emissions Through Introduction of Feed Additives

Introduction

Enteric fermentation is a common problem of livestock farms across the globe. This process is the result of microbial fermentation and decomposition of food in the digestive systems of ruminant animals, such as cattle, sheep, goats, and buffalo. The decomposition processes produce methane (CH_4), a powerful greenhouse gas (GHG). The EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019 mentions that while CH_4 accounts for only 10% of all GHG emissions in the U.S., it traps atmospheric heat at a considerably higher rate. This rate is 25 times that of carbon dioxide (CO_2) over a 100-year period (EPAb, n.d.). Nationally, enteric fermentation is the leading cause of most methane emissions. The 2020 EPA GHG Inventory report estimated 177.6 MMT CO_2e of this CH_4 source output for 2018, equivalent to about 28% of this gas' total emissions (EPA, 2020). Therefore, the use of feed additives represents a viable solution for mitigating CH_4 emissions associated with livestock, both within the state and at a national level.

Literature suggests that a plant-based essential oil, Agolin, can effectively increase farm productivity and reduce GHG emissions (Belanche et al., 2020). Chemical interactions between this feed oil and the digestive processes of the livestock's stomach result in reduced amounts of protozoal concentrations, diminishing the amount of CH_4 produced. Other amendments that have been studied, in this case by the American Dairy Science Association (ADSA), include 3-nitrooxypropanol (3-NOP), an organic compound on CH_4 emissions over a 14-week period (Hristov et al., 2013). Here, feed additives supplements were tested as both 3-NOP mixed into the dietary fiber, or roughage, and incorporating 3-NOP into the concentrated pellet food supply.

Emission Reduction Potential

A 10% reduction in CH_4 emissions was observed in lactating dairy cows that were given feed supplements (over a span of 28 days or more), compared to the controlled, unsupplemented cows. This value is consistent with the majority of the 23 studies examined (Belanche et al., 2020). The results of the 3-NOP experiment revealed a greater feed effect, resulting in a 23-28% CH_4 reduction for the treatment period (Wesemael, 2018). Even though there is uncertainty tied to the variety of livestock food additives available in the future, the studies conducted show promising potential of effectively using feed supplements to minimize GHG emissions. The response ratio recorded from the Belanche et al. report indicated a 0.912 g/d methane production value effect size based on the means, which were highly consistent across the considered treatments in the meta-analysis. The results of the Wesemael study can be used to estimate that by 2050, the sample size of 30 cows used in the experiment can provide a total emissions reduction of 1.364 MT CO_2e. This value multiplied by the 2018 total amount of cattle and calves in Florida estimates a state emissions reduction total of more than 0.074 MMT CO_2e from 2018 to 2050, should the 3-nitrooxypropanol additive be introduced to cow feed. To account for the introduction of feed additives, as well as methane capture facilities that house cows and improvements to production efficiency, we estimated a 9% reduction in emissions associated with enteric fermentation beginning in 2025 to achieve net-zero emissions by 2035. A more modest annual reduction can still be adopted to achieve net-zero emissions by 2050.

Feasibility & Financial Costs

Based on existing studies, incorporating food additives/supplements in the livestock diet can effectively reduce associated CH_4 emissions. This strategy can be adopted by numerous livestock farms throughout Florida. Other potential food additives that would also mitigate CH_4 emissions include seaweed, fatty acids, oregano, nitrate, monensin, biochar, cinnamon, and garlic (Honan et al., 2021). Given the array of options, livestock farms have the ability to choose and implement the food additives that best suit their needs based on their location, size, and financial abilities.

A study conducted at the Spruce Haven Dairy farm in New York revealed that the use of Agolin as a food additive resulted in a $0.72 gain per cow per day, while the associated cost was $0.05 per day for each animal (Willliams et al., 2021). Extrapolating this result over a year's time frame results in a potential increased earnings estimate of $263 for every cow consuming the supplemented feed. The costs associated with purchasing feed additives can vary depending on brand, ingredients, and availability, however, given the array of possible options, this still represents a viable GHG mitigation strategy. Based on the USDA National Agricultural Statistics Service (NASS) numbers for Florida livestock, the number of cattle and calves totaled 1.63 million heads in 2018 (NASS, 2019). This total value multiplied by the estimated annual financial gain of $263 equates to about $428,690,000 in savings per year.

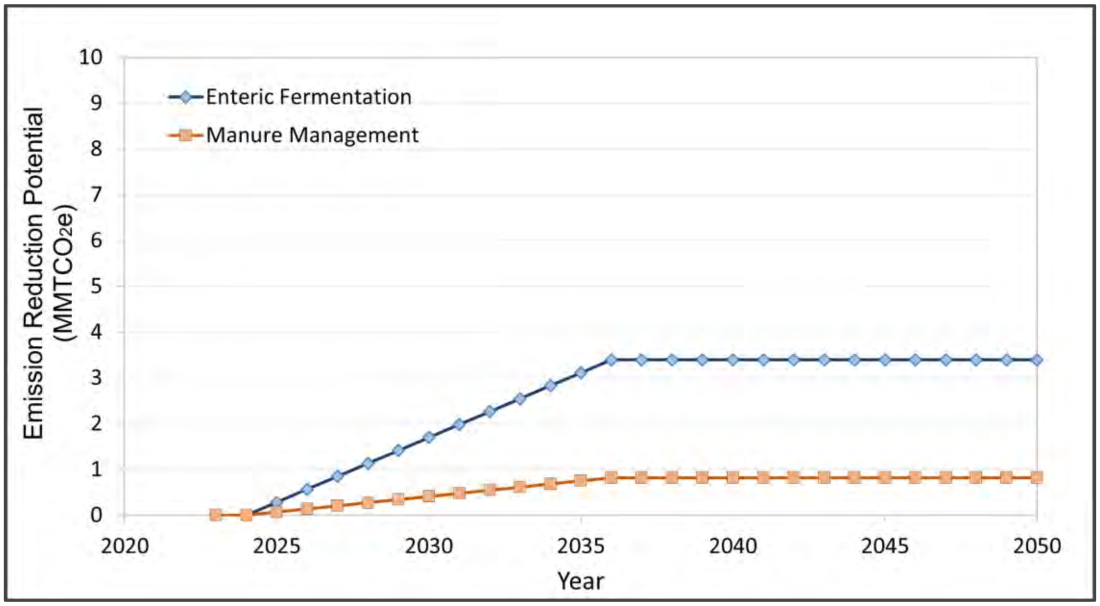

Figure 7-4: Cumulative emission reduction potential from the Agriculture sector (MMT CO_2e).

7.3.2. Land Use, Land-Use Change, & Forestry (LULUCF)

7.3.2.1. Flooding of Drained Organic Cropland Soils

Introduction

Drainage of organic soils exposes organic matter that has very low rates of decomposition under flooded conditions to atmospheric oxygen and greatly increases its rate of decomposition. The Everglades Agricultural Area in Florida is a large area of cultivated croplands primarily for sugarcane production. The EPA in its 2021 inventory report identified the Everglades Agricultural Area (EAA) with CO_2 emissions of greater than 40 MT CO_2/ha/yr. The EAA covers approximately 375,000 acres with about 320,000 acres on organic soils. Thus, the EAA emits approximately 5.2 MMT CO_2e/yr. Flooding these cultivated organic soils would immediately reverse this atmospheric source of GHG emissions.

Emission Reduction Potential

Flooding 10% of the EAA land area (e.g., 32,000 acres) per year, starting in 2025 continuing through 2035, would reduce LULUCF GHG emissions by 0.52 MMT/yr with a cumulative reduction of approximately 5.7 MMT CO_2e.

Feasibility & Financial Costs

A transition towards substitution of less GHG intensive agricultural products for Florida, for example, land-based aquaculture products, would ensure that agricultural productivity maintains strong economic revenues for Florida's farmers.

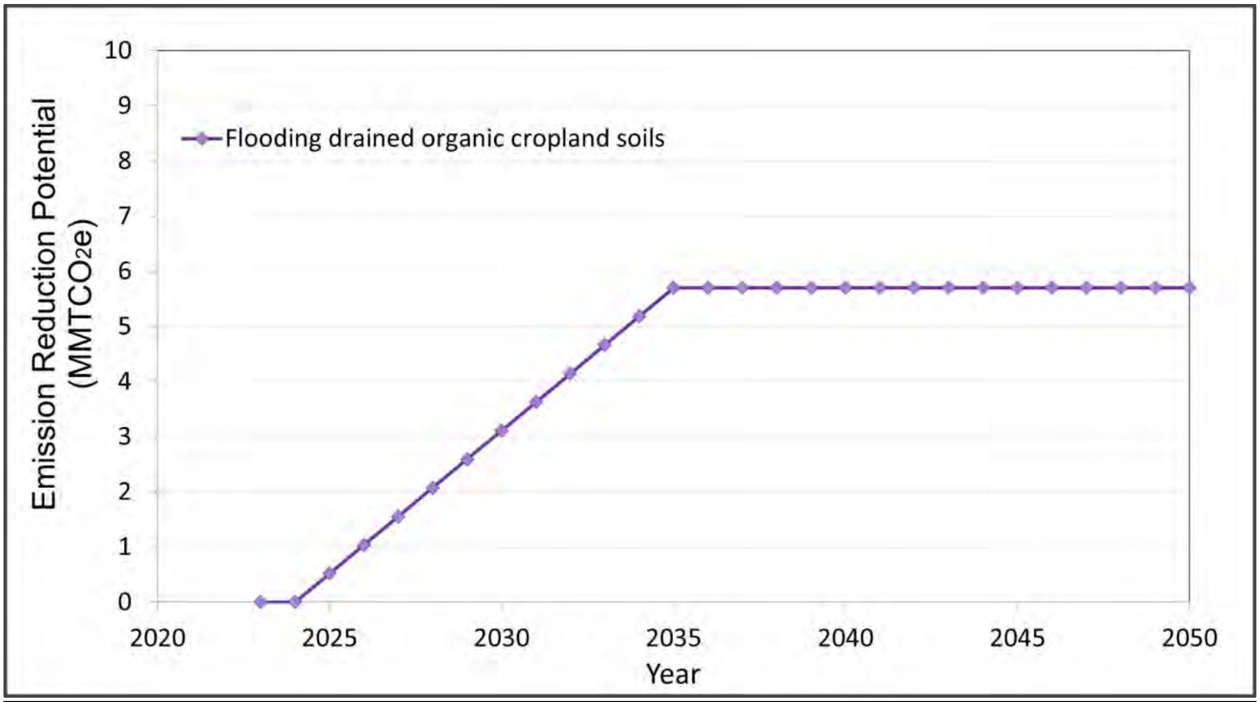

Figure 7-5: Cumulative emission reduction potential from the LULUCF sector (MMT CO_2e).

7.4. Waste Sector

7.4.1. MSW Waste-To-Energy

Introduction

Investing in alternative energy strategies such as waste-to-energy (WTE) technologies is seen as a potential pathway to sustainable development (Kothari & Pathak, 2010), and a way to move away from traditional energy and fuel sources (Kumar & Samadder, 2017). Municipal solid waste (MSW) can be used to produce energy through two different pathways – either through direct burning of municipal solid waste or through the use of biogas as a fuel source. Developing energy from waste and waste products is a waste management option that produces electricity, reducing the amount of material that would be buried in landfills (EIAa, 2021). According to the data provided by the US Energy Information Administration (EIA) (2021) in 2018, approximately 12% of the 292 million tons of MSW produced in the U.S. was burned to generate energy in waste-to-energy plants (EIAa, 2021).

Collecting and using biogas from landfills is yet another source of energy from the biomass found in MSW. Biogas is produced by anaerobic bacteria found in solid waste landfills and consists mainly of methane and carbon dioxide (EAIb, 2021). The majority of biogas produced in the U.S. is used for electricity generation since it qualifies under the U.S. Renewable Fuel Standard Program as an advanced or cellulosic biofuel (EAIb, 2021).

Given the importance of investing in alternative energy sources, developing new technologies to more efficiently convert waste to energy is a key element in sustainable waste management (Brunner & Rechberger, 2015), and a promising step in mitigating emissions.

Emission Reduction Potential

One action considered was using landfill gas to substitute fuel in fossil natural gas vehicles with renewable natural gas. As some heavy-duty highway vehicles that rely on distillate fuel can be transitioned to natural gas vehicles, these vehicles can be fueled by renewable natural gas from landfill gas rather than fossil natural gas. Another action that can enable the substitution of fossil natural gas is to replace on-site energy consumption in commercial and industrial facilities. A residential-scale complementary action is composting. Community composting can also help to divert organic waste from landfills, reducing methane emissions. Composting has additional benefits of increasing soil health, reducing the burden on septic and centralized sewer systems, and promoting community gathering sites that can also support food access in neighborhoods of food insecurity or characterized as food deserts. Through a combination of actions that result in a 1% substitution of distillate fuel and fossil natural gas and composting to reduce methane emissions through 2027, 5% through 2031, 15% through 2035, and an additional 6% each year through 2050, a cumulative reduction of 12 MMT CO_2e can be achieved, and landfill methane emissions eliminated from the GHG inventory.

Feasibility & Financial Costs

The substitution of heavy-duty vehicles that use natural gas is already underway, and these vehicles can be fueled by renewable natural gas. If fleets are progressively transitioned as vehicles are retired, there should be no significant additional associated costs. Similarly, commercial and industrial facilities that already rely on independent sources of natural gas can take advantage of this opportunity as an alternative fuel source and represents a potentially new revenue source for waste management companies. Costs may include upgrades to transportation or transmission infrastructure that could be supplemented with federal infrastructure funds. The EPA (2020) identifies a number of local public works and solid waste departments currently supporting such infrastructure in the US. Further analyses will be required to develop a rough estimate of costs.

8. GHG Removals & Storage

8.1. Revegetation & Afforestation on Urban Lands

Introduction

Using natural ecological processes to sequester atmospheric carbon could help Florida reach a net-zero target. Studies done by The Nature Conservancy (TNC) have shown the CO_2 sequestration potential associated with different ecological investments and land management improvement strategies. Therefore, using different conservation mechanisms such as purchasing lands for conservation purposes can be an effective GHG mitigation strategy in Florida. Other states, such as California through the California State Coastal Conservancy, purchase numerous coastal properties preventing land conversion to other uses and maintaining the coastal lands in their natural state for the public good (California State Coastal Conservancy, 2020).

Emission Reduction Potential

According to TNC, approximately 5.33 million acres of land in Florida can be used for carbon emission reduction through reforestation, urban reforestation, avoided grassland conversion and its restoration, cropland nutrient management, alley cropping, and improved manure management (TNC, 2018). This assessment focused on areas of development, open space, and bare land. We applied 50% of the land area of low density developed land and all open space and bare lands in Florida as of 2016 (NOAA CCAP), or 1,018,906 ha. We also added to the land area 12.5% of medium intensity developed land, or 54,131 ha. Applying the IPCC default for subtropical forests, 9.175 tonnes CO_2 ha-1 yr-1 can be sequestered. Implementing these activities at 5% through 2035 and 20% from 2036 to 2040, a cumulative of 9.85 MMT CO_2e could be reduced by 2040.

There are numerous additional opportunities to increase the uptake of carbon by natural lands. While not included in this scenario at this time, additional carbon gain can be achieved by activities that include improved forest management to increase forest health, restoration of degraded woodlands, grasslands, and wetlands, and certain agricultural practices including soil biochar amendments could also be included to increase the carbon stored in trees and soils on natural lands. This action will also have additional benefits in terms of improving air and water quality and soil health. More information about additional areas of uplands potentially degraded, areas where coastal wetlands and seagrasses have been lost, what coastal management practices can facilitate transgression of healthy coastal ecosystems with sea-level rise, more opportunities for realizing additional natural carbon removal could be achieved within Florida.

Feasibility & Financial Costs

Allocating time and resources towards land restoration in Florida is not a new concept. Recently, the Florida Forest Service started a $10 million Carbon Sequestration Grant Program with the goal of sequestering 69,000 tons of CO_2 per year (FDACS, 2021). A policy that incentivizes funding to restore lands to their historic natural state would significantly help reach net-zero greenhouse gas (GHG) emissions. Land restoration policies can help build public-private partnerships, restore natural ecosystems and native ecological communities, and provide and protect numerous ecosystem services such as carbon sequestration.

Assessing costs associated with land restoration can be difficult since each restoration site is unique, and has its own set of variables and ecological characteristics. Additionally, different projects require different amounts of labor and resource costs. However, natural land restoration strategies can be effective in reducing emissions and providing multiple other ecological benefits. Policies that incentivize land conservation programs and investments are highly recommended.

8.2. Restoration of Coastal Wetlands and Degraded Seagrass Meadows with Water Quality Improvements

Introduction

Coastal wetlands and seagrasses are an integral part of Florida's coastal and nearshore aquatic systems, offering habitat and food for numerous species. Additionally, both coastal wetland and seagrass habitats provide a suite of valuable ecosystem services and contribute to the health and function of the state's marine ecosystems, fisheries, and tourism industries (FWC, n.d.). These habitats also have the ability to sequester atmospheric carbon and can act as long-lasting carbon sinks. Also known as blue carbon, the coastal wetland and seagrass sequestration potential of these communities could significantly help mitigate emissions. Therefore, protecting seagrass habitats from pollution, habitat fragmentation (boat anchor damage also referred to as seagrass scarring) and other threats is crucial. Seagrass restoration is also a key element that can help improve the health of coastal ecosystems. Healthy seagrass communities not only maintain marine ecosystem balance but also can help Florida reach its goal of net-zero carbon emissions.

Emission Reduction Potential

According to a 2012 article published in Nature Geoscience, the average global amount of carbon dioxide equivalent (CO_2e) stored per hectare in the first 1-meter of seagrass bed soil equals 512.23 metric tons (MT) (Fourqurean et al., 2012). Converting the total number of acres of seagrass beds estimated in Florida (2.48 million) to hectares amounts to approximately 1,003,624.4 hectares of seagrass (Yarbro & Carlson, 2016). Multiplying this global average of CO_2e stored by the total number of hectares in Florida, it can be estimated that over 514 MMT CO_2e are currently stored within the first 1-meter of all seagrass beds (Salinas et al., 2020).

The carbon sequestration potential of healthy seagrass beds is significant. According to a 2010 study, seagrasses per hectare can sequester 4.36 metric tons of CO_2e per year (Duarte et al., 2010). As a comparison, the Amazon rainforest only absorbs on average 3.7 tons of CO_2e per hectare per year (Grace et al., 1995). Since what we are interested in is additional CO_2 sequestration with either enhanced or new (restored or created) areas of seagrass meadow, and given the uncertainty in historic coverages of seagrass meadow in Florida, we based on carbon removal estimate on the fraction of Florida seagrass meadow area that is likely degraded by poor water quality and thus with low or negligible rates of CO_2 sequestration. Applying the IPCC (2013) default value of 1.58 tonnes CO_2 ha-1 yr-1, and the fraction of current seagrass coverage that could be recovered with water quality improvements as 60%, implementing water quality improvements at a rate of 5% per year starting in 2030 (given the long time periods with which immediate water quality remediation results in water quality improvements (e.g., Tampa Bay), recovering seagrass meadows could sequester another 1 MMT CO_2e by 2050 and each year thereafter, assuming coastal management practices maintain water quality conditions. With more information, additional carbon removal could be achieved with seagrass restoration in areas where they have been lost, building on efforts to improve water quality in degraded areas where seagrass meadows still persist. Notably, our GHG inventory did not include the contribution from current seagrass meadows which should be considered as additional improvements to the Florida GHG inventory (~ 1.6 MMT CO_2e per year). Therefore, conserving our existing seagrass habitats beds, recovering water quality to improve degraded areas, and restoring historic seagrass beds is an opportunity for the state of Florida and its recreation, tourism, and waterfront real estate-based economy.

Feasibility & Financial Costs

According to the Florida Fish and Wildlife Conservation Commission 2016 Seagrass Mapping and Monitoring Report, there are roughly 2,480,000 acres of seagrass beds around Florida’s nearshore waters. When determining the carbon sequestration potential of seagrass communities, it is important to consider two different variables. The first is the amount of carbon that is currently stored within the first meter of seagrass soil, which has been deposited and stored through autotrophic seagrass activity over a long period of time. The second variable is the amount of carbon dioxide that is actively sequestered by all growing seagrasses in Florida over time.

There are several seagrass restoration methods available, some of which are fairly cost-efficient. One example is the seagrass restoration efforts of Virginia’s Chesapeake Bay. In the Chesapeake Bay, 70 million seeds were dispersed over a 20-year period. The large-scale dispersal was mostly conducted by activists and other volunteers, making this project stand out financially with costs saved on staffing a crew to carry out the work. Restoration efforts can grow exponentially and successfully if sufficient support and assistance are readily available throughout the project’s lifetime. Enabling a volunteer system within the project will not only contribute to its progress but also relieve budgetary constraints

In a 2015 report to the U.S. Army Corps of Engineers, seagrass restoration projects are estimated to cost roughly $1 million per acre (Keys Restoration Fund, 2015). This value was determined following an investigation of 45 locations in the Florida Keys which measured the cost range on a per square foot restored basis. The costs can be highly variable depending on the type of project, and carbon monitoring is essential to assess and quantify the amount of carbon sequestered.

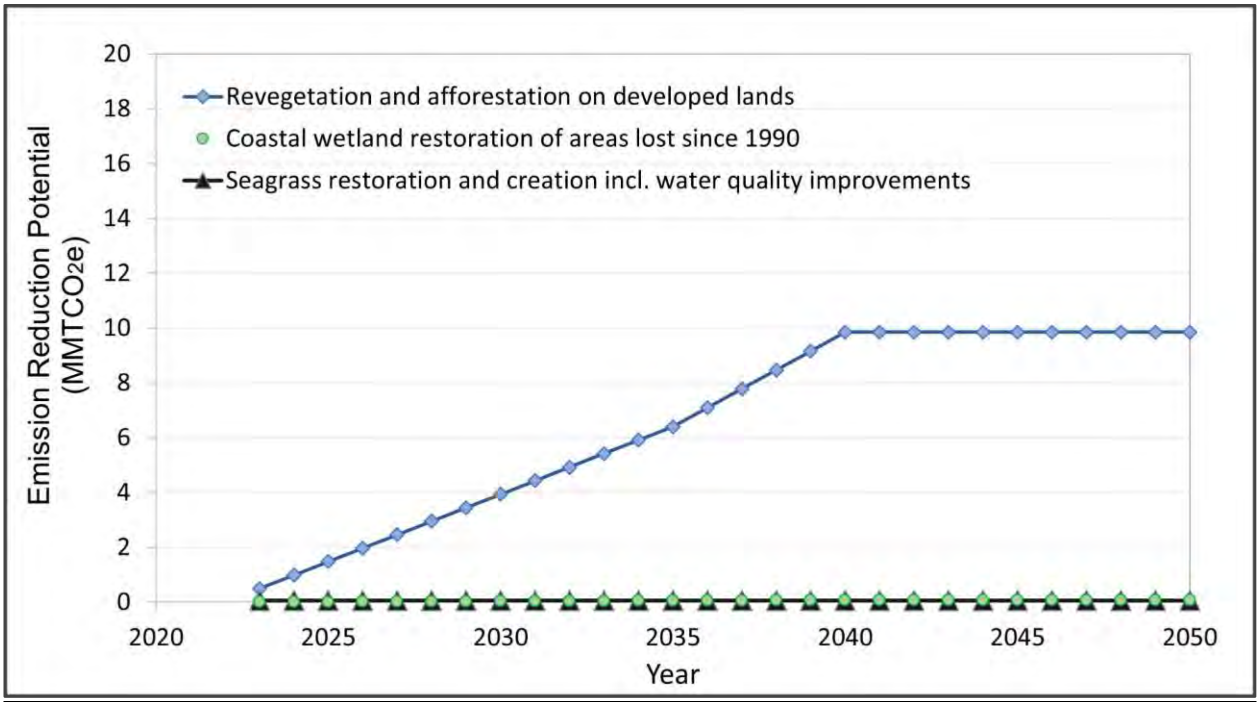

Figure 8-1: Cumulative emission removal potential from the LULUCF sector (MMT CO_2e). Note that a number of additional activities could be included here that were not estimated as part of this scenario.

8.3. Atmospheric Carbon Capture based on Advances in Technology

Introduction

New, innovative technologies for advanced carbon capture have the potential to significantly reduce emissions. Reducing CO_2 emissions from the transportation sector could be a challenging, yet critical step in reaching target net-zero emissions in the near future. Air capture technologies have industrial applications that can be traced back to the 1930s. There are different technologies involving carbon-capturing methods. Currently, three approaches are frequently used: post-combustion capture, pre-combustion capture, and oxy-fuel combustion capture. Each method has its own set of advantages, disadvantages, and associated costs. In order to have a noteworthy impact on the state of the atmosphere, carbon dioxide removal interventions require large-scale deployment over a broad time span.

Some methods of advanced carbon capture involve direct CO_2 atmospheric removal at the emission source. Research shows that internal combustion engines have an average efficiency of about 30%, with 30% of the thermal energy wasted in exhaust gases (Barrufet et al., 2021). Therefore, there are opportunities to capture some of the emitted carbon and enhance the efficiency of exhaust systems. For example, the integration of an onboard CO_2 capture and storage unit with an internal combustion engine has been proposed as an effective method to reduce atmospheric emissions (Sharma & Maréchal, 2019). This innovative CO_2 capture system can be installed on the exhaust stream of vehicles and has the potential to capture as much as 90% of the emitted CO_2 (Sharma & Maréchal, 2019). The CO_2 capture system would consist of a sequence of processes, cooling, heating, mass transfer, and compression (Barrufet et al., 2021). All these processes would take place while driving. This process wouldn't have an energy penalty and the CO_2 can be further recycled as a conventional liquid or gaseous fuels produced from renewable energy sources (Sharma & Maréchal, 2019).

The captured CO_2 not only helps mitigate emissions associated with transportation, but it can be further used in the agricultural and food system to enrich greenhouses and stimulate plant growth (Barrufet et al., 2021). Adding CO_2 to greenhouses is an important step in enhancing production since 450–1200 ppm of CO_2 is required to grow healthy fruits and vegetables, while atmospheric CO_2 is approximately 400 ppm (Barrufet et al., 2021). Therefore, CO_2 enhancement is a common process in the cultivation process of numerous agricultural commodities. Studies show that supplying liquid CO_2 recovered from exhaust waste thermal energy can significantly help address sustainability challenges associated with food systems while improving energy efficiency and reducing GHG emissions (Barrufet et al., 2021).

Emission Reduction Potential

If this action were part of a larger portfolio to reduce emissions from the transportation sector, it could be used on a short-term or case-specific basis to complement other actions, where other actions are more difficult to implement in the near-term or when it may be more cost-effective for transitioning a fleet of vehicles to alternative fuels. For instance, we implemented this strategy in scenario III in order to reduce emissions from specific heavy-duty diesel vehicles (combination trucks) to reduce distillate fuel emissions of 16 MMT CO_2e per year by 80% by 2050. We assumed 75% efficiency in carbon capture, with technology implemented at about 4% per year, beginning in 2025.

Feasibility & Financial Costs

The feasibility and cost of carbon capture at the engine level require additional research.

9. Financial Mechanisms for Reductions, Removals, & Storage of GHGs

9.1. Financial Incentives for Solar Energy

Purchase power agreements (PPAs) are the most common avenue to encourage the adoption of solar energy through financial incentives. According to Better Buildings, a PPA is an arrangement in which a third-party developer installs, owns, and operates an energy system on a customer’s property. The customer then purchases the system’s electric output for a predetermined duration - typically around 15 to 25 years (Better Buildings, n.d.). Customers receive electricity generated from the solar array and avoid up-front capital costs. At the same time, developers are incentivized to fund these projects as they offer profitable investment opportunities, along with a chance to use the federal Investment Tax Credit (ITC) (Stevens et al., 2020). The ITC allows the solar developer to deduct 26% of the cost of installing the solar array in their federal taxes, in which the savings are used to lower electricity rates for the buyers (Stevens et al., 2020). PPAs are proven to have many economic and environmental benefits for buyers, sellers, and the community.

9.2. Carbon Pricing

To effectively address and mitigate climate change impacts, policymakers need to create incentives for households and firms to reduce their carbon footprint while encouraging the innovation and development of clean technologies. A strong policy that has proven to effectively tackle this goal is carbon pricing. Carbon pricing is a market-based strategy for reducing GHG emissions. The goal is to capture the external costs of GHG emissions and place a price on the sources of these emissions, typically in the form of a price on the amount of CO_2 emitted. Some of these external costs include damage to crops, healthcare costs associated with increased GHG emissions, loss of property due to sea-level rise, and increased flooding (World Bank Group, 2022). This regulatory mechanism passes the cost burden of increased GHG emissions from the public to the emitters themselves; thus, incentivizing the polluters to reduce emissions.

A well-designed carbon pricing program can facilitate innovation of low-carbon technologies and help reach environmental protection objectives, while also triggering a shift to a clean energy economy and increased state revenue (Marron et al., 2015). Carbon pricing policies are often implemented through two approaches: a carbon tax or an emission trading system (ETS). Under a carbon tax policy approach, governments charge a fixed fee that companies or other entities must pay on every ton of carbon they emit. In contrast, ETSs refer to policy instruments where the government sets an emissions cap in one or more sectors, and emitters are allowed to trade emissions permits. The main form of ETS is cap-and-trade. Cap-and-trade is a system in which power plants, refineries, and other large facilities buy and sell GHG emissions allowances in order to meet emissions targets. Within this framework, the cap is on GHG emissions, and trade is facilitated by an open market in which companies buy and sell emission allowances. This trading system provides companies with an incentive to save money by cutting their emissions in cost-effective ways. Although ETS policies are more widely used across the U.S, both approaches reduce atmospheric GHG emissions. Compared to a carbon tax, cap-and-trade provides a high level of certainty about future emissions. A cap may be the preferable policy when the state has a specified emissions target.

Florida could have a wide portfolio of emission reduction opportunities, and scale the price of carbon or cap the emissions to accomplish the GHG reduction targets needed in lieu of the energy efficiency programs (Hastings, 2015). Thus, carbon pricing strategies can be complementary policies, successfully encouraging investments in renewable energy sources beyond that achieved by one of these policies alone.

9.2.1. Carbon Tax

Carbon tax is a price-based approach to reducing GHG emissions. Compared to the cap-and-trade approach, carbon taxing has some advantages as it would not cause additional volatility in energy prices. A 2019 Brookings Institution report projects that under a \$25/ tCO_2e carbon tax that rises by 1% per year would reduce emissions by 17% – 38% relative to 2005 benchmark levels by 2030 (Barron et al., 2019). This study further calculated that under a \$50/ tCO_2e carbon tax rising by 5% per year would reduce emissions by 26% to 47% relative to 2005 levels (Barron et al., 2019). Hastings (2015) also stated that based on projections, at a marginal abatement cost of \$50/ tCO_2, a carbon tax can reduce emissions by almost 20%.

In addition to the emission reduction values, numerous lives could be saved from implementing such a policy. A recent study by Daniel Bressler (2021) determined the human mortality impacts based on a suite of integrated assessment models including temperature-related deaths. Bressler calculated that reducing emissions by 1 million metric tons of carbon dioxide in 2020 saves 226 lives from 2020 to 2100 according to the baseline emissions scenario (Bressler, 2021).

Florida should consider implementing a carbon pricing policy to meet carbon reduction goals. One of the main benefits of a carbon pricing policy is that it can be implemented among multiple GHG-reducing mechanisms such as direct emission reductions (command-and-control regulation) along with energy efficiency projects and programs (Hastings, 2015). The policy's easy integration with other policies is due to its simple design and implementation. Carbon tax may provide some advantages in terms of transparency, reduced administrative burden, and relative ease of modification.

Although there are numerous benefits from implementing a carbon pricing policy (see Appendix Q for section on *Successful Implementation of Carbon Pricing*), there are also costs that individuals or households would endure. A carbon tax would increase the price of burning fossil fuels and the resulting goods and services that come from it. For example, a tax of $40 per ton would add about 36 cents to the price of a gallon of gasoline, or about 2 cents to the average price of a kilowatt-hour of electricity (Marron et al., 2015). These higher energy prices, which would be implemented in both a carbon tax and an ETS, would raise costs for industries and households, resulting in lower profits, wages, and consumption (Tax Policy Center, 2020). These negative impacts would fall more heavily on workers and investors in carbon-intensive industries as well as on regions that rely on carbon-intensive fuels (Tax Policy Center, 2020).

9.2.2. Cap-and-Trade

The Cap-and-Trade program is an approach that establishes a declining limit over time on GHG emissions from major sources. It sets a cap on GHG emissions and creates an economic incentive to invest in cleaner, more efficient technologies for utilities, industries, and fuel distributors that generate above a certain amount of GHGs. It sets a certain percentage reduction annually from prior years and it provides the covered entities the flexibility to implement the lowest-cost options to reduce emissions. The cap shares are allocated to the emitters in the form of emission permits and the trade allows them to sell unused permits to other emitters that cannot reduce emissions with a reasonable cost or to those that want to increase their emissions. In order to effectively implement the Cap-and-Trade program, there needs to be mandatory reporting of GHG emissions by each covered entity.

In California, utilities, large industrial facilities, and distributors of transportation fuels are included in the Cap-and-Trade program (C2ESa, n.d.). In the case of power utilities and industries, those emitting more than 25,000 MT CO_2e are required to comply with the cap-and-trade program.

The amount of GHG emissions reduction depends on the cap set by the State. At a cost of $50/ t$CO_2$, the cap-and-trade program would reduce emissions by 12% (Hastings, 2015). In California, the Cap-and-Trade program resulted in a 10% decline in GHG emissions between 2013 and 2018 from the entities involved in the program (EDF, n.d.). The program has been extended until 2030.

Although there are benefits to both a carbon tax and an ETS policy, Florida might benefit more from a carbon tax. Carbon tax policies are easier to design and faster to implement (Hastings, 2015). Projections show that the Cap-and-Trade of tradable emission permits (compared to auctioned permits) is less efficient (Hastings, 2015).

The cap-and-trade program can be a revenue-generating mechanism based on carbon allowances auctioned. With a reasonable budget for administration and auction prices, this program can be attractive.However, this type of mechanism can also pose a cost burden to the

State if allowances are given away for free. Also with the gradual retirement of non-renewable sources, the Cap-and-Trade may not generate the needed revenue for the State.

The California Air Resources Board has set the auction price for allowances to emit one metric ton of carbon dioxide at $28.26 (CARB, 2021). The program needs to take into account situations where allowances may not be sold when emissions are reduced due to various reasons (such as worldwide shutdowns due to the COVID-19 pandemic). During the aftermath of COVID-19 auctions of allowances generated only $25 million, which was significantly less than the amount raised ($600-850 million) pre-pandemic (CARB, 2020).

9.3. Carbon Offset Programs (Purchasing Credits)

An offset credit is equivalent to a GHG reduction or GHG removal enhancement of one metric ton of CO_2e. It refers to a reduction in GHG emissions or an increase in carbon sequestration that is used to compensate for emissions that occur elsewhere. In order to earn carbon offset credits, the carbon offset program must be real, additional, quantifiable, permanent, verifiable, and enforceable. In addition to this, the program may only be issued to offset projects using approved Compliance Offset Protocols. These can be applied to offset difficult to remove emissions, for instance, from airplane emissions from jet fuel consumption.

Some of the potential offset projects include investment in forestry, livestock digesters, and reduction in production and use of ozone-depleting substances. Carbon offset programs often produce other social and environmental benefits beyond GHG reductions. Carbon offset programs are considered after all GHG reduction potentials are considered. This is particularly used for the net-zero scenario when all potential emission reduction and removals have been exhausted.

Enhancements in forest management and increasing forest cover including urban forestry can be a potential option in Florida that allows the State to claim carbon offset credits. In addition, the investments in methane capture for energy through the expansion of biodigesters should also be considered. Depending on the type of project under consideration, the price of an offset credit can range from $1 to over $35 (Carbon Offset Guide, n.d.). Carbon offset credits can also be implemented along with the Cap-and-Trade program where entities can use this credit to purchase allowances to meet the imposed cap.

10. Potential State Policy Actions for Net-Zero Objectives

10.1. The Creation of a Statewide Greenhouse Gas Emission Reduction Task Force

GHG emission reduction strategies should be a top priority in Florida. Even though non-governmental institutions can play a central role in studying and developing GHG emission reduction strategies, the State government has the ability to implement and enforce effective GHG emission reduction policies. Therefore, an ideal starting point to achieve reduction goals would be a state-led GHG Emission Reduction Task Force. This task force would develop the legislative framework needed to reduce emissions, encourage innovation and create economic opportunities throughout the state of Florida.

Numerous actions can be adopted at the state level to reach emission reduction targets. For example, a GHG emission reduction task force can effectively guide efforts, provide expertise, and design policies that would support GHG reduction efforts. Other states, such as Louisiana, Hawaii, and Colorado, have already established dedicated efforts for studying, designing, and implementing emission reduction strategies. For instance, Louisiana's Climate Initiatives Task Force is developing its own Climate Action Plan and policy recommendations by February 1st, 2022. In 2018, Hawaii signed the HB 2182 bill into law, a bill that established the state's Greenhouse Gas Sequestration Task Force. This task force is investigating ways to measure state greenhouse gas levels and will propose policies to promote and incentivize increased carbon sequestration by 2023. Colorado also created the Carbon Capture, Utilization, and Sequestration Task Force to design emission mitigation strategies and identify emission reduction opportunities.

Several Florida municipalities and districts have started their own task forces to reduce GHG emissions and mitigate climate change. Some examples of local Florida entities working to collaboratively reduce emissions within the state include Broward County's Climate Change Task Force, Pensacola City's 2018 Climate Mitigation and Adaptation Task Force, and the group that published Miami-Dade County's 2021 Climate Action Strategy.

An effective task force would first assess the state's total amount of emitted GHGs resulting from different economic sectors and develop a living inventory of the state's total emissions. In addition to this, the task force should set goals to reduce emissions across the different sectors by predetermined future dates, as well as strive to reduce overall emissions to net-zero levels in due course. For example, among entities, a common predetermined goal and timeline is reaching net-zero emissions by 2050. This time period and emission reduction target is generally viewed as feasible. Establishing milestones of five or ten-year intervals (e.g. 2025, 2030, 2035, or 2030, 2040, 2050) could help guide the gradual decrease in the state's net-emissions relative to a benchmark of pre-established annual historic emission outputs. Usually, this benchmark is based on a significant year of the entity's economy (e.g. the year with the most growth across sectors) or the most recent year in which emissions were inventoried (e.g. 2018 in this report's case). The task force could aim to reduce state emissions relative to a historical standard with benchmarks of 25% overall reduction by 2025, 50% by 2035, 75% by 2045, and reach net-zero by 2050.

To achieve these ambitious goals and milestones, the task force would have to evaluate Florida's emissions landscape and create effective legislative policy suggestions, as well as incentives for residents and entities. Policy mechanisms used to reach emission targets could include: 1) restructuring of energy markets; 2) implementation of a cap-and-trade system between governments and entities; 3) incentivizing carbon sequestration projects; 4) assisting agricultural communities with emission reduction strategies; 5) supporting entrepreneurial entities to create incentive programs; and 6) encouraging residents/entities to adopt emission reduction actions and lifestyles/operations.

A small and simple task force could be created from an assembly of Florida's municipal governments, all working on emission reductions at the municipality level, to therefore reduce the state's total net emissions collectively. A larger, comprehensive, and robust task force addressing overall state-level emissions, ideally, would include representatives from: all Florida districts and/or counties; major industries; academic institutions; climate scientists and researchers; sector area experts; state legislators and executives; agency officials; advocacy groups and professionals; and diverse cultural and ethnic communities.

Using the example of Louisiana's Climate Initiatives Task Force, potential emission reduction targets for Florida could be: lowering emissions 26-28% of 2005 levels by 2025; 40-50% of 2005 levels by 2030; and reaching net-zero emissions by 2050.

Throughout the years, Florida has assembled different task forces to mitigate environmental hazards, reduce socio-ecological impacts, and protect valuable ecosystems. In 2019, Governor DeSantis formed the Blue-Green Algae Task Force to improve protective measures for Florida's water and water-related resources impacted by blue-green algae blooms. The task force is made up of five nationally recognized and well-respected scholars from institutions and organizations across the state. The appointed members have used their collective scientific knowledge and expertise to guide the state's leading efforts for improved water quality. A similar task force can be assembled to efficiently reduce Florida's total GHG emissions and mitigate climate-related impacts.

In addition to this, Florida's Innovative Technology for Harmful Algal Bloom Management Grant Program provides funding opportunities for projects that prevent, mitigate, or clean up harmful algal blooms. A similar grant program could be established to incentivize the development and use of emissions reduction methods and technologies.

The costs associated with the creation of a GHG emission reduction task force can vary depending on the total amount of resources the state government wants to invest in such an initiative. Since its creation in 2019, the five-member Blue-Green Algae Task Force has been funded at $10.8 million each fiscal year by the General Appropriations Act costing the state a total of $32.4 million (The Florida Senate, 2021). A larger task force assigned to investigate and recommend GHG emission strategies could cost a comparable amount.

The state has funded the Innovative Technology for Harmful Algal Bloom Management Grant program each fiscal year at $10 million, costing the state a total of $30 million. It could cost a similar amount to institute a grant program in Florida that incentivizes the research, development, and use of emissions reduction technologies.

10.2. Encourage or Require the Reporting of Estimated Annual Emission Values by Point-Source Emitters

While the carbon footprint of every individual Floridian is difficult to calculate, most of Florida's emissions result from identifiable point sources within certain major sectors. For example, the energy production industry in Florida is responsible for a large majority of state emissions. This is mainly through the combustion of natural gas and other fossil fuels to generate electricity at utility companies. Other large-scale industrial activities, such as concrete or fertilizer production account for significant GHG emissions. Given the wide-scale reliance on the energy sector in Florida, it is important that residents are aware of associated emission externalities and environmental impacts.

To increase customer transparency, promote healthy competition, and allow for more effective government oversight, major emitting entities across sectors could be required to report their total yearly estimated GHG emissions. This type of reporting requirement would not change or impact normal operating procedures, yet it would simply require important operation information to be reported. Monitoring emissions associated with energy production would be a first step in designing emission reduction approaches and implementing new technologies. Important steps have already been undertaken in this direction. Some energy companies have already started, or have planned to implement emission reduction actions while maintaining production levels.

An emission reporting policy would have multiple benefits. First, it would complement the actions of energy companies and industries that have already started to reduce their emissions. Second, this type of initiative would also inform residents, allowing them the opportunity to assess and evaluate the estimated GHG emissions resulting from their daily energy use. Third, the reporting mechanisms if implemented would allow policy-makers to assess different emission monitoring strategies that would ultimately result in lowering GHG emission rates. Lastly, a transparent method of reporting emissions could lead to the development of a statewide living GHG inventory which would systematically allow regulators and residents alike to track emissions and help reach a net-zero target.

An emission reporting policy requirement would not directly result in lowered GHG emissions. However, this policy mechanism can promote transparency and accessibility to emission activity information, and assist with the evolution of market trends. Additionally, it can be an instrumental tool for decision-makers and local residents in directing attention to large point source emission entities. This type of policy would also allow for effective monitoring of emission standards and showcase opportunities for the development of emission trading schemes. The Greenhouse Gas Reporting Program (GHGRP) is a key tool used by the EPA to collect GHG emissions data and other relevant information from large sources and facilities that report more than 25,000 MT CO_2e. Nonetheless, the state of Florida could well allow the reporting information from smaller, more local sources for a more comprehensive emission account (EPA, n.d.).

An effective emission reporting mechanism could be easily implemented in Florida. Large GHG-emitting entities such as utility companies already produce reports describing business practices, displaying qualitative and quantitative data, and defining future production plans and consumer estimates. Requiring companies to add emission estimates to their reports or in another publicly accessible and trackable medium would be feasible.

The costs of an emission reporting policy would be negligible. Emitting entities might incur additional costs associated with estimating and measuring the total amount of GHG produced. Yet, these costs are expected to be minimal and numerous jobs could be created for individuals tasked with measuring and reporting the total net emissions for entities.

10.3. Increase the Use of State-Owned Waters for Economically & Environmentally Beneficial Products that Support Emissions Reductions

Florida state waters expand 3 nautical miles from the shoreline along the Atlantic Coast and extend 9 nautical miles from the shore of the Gulf Coast. The state's 1,350 miles of coastline provide ample possibilities for developing and implementing GHG emission reduction strategies. Numerous economic and emission reduction opportunities arise from the development of new aquaculture technologies, carbon capture and storage mechanisms, and the use of alternative fuels. For example, ocean-based renewable energy installations can serve as a valuable source of clean, renewable energy.

In addition, protecting shallow water marine and coastal habitats such as seagrass beds can store significant amounts of carbon (also referred to as blue carbon). Moreover, private companies could use Florida's offshore areas to build and develop innovative climate-friendly technologies and novel emission reduction solutions. For instance, algae cultivation has been proposed as a viable carbon capture mechanism (DOE, 2017). In addition, algae cultivation can produce material used as a feedstock supplement. This approach has the potential of reducing emissions from cattle, and some argue that it is a mechanism for creating resilient food systems (DOE, 2017; Guarneri, 2021). This in turn could further facilitate and enhance emission reduction efforts. Implementing policies that would encourage the development of nearshore algae farms could provide valuable economic opportunities. Moreover, these types of policies could also encourage cutting-edge technologies and research and development (R&D) efforts for the design of emission reduction and climate mitigation strategies.

Policies to support these public and private interests would be variable, and in some cases, activity-specific, with each entity using the submerged lands having their own unique contribution to potential emission reductions. Example industries could include those growing algae to be used as a supplemental feedstock for cattle in Florida and across the country.

In markets that value carbon credits, companies exist that can offset emissions produced by industries using their own unique technologies that store carbon within the seabed. Similarly, the creation of nature-based mitigation banks through the mass area redevelopment of marine plant systems like seagrass beds can be utilized to sequester carbon naturally over time. Lastly, ocean-based renewable energy plants can be constructed, using the natural processes and area of the ocean to produce clean, low emission power.

Developing incentives to use Florida’s offshore areas for the development of algae farms can serve as an effective approach to help the state reach its net-zero emission target.

The Florida Department of Agriculture and Consumer Services allows private industries to lease tracts of state-owned submerged lands. Some examples include lands leased for oyster and live-rock production. Florida could consider developing a policy that would encourage industries to lease submerged areas for the development of carbon capture and storage projects and renewable energy installations. Associated costs would be related to field expeditions and site suitability analyses, as well as the enforcement and compliance mechanisms designed to ensure environmental protection and marine resource conservation. These costs may be offset by potential tax revenues resulting from the development of new industries off the Florida coast.

10.4. Incentives Policy for End-User Distributed Power and Solar Electric Vehicle Charging Infrastructure

Across the United States, several state governments have created financial incentives to support the deployment of renewable energy along with energy efficiency technologies and practices. Financial incentives can improve access to capital, reduce the burden of high upfront costs, lower financing costs, support the creation of new markets, and address split incentives associated with energy-efficient technologies (Cox, 2016). Generally, renewable energy technologies experience difficulty in maintaining any short-run success in mainstream energy markets (Gouchoe, 2002). To combat the barriers to new technology development, governments have invested millions of dollars in price support. Common financial incentives include 1) tax measures; 2) rebates, grants, performance-based incentives; and 3) loan programs, guarantees, and credit enhancements (Cox, 2016). The goal of these incentives and strategies is to motivate consumers to use renewable energy technologies by “leveling the playing field” in an economic and institutional sense (Gouchoe, 2002).

Currently, Florida ranks third in the nation for solar potential but is only 12th in the nation for installed solar PV capacity; in addition, only 2% of all electricity generation in Florida in 2019 was from solar, and about 4% in 2020 (Stevens et al., 2020; Solar Energy Industries Association, 2021). One of the reasons for this discrepancy is due to Florida's ban of the solar power purchase agreement (PPA). Enabling PPAs may allow more non-profits, like schools and faith communities, as well as municipalities, to install smaller-scale solar projects for electricity generation (Stevens et al., 2020). The statute could be revised to exempt solar service providers from utility regulations.

Recognizing the need and future demand to efficiently expand EV charging station infrastructure, other states such as California, Colorado, and New York have developed statewide initiatives to fund and encourage the charging station installation (see Appendices). Taking into account the public wellbeing, sustainability considerations, and emission reduction goals, Florida should support the development of policies that expand EV charging station infrastructure and accessibility throughout the state.

10.5. Renewable Portfolio Standard (RPS)

To effectively reach 100% clean energy by 2035, it would be beneficial if Florida created and implemented a portfolio standard. A portfolio standard requires load-serving entities (typically utility companies) to supply and sell a minimum percentage or amount of retail load along with eligible sources of renewable energy (Barbose, 2021).

Currently, thirty states and the District of Columbia have some version of a clean energy standard (Waldman, 2021). Although this is promising, it is essential for all fifty states, including Florida, to enact energy efficiency goals. Without effective climate change action strategies implemented by all states, the Energy Information Administration (EIA) projects that just 41% of U.S. electricity will come from clean energy sources in 2050 (Fitzpatrick, 2018). This is far from the 100% low-carbon electricity goal in Biden's plan, and only a slight increase from the 37.5% the U.S. is using in "clean" energy today (Biden, Harris Democrats).

Thus, creating and enacting a renewable portfolio standard (RPS) in the state of Florida is essential. The RPS is a public policy tool that requires a certain amount of renewable energy targets and incorporates a compliance penalty for non-performance (Heeter et al., 2019). Essentially, RPS is a cost-effective, market-based policy that requires electric utilities to gradually increase their use of renewable energy resources such as wind, solar, and bioenergy (Dobson, 2008). The goal of an RPS is to displace fossil fuels, reduce greenhouse gas emissions, and promote customer affordability through stable customer rates (University of California, 2019).

The RPS is extremely beneficial for the following reasons: 1) it stimulates economic development, 2) contributes to a vibrant renewable energy market; 3) reduces the dependence on foreign fuels; 4) protects the public's health by promoting cleaner energy resources; 5) promotes stable electricity prices for consumers through a mix of energy generation resources; and 6) improves environmental quality and increases the amount of renewable energy generation (Dobson, 2008).

Since an RPS is unique to every state, Florida's emission reduction values could vary depending on the chosen timeline and targets. However, RPS programs substantially reduce carbon emissions (Greenstone et al., 2020). Depending on the policy specifications, Greenstone et al. (2020) found that CO_2 emissions fall by 10–25% in the seventh year after the start of the RPS program, and 23–36% in the 12th year (Greenstone et al., 2020).

An RPS policy in Florida is not only feasible but would be extremely reasonable. Since the Southeast of the U.S. lacks RPS and other energy efficiency policies, Florida has the opportunity to be a leader within this region. Many states with greater population and electricity output have already implemented RPS policies. Therefore, Florida should not shy away from following suit. A further look into the RPS implementation process may be a more thorough way of illustrating the steps Florida could take to establish this policy. Suggestions on the implementation process of RPS can be found in Appendix R, or a thorough example of RPS Eligibility can be found in California Energy Commission's online guidebook (California Energy Commission, 2017).

According to EIA estimates, Florida's average retail electricity rate is 11.58 cents and the average consumption is 1,141 kilowatt-hours per month, totaling $132.16 (Silberman, 2017). Silberman estimates that for every one percent increase in renewable energy, electricity rates will increase to 11.64 cents (a 0.06 cent increase) totaling $132.81 per month. Thus, an increase in consumers' monthly electricity bill by $0.65 for every one percent increase in renewable energy. Although an increase in consumers' electricity bills is unfavorable, this increase is not significant, and as the supply of renewable energy sources increases, this may decrease electricity rates for future ratepayers (Silberman, 2017).

Generally, costs incurred for implementing an RPS policy are split between two areas: electricity system costs and electricity prices. In Silberman's "Costs and Benefits of Renewable Portfolio Standard in Florida," he created a suite of complex financial models to test different RPS-implementation scenarios. These scenarios estimated 15%, 35%, and 50% energy consumption from renewable sources by 2050. Costs associated with these scenarios were estimated as $11B, $16B, and $28B respectively. However, the resulting benefits were $21B, $24B, and $31B. As benefits outweigh the costs, Silberman concludes that implementing an RPS in Florida would be cost-effective (Silberman, 2017). In this report, the author defines benefits as the incremental savings in carbon dioxide emissions based on the EPA's social cost of carbon dioxide per metric ton, and costs as incremental based on the percentage of renewable energy (Silberman, 2017).

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APPENDICES

I. Appendices for GHG Inventory & Projections

GHG emissions methodologies, results, key uncertainties, and sources for each sector

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ENERGY SECTOR

Appendix A

CO_2 from Fossil Fuel Combustion

Overview

This section presents carbon dioxide (CO_2) emissions from fossil fuel combustion for energy use in the residential, commercial, and industrial (RCI) sectors. Additionally, the sectors of transportation, electric power, and international bunker fuels[5] were also analyzed. Emissions are estimated based on the collection of data pertaining to combustion efficiency (percentage of carbon oxidized during combustion) and carbon content coefficients. For the industrial sector, carbon stored in products takes non-energy consumption of fuels into account.

Methodology

The methodological steps used for estimating CO_2 emissions are divided according to activities tracked within the US Environmental Protection Agency's (EPA) State Inventory Tool's (SIT) module for Fossil Fuel Combustion (FFC). These activities are described below. Additionally, Table A-1, directly pulled from the EPA's module user guide, lists the fuel types consumed per sector which this module analyzes.

Sector-based CO_2 emissions equations:

- Residential and commercial sector – estimated emissions were calculated using the following equation:

  Emissions (MMT CO_2e) *= Consumption (BBtu) × Emission Factor (lbs C/BBtu) × 0.0005 short ton/lbs × Combustion Efficiency (% as a decimal) × 0.9072 (ratio of short tons to metric tons) ÷ 1,000,000 ×(44/12)*

- Industrial sector – carbon emissions are estimated first by separately calculating the net fuel consumption, due to the fact that some of the fuel can be consumed for non-energy uses. The two-step calculation is provided in the equations below:

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[5] International bunker fuels are activities related to international transportation, through both aviation and maritime transport; Emissions from international bunker fuels are the result of fuel combustion for these transport activities (EPA, 2021).

- ***Net Consumption (BBtu)*** = *Total Consumption (BBtu) - [(Non-Energy Consumption (BBtu) x Storage Factor (%)]*
- ***Emissions* (MMT CO_2e)** = *Net Consumption (BBtu) x Emission Factor (lbs C/BBtu) × 0.0005 short ton/lbs × Combustion Efficiency (% as a decimal) × 0.9072 (ratio of short tons to metric tons) ÷ 1,000,000 ×(44/12)*

Combustion Efficiency:

Carbon emissions are calculated based on the combustion efficiency (percent carbon oxidized). For this section, combustion efficiencies are identified for coal, natural gas, petroleum, and liquid petroleum gas (LPG) as percentages, used if carbon is not entirely oxidized during the combustion of these fossil fuels. The fraction oxidized is assumed to be 100 percent for each of these fossil fuels, according to the Intergovernmental Panel on Climate Change (IPCC, 2006).

Carbon Content:

Carbon content coefficients express the maximum quantity of carbon emitted per unit of energy released which, in the case of fossil fuel, varies by fuel type (EPA 2020). This is the second data control required to complete the emission estimates. Determined by the US Department of Energy’s (DOE) Energy Information Administration (EIA), samples are tested to distinguish carbon content by fuel types and assessed upon market requirements.

The default carbon content based on national values in the SIT was used to estimate emissions. The coefficients do not vary significantly from state to state, with coal as an exception. Carbon content values are retrieved from the EPA’s Inventory of US GHG Emissions and Sinks (EPA, 2020).

- Carbon content units are listed as pounds carbon/million British thermal units (lbs C/MMBtu)
- Various carbon contents vary by year according to fuel quality

Non-Energy Use Storage Factors:

In the industrial sector, various fossil fuels (e.g. LPG) have potential non-energy uses which do not all result in fuel combustion. Therefore, industrial emission estimates consider non-energy products and their associated storage factors (in percentage) when estimating emissions from fuel use in the industrial sector. Default storage factors were retrieved from national data in the EPA’s Inventory of US GHG Emissions and Sinks. The EPA used stocks and flows to assume storage factors based on the ratio of: (1) total carbon stored by the non-energy products of fuels, to (2) the complete carbon coefficient of the fuel consumed. Some of the common non-energy uses of fuels include: LPG, Feedstocks (Naphtha), Feedstocks (Other Oils), Pentanes Plus, and Natural Gas. Their storage factors vary by year.

Residential	Commercial	Industrial	Transportation	Electric Utilities	International Bunker Fuels
Coal	**Coal**	**Coking Coal** **Other Coal**	**Coal**	**Coal**	
Natural Gas	**Natural Gas**	**Natural Gas**	**Natural Gas**	**Natural Gas**	
Petroleum: Distillate Fuel Kerosene Hydrocarbon Gas Liquids	**Petroleum:** Distillate Fuel Kerosene Hydrocarbon Gas Liquids Motor Gasoline Residual Fuel	**Petroleum:** Distillate Fuel Kerosene LPG Motor Gasoline Residual Fuel Lubricants Asphalt/Road Oil Crude Oil Feedstocks Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Naphthas Unfinished Oils Waxes Aviation Gasoline Blending Components Motor Gasoline Blending Components	**Petroleum:** Distillate Fuel Hydrocarbon Gas Liquids Motor Gasoline Residual Fuel Lubricants Aviation Gasoline Jet Fuel, Kerosene Jet Fuel, Naphtha	**Petroleum:** Distillate Fuel Residual Fuel Petroleum Coke	**Petroleum:** Jet Fuel, Kerosene Distillate Fuel Residual Fuel
Other (e.g. geothermal)	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**	

Table A-1: CO_2FFC - Fuel Types Consumed by Sector (Source: EPA 2020)

Data Sources

- *Carbon Efficiency* values can be found in the 2006 IPCC Guidelines For National Greenhouse Gas Inventories, Volume 2, as referenced by the EPA. Data used are universal values that can be applied in all states.
- *Carbon Conten*t is based on Table A-43 of Annex 2 of the EPA's 2020 Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2018. The report provides national carbon content data that varies by year for specific fuel types.
- *Storage Factors* are based on Table 3-22 of Annex 2 of the EPA's 2020 Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018.
- *Carbon Consumption* is based on a database file available at the US DOE's EIA. Data is found within the State Energy Data System (SEDS) of EIA where national values are allocated according to state and sector.
- *Florida's Energy Consumption* data were taken from the EIA's SEDS. Values were revised upward significantly for Florida consumption in the 2019 SEDS estimates. In particular, the method for jet fuel consumption estimation was revised from 2010 onward. Florida consumption data for 2017 and 2018 were the most commonly updated, with sporadic earlier year values.
    - Product supplied data approximately represents the consumption of petroleum products because it measures the disappearance of the surveyed products from primary sources.
    - Florida consumption is measured in billion btu (BBtu), as used in the SIT.

Results

Residential Sector:

Figure A-1 displays the carbon emissions (MMT CO_2e) from the residential sector. Emissions are calculated using relevant fuel types from the years 1990 through 2018.

For the residential sector, emissions are mainly released from petroleum and natural gas uses. Coal emissions have not been relevant to Florida's residential sector throughout the twenty-eight-year time series. Emissions from petroleum were the highest in the early 1990s, which peaked at 0.89 MMT CO_2e in 1992. In 2018, the emission fell to 0.42 MMT CO_2e. Natural gas consumption surpassed petroleum use in 1994. Emissions consistently increased through the years, ranging from 0.83 MMT CO_2e in 1994 to 0.93 MMT CO_2e in 2018. Total residential carbon emission from fossil fuels combustion has decreased an estimated 11% since 1990.

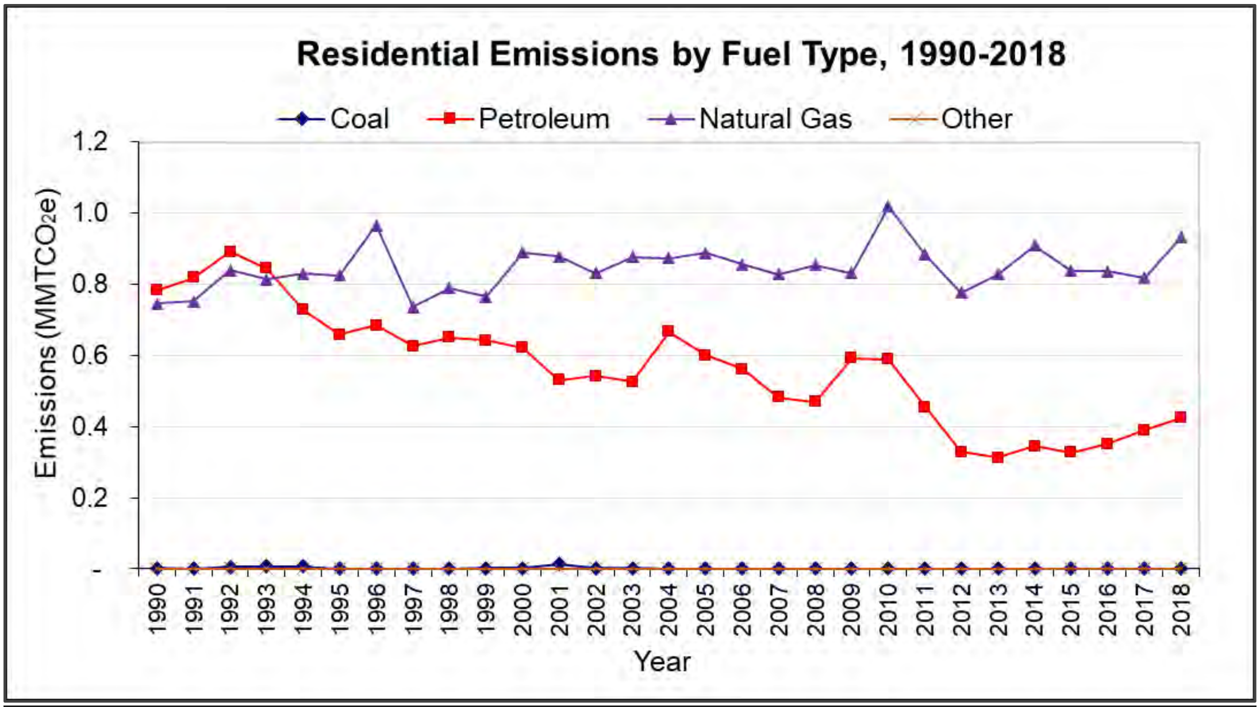

Figure A-1: CO_2FFC - Historical emissions from the different fuel sources in the residential sector.

Commercial Sector:

Figure A-2 displays carbon dioxide emissions from the commercial sector according to fuel types. Emissions are calculated using relevant fuel types from the years 1990 through 2018.

For the commercial sector, petroleum was consumed at an all-time high in 1990, with emissions estimated to be valued at 4.15 MMT CO_2e. Petroleum emissions decreased significantly by nearly 66% until 1998 and have held relatively consistent until spiking again after 2014. Petroleum emissions have reverted back to high values of 3.61 MMT CO_2e in 2018. Coal in the commercial sector has emitted zero emissions since 2003. Natural gas has a gradual increase of about 67% from 1990 to 2018, emissions have peaked at 3.48 MMT CO_2e in 2018. Total carbon emissions have seen an increase of more than 13% in the commercial sector.

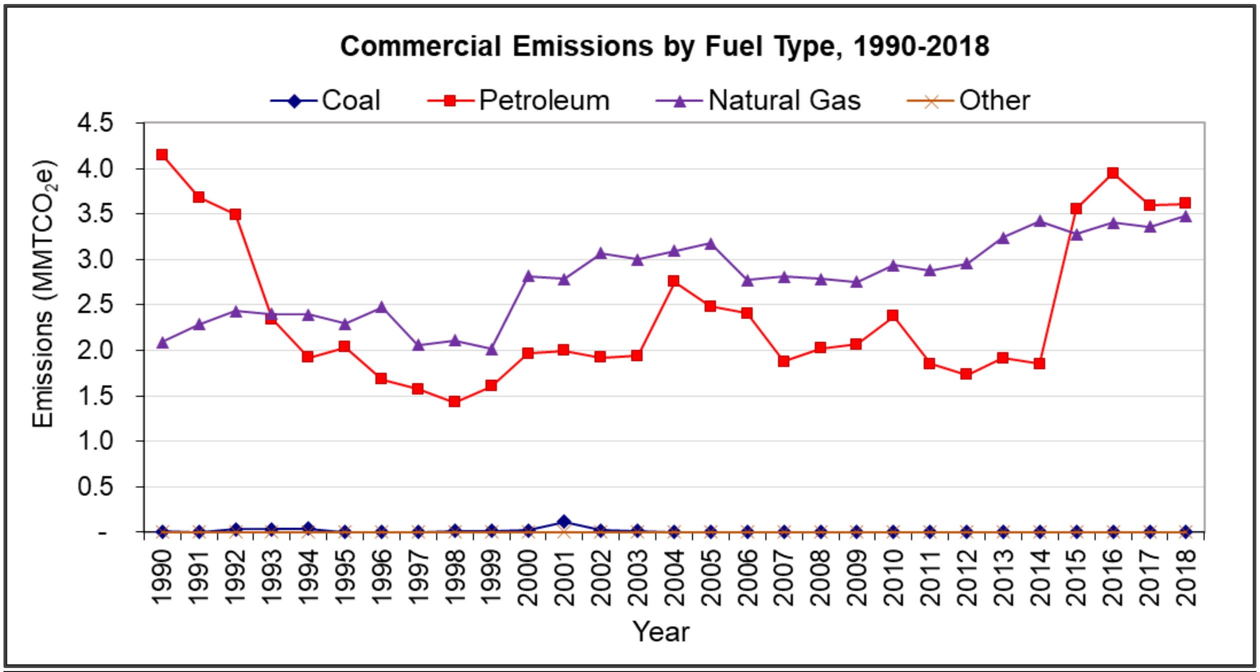

Figure A-2: CO_2FFC - Historical emissions from the different fuel sources in the commercial sector.

Industrial Sector:

Figure A-3 presents carbon emissions (MMT CO_2e) from the industrial sector. Emissions are calculated using relevant fuel types from 1990 through 2018. Industrial sector emission calculations consider non-energy consumption estimated with the SIT.

For the Industrial sector, each type of fuel is consumed as a contributor to total carbon emissions. Coal has been consumed at a near consistent rate from 1990 to 2010, averaging at about 2.76 MMT CO_2e. Coal's carbon emissions for the industrial sector have decreased through the 2010s, estimated at 1.2 MMT CO_2e in 2018. Petroleum consumption has fluctuated from 1990 through 2018, reaching a peak of 6.99 MMT CO_2e in 2003. While petroleum carbon emissions have decreased since then, emissions have had a total increase of nearly 12%, in 2018 since the early 1990s. Natural Gas has been used more than any other fuel type from 1993 to 1999, with a significant drop in emissions starting in the year 2000. Natural gas consumption gradually increased from 2009 to reach 5.8 MMT CO_2e in 2018. Total Industrial emissions have decreased by 1.31% since the beginning 1990s.

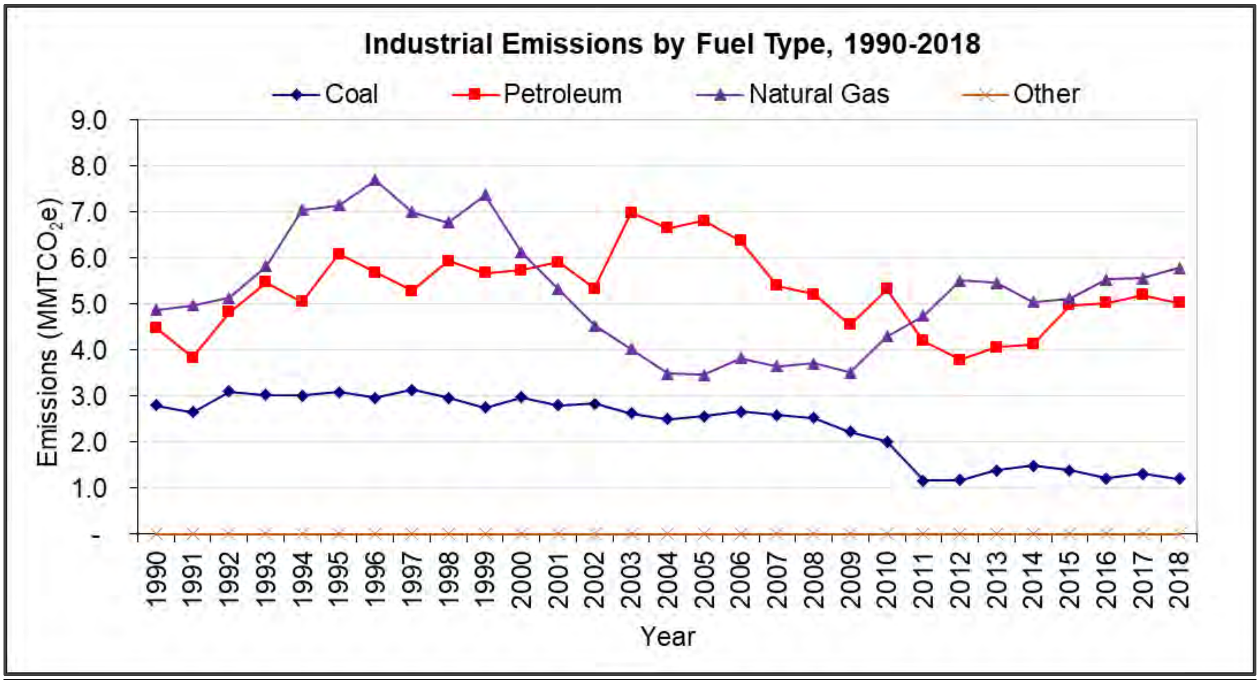

Figure A-3: CO_2FFC - Historical emissions by fuel type in the industrial sector.

Transportation Sector:

Figure A-4 displays CO_2 emissions from the transportation sector according to fuel types. Emissions are calculated using relevant fuel types from the years 1990 through 2018.

Petroleum is the significant fuel type estimated to have emissions for the transportation sector. Its estimates have seen a steady increase in carbon emissions, starting at 81.32 MMT CO_2e in 1990 to 126.32 MMT CO_2e in 2018. Natural gas has marginally contributed to the total carbon emissions in the transportation sector, with a gradual increase from 0.16 to 1.15 MMT CO_2e between 1990 and 2018. Emissions in 2018 for transportation have seen a 56.44% increase since 1990.

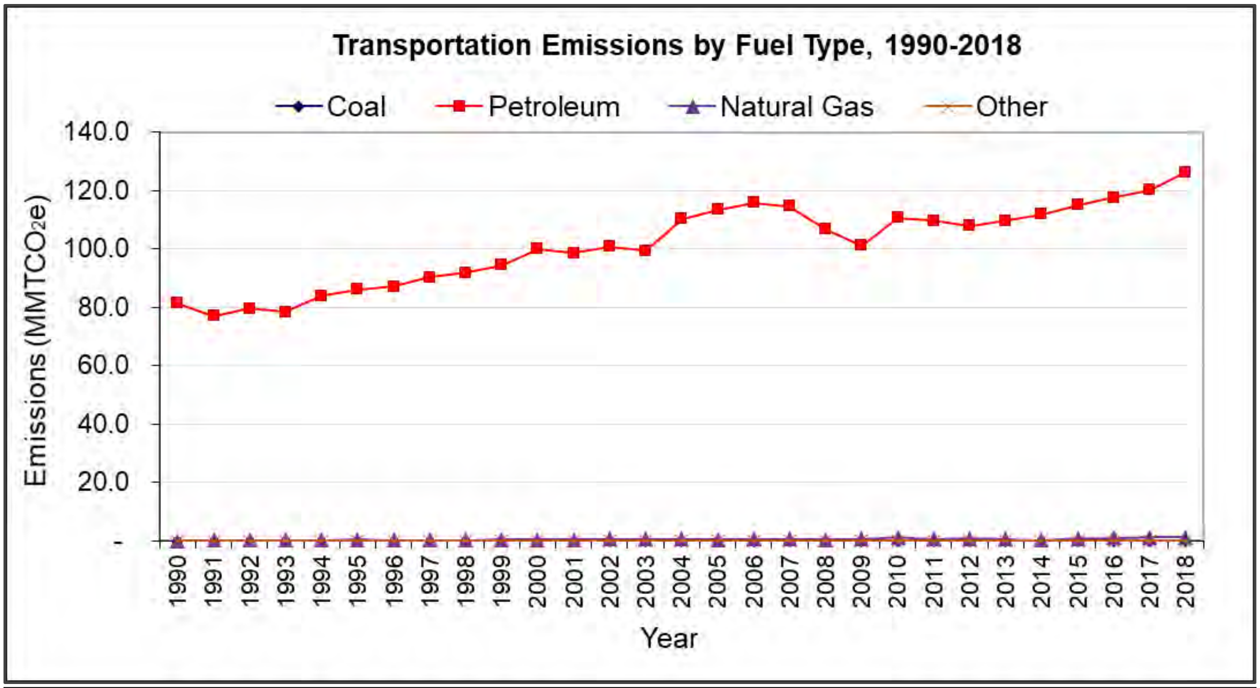

Figure A-4: CO_2FFC - Historical emissions by fuel type in the transportation sector.

Electric Power Sector:

Figure A-5 displays the carbon emissions (MMT CO_2e) from the electric power sector. Emissions are calculated using relevant fuel types from 1990 through 2018.

Coal is used more in the electric power sector than in any other sector. Coal emissions have ranged from 55.94 to 61.3 MMT CO_2e from the years 1990 to 2008. The coal sector began to noticeably decrease after that. By 2018 emissions have dropped to 28.99 MMT CO_2e, the lowest emissions on record for coal in the electric power sector. Alternatively, natural gas consumption has drastically increased by almost 576% from 1990 to 2018, reaching emissions of 68.7 MMT CO_2e. Petroleum has also contributed to total carbon emissions, however very minimally since about 2011. Petroleum only contributes an estimated 2% of the total 99.77 MMT CO_2e from the electric power sector.

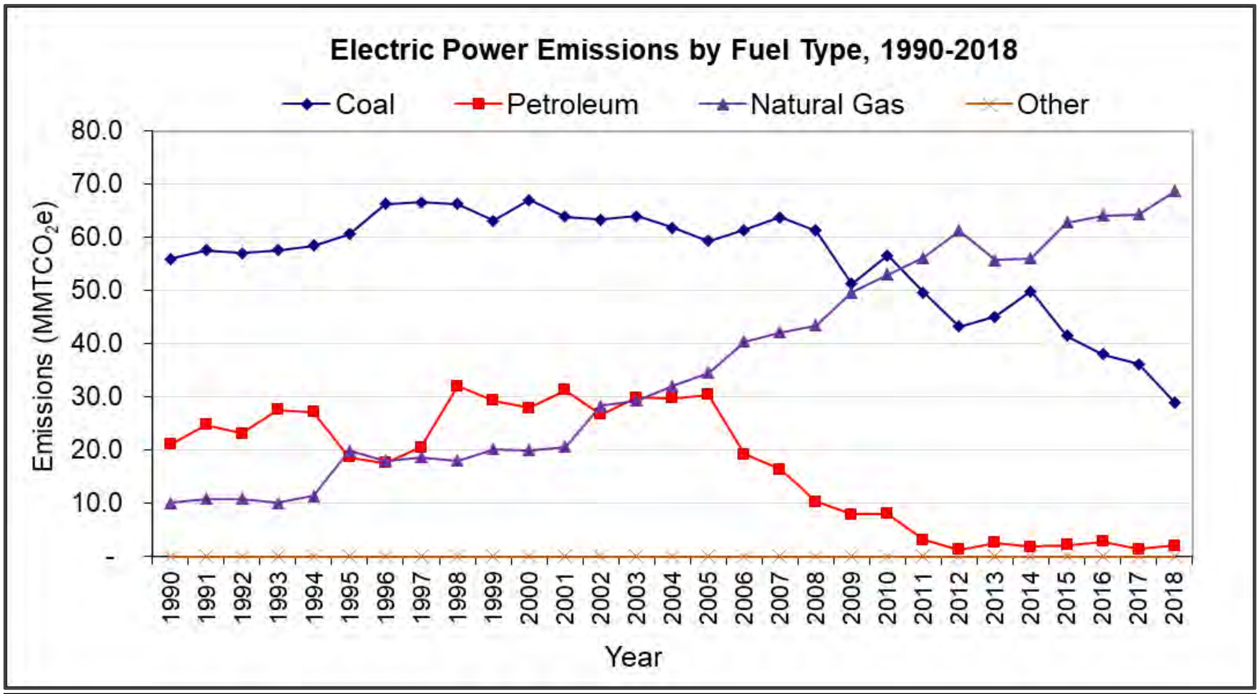

Figure A-5: CO_2FFC - Historical emissions by fuel type in the electric power sector.

Emissions by Fuel Type and Sector:

As estimated in the SIT, Figure A-6 displays petroleum as the major carbon emissions contributor, valued at 137.47 MMT CO_2e in 2018, followed by natural gas which is estimated at 80.06 MMT CO_2e. Thus, petroleum and natural gas are the main sources of energy in the state and hence the main contributors to GHG emissions. While emissions from petroleum and natural gas have increased over the years, emissions from coal have shown a decline since 2009. Table A-2 displays carbon emissions by fuel type at 5-year intervals from 1990 to 2018.

According to Figure A-7, transportation and electric power are the two main contributors to the total carbon emissions from 1990 to 2018.

Table A-2 and Table A-3 summarize emissions by fuel type and by sector. Total carbon emissions from the transportation and electric power sectors are estimated to equal 227.24 MMT CO_2e in 2018, accounting for 91.7% of total carbon emissions from all sectors that year. In 2005, the other baseline year, those same two sectors emitted a combined total of 238.27 MMT CO_2e, just over 92.2% of all sector emissions. The residential, commercial, and industrial sectors have stayed relatively consistent in their emissions, each one contributing only slightly in comparison to the other transportation and electric power sectors. International bunker fuel is estimated but not included in the total emission for the state. International bunker fuels are used outside the US and are not considered to specifically contribute to the state GHG emissions.

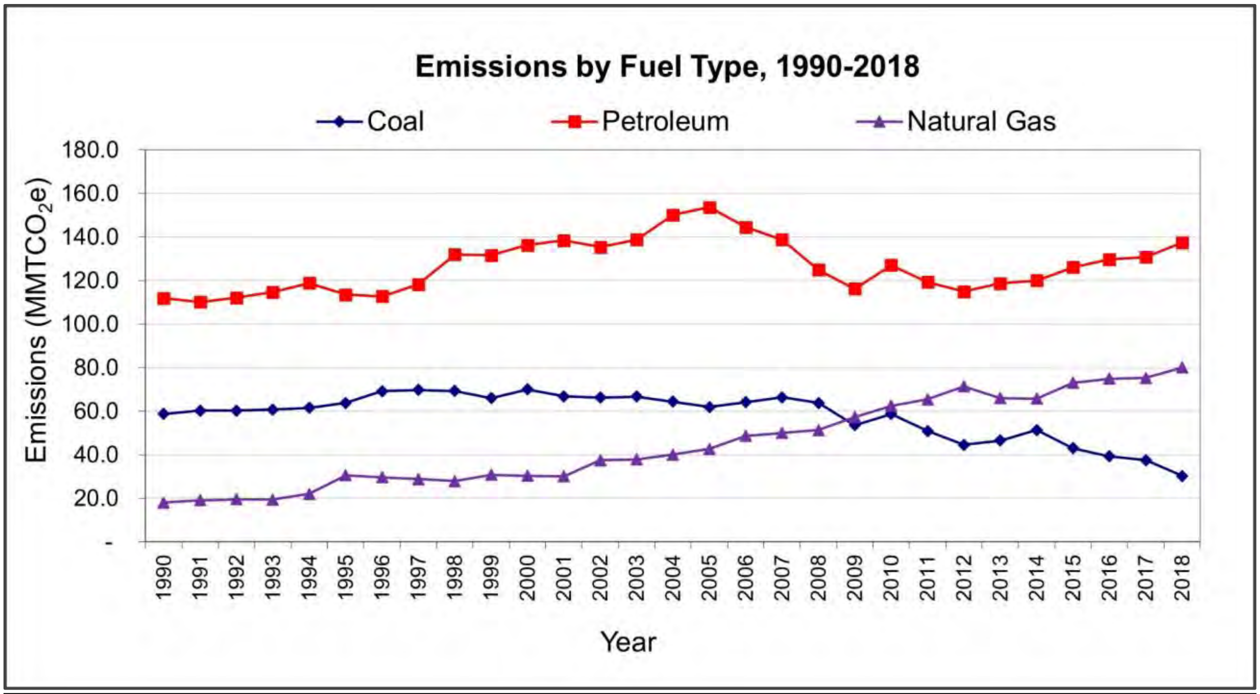

Figure A-6: CO_2FFC - Historical emissions by fuel type in all sectors (residential, commercial, industrial, transportation, and electric power).

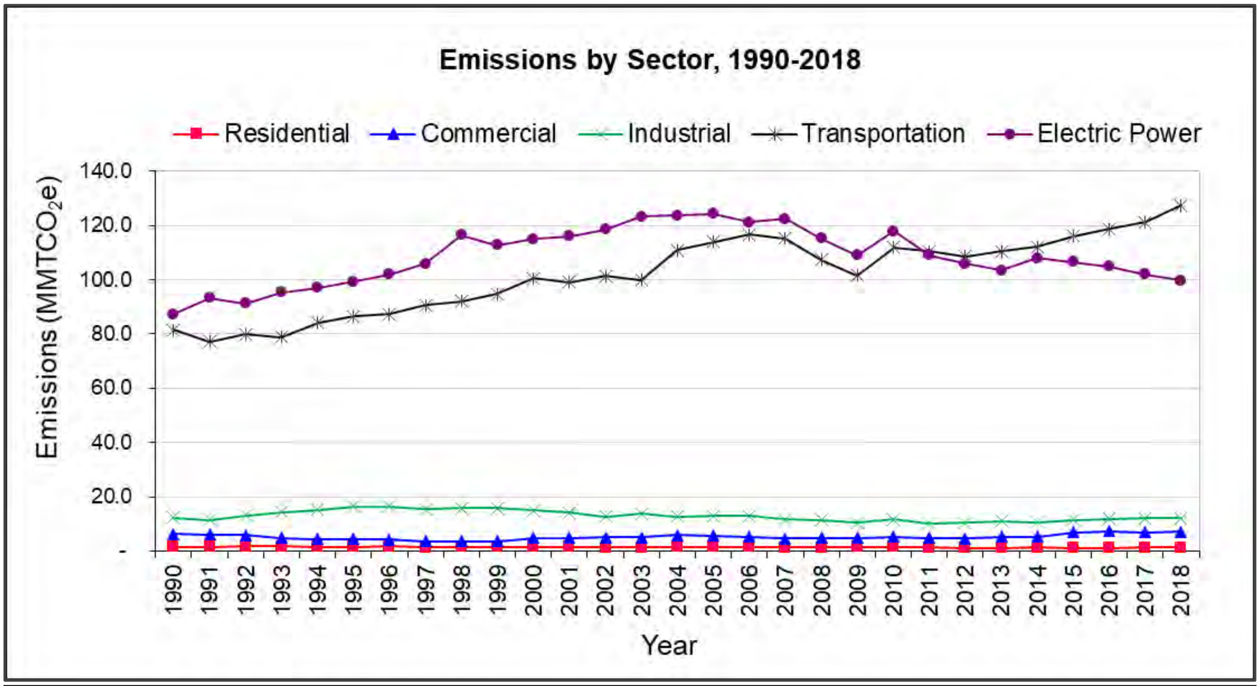

Figure A-7: CO_2FFC - Historical emissions by sector.

Fuel Type	1990	1995	2000	2005	2010	2015	2018
Coal	58.77	63.73	70.03	61.91	58.70	42.96	30.19
Petroleum	111.83	113.51	136.28	153.70	127.04	126.05	137.47
Natural Gas	18.04	30.58	30.31	42.66	62.53	73.00	80.06

Table A-2: CO_2FFC - Emissions by Fuel Type (MMT CO_2e).

Sector	1990	1995	2000	2005	2010	2015	2018
Residential	1.53	1.48	1.51	1.49	1.61	1.17	1.36
Commercial	6.25	4.33	4.80	5.66	5.31	6.83	7.09
Industrial	12.19	16.35	14.85	12.85	11.65	11.50	12.03
Transportation	81.48	86.47	100.45	113.92	111.89	115.98	127.47
Electric Power	87.19	99.18	115.00	124.35	117.80	106.54	99.77
International Bunker Fuel	0.03	0.02	0.02	0.02	0.04	0.03	0.03
Total	**188.64**	**207.81**	**236.63**	**258.27**	**248.26**	**242.01**	**247.72**

Table A-3: CO_2FFC - Emissions by Sector (MMT CO_2e).

Key Uncertainties

State-specific consumption data can often have uncertainties when allocating data according to sector (residential, commercial industrial, transportation, and electric power).

Energy consumption from SEDS accurately allocates data according to state, however, it is possible that Florida actually consumed fuels that display zero consumption values. These are either reported as zero in the EIA surveys or the state level consumption values by state allocators show nothing for Florida. For example, coal consumption in the residential and commercial sectors is reported as zero for 1997, 2004, and 2008-2018.

Combustion efficiency and carbon content coefficients have significantly fewer uncertainties due to their universal values that do not vary significantly from state to state.

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Appendix B

Stationary Combustion

Overview

The Environmental Protection Agency (EPA) State Inventory Tool's (SIT) stationary combustion module estimates methane (CH_4) and nitrous oxide (N_2O) emissions from fuel combustion in the residential, commercial, industrial, and electric power sectors. For different types of fossil fuel combustion, there are energy and non-energy types of consumption by fuel type and sector, where energy consumption statistics should be collected on an energy basis, most preferred in British thermal units (Btu). For the industrial sector, non-energy usage-related consumption is deducted to avoid double counting.

Parameters and data required in the module include:

- State-specific sector-wise *fuel consumption* by year
- State-specific, sector-wise, fuel-specific *emission factors* for CH_4 and N_2O

Methodology

Sector-based CH_4 and N_2O emissions equations:

- ➢ Residential, commercial, and electric power sectors – for all of the emission calculations, the IPCC tier-1 approach is used in the SIT tool. The equation used in SIT to estimate emissions by sector and fuel type is as follows:

  Emissions (MMT CO_2e) *= Consumption (BBtu) × Emission Factor (MT/BBtu) × GWP ÷ 1,000,000*

- ➢ Industrial sector – here, default data in the tool has been used as state-specific non-energy fuel consumption data. The equation is as follows:

  Emissions (MMT CO_2e) *= [Total Consumption (BBtu) – Non-Energy Consumption (BBtu)] × Emission Factor (MT/BBtu) × GWP ÷ 1,000,000*

Emission Factors:

Intergovernmental Panel on Climate Change (IPCC) guidelines provide an aggregated emissions factors (EFs) table for each of the non-CO_2 gases (CH_4 and N_2O). Additionally, EPA has published EFs at the national level for several fuel types. Considering that sector-specific and fuel-specific data are available at the national level, stationary combustion values for Florida CH_4 and N_2O emissions are calculated from national-level data.

Global Warming Potential value of CH_4 and N_2O:

Global Warming Potential (GWP) is a crucial factor in the calculation of emissions from greenhouse gases (GHGs). GWP values, of the 100-year time horizon, were pulled from the EPA's Inventory of US GHG Emissions and Sinks report. Total emissions, measured in carbon dioxide equivalent (CO_2e), were calculated considering CH_4 valued at 25 GWP and N_2O at 298 GWP (EPA 2020).

Default State Energy Data:

State energy data is the bulk energy consumption data, categorized by fuel type, year, use, and sector. This information is obtained from the United States Department of Energy (US DOE) Energy Information Administration's (EIA) State Energy Data System (SEDS). The unit required in SIT is billion Btu (BBtu), so the source data, which is often available in other units such as trillion Btu (TBtu), is converted to the desired unit of the tool. Some of the SIT's default data is taken into account from 1991-1999 (except 1995) because those years are not available in SEDS. In the case of wood fuel, SEDS has a combined value of "Wood, wood-derived fuels, and biomass waste." Table B-1, directly pulled from the EPA's module user guide, lists the fuel types consumed per sector which this module analyzes.

Residential	Commercial	Industrial	Electric Utilities
Coal	**Coal**	**Coking Coal** **Independent Power Coal** **Other Coal**	**Coal**
Natural Gas	**Natural Gas**	**Natural Gas**	**Natural Gas**
Petroleum: Distillate Fuel Kerosene Hydrocarbon Gas Liquids	**Petroleum:** Distillate Fuel Kerosene Hydrocarbon Gas Liquids Motor Gasoline Residual Fuel	**Petroleum:** Distillate Fuel Kerosene LPG Motor Gasoline Residual Fuel Lubricants Asphalt & Road Oil Crude Oil Feedstocks Napthas < 401ºF Other oils > 401ºF Misc. Petroleum Products Petroleum Coke Pentanes Plus Still Gas Special Naphthas Unfinished Oils Waxes Aviation Gasoline Blending Components Motor Gasoline Blending Components	**Petroleum:** Distillate Fuel Residual Fuel Petroleum Coke
Wood	**Wood**	**Wood**	**Wood**
Other (e.g. geothermal)	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**	**Other (e.g. geothermal)**

Table B-1: Stationary Combustion - Fuel Types Consumed by Sector (Source: EPA 2020).

Data Sources

- *EF* data was pulled from two sources which were combined based on sector-specific and fuel-specific data availability:
    - Sector-specific, fuel-specific data was first pulled from the IPCC's Non-CO_2 Emissions from Stationary Combustion.
    - For fuel-specific data which were not provided in the above IPCC source, the GHG Emission Factors Hub created by the EPA's Center for Corporate Climate Leadership was used to fill these gaps.
- *Default State Energy Data Table* used EIA's SEDS to determine state-specific, sector-wise, fuel-specific, and year-wise data [DOE/EIA-0214(2019].

Results

Residential Sector:

Figures B-1a and B-1b show the CH_4 and N_2O emissions by fuel type from the residential sector in CO_2 equivalent (CO_2e). Emissions are calculated using relevant fuel types from the years 1990 through 2018. For the residential sector, emissions are mainly released from wood for most years, especially between 1990 to 1992 and 2009 to 2014. The highest emissions were in 1992 with CH_4 totaling 0.22 MMT CO_2e and N_2O totaling 0.03 MMT CO_2e. For the other fuel types used by the residential sector, CH_4 and N_2O-related emissions lie relatively low with minimum fluctuation over the years.

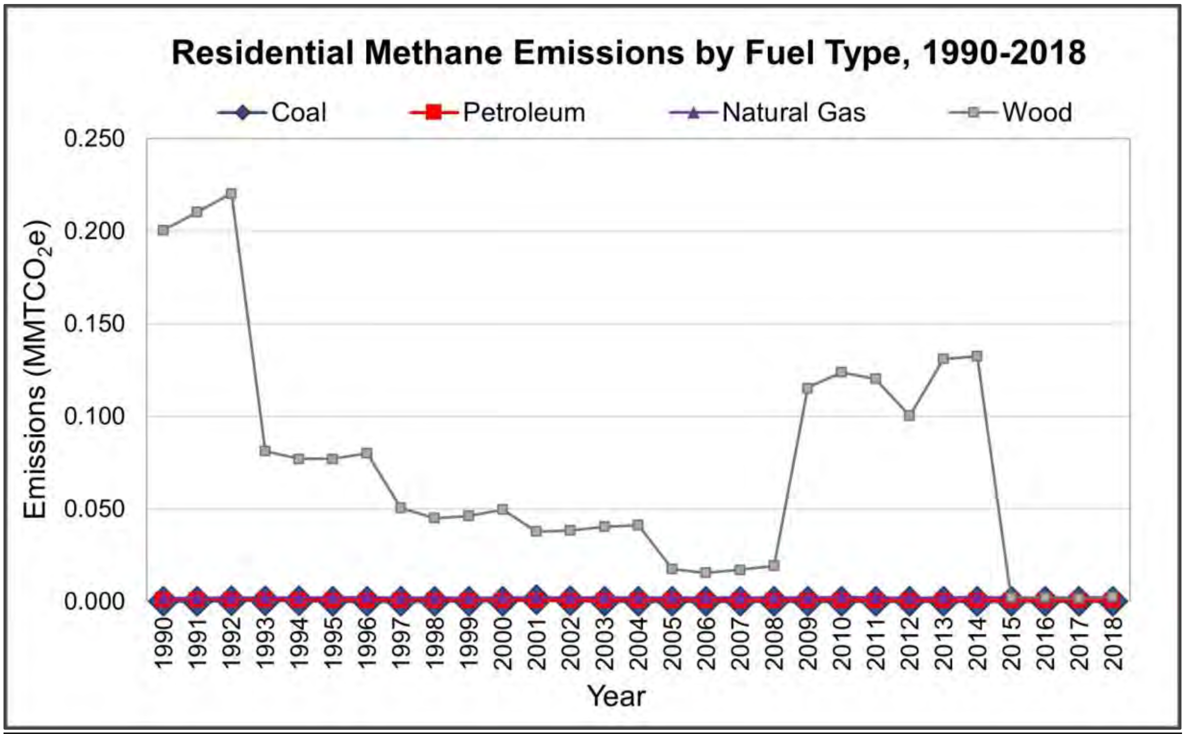

Figure B-1a: Stationary Combustion - Emissions for CH_4 by fuel type in the residential sector.

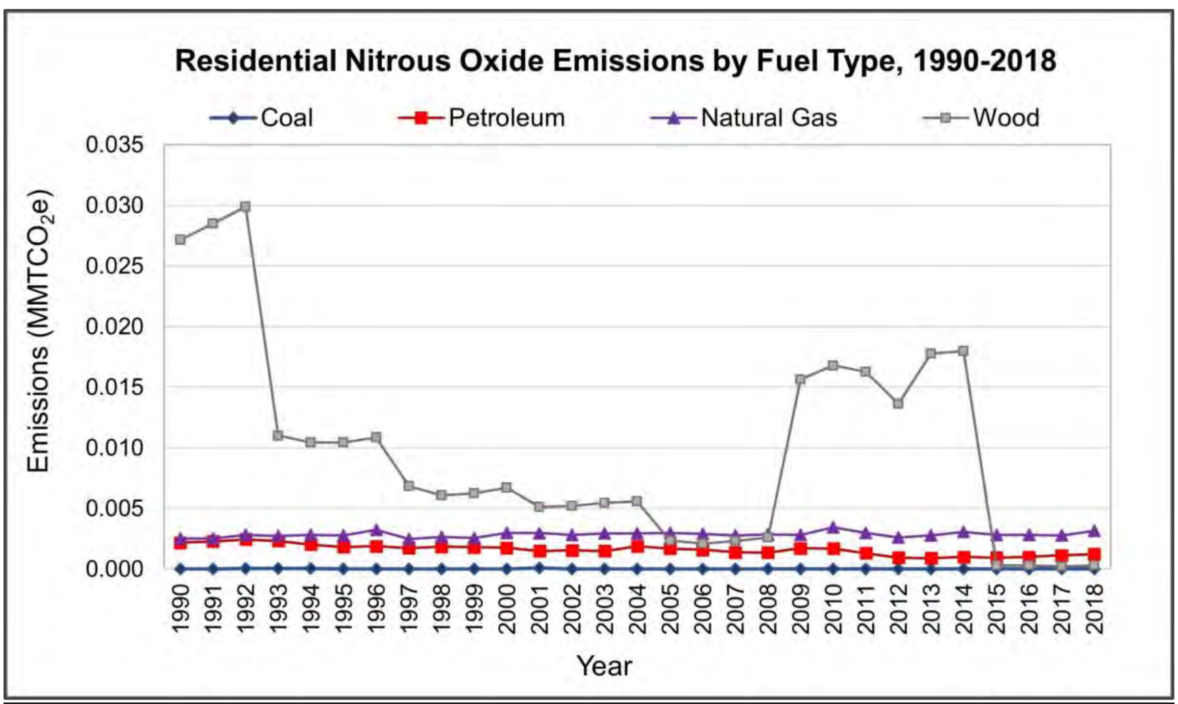

Figure B-1b: Stationary Combustion - Emissions for N_2O by fuel type in the residential sector.

Commercial Sector:

Figures B-2a and B-2b show the CH_4 and N_2O emissions (MMT CO_2e) profile for commercial sector users in Florida by fuel type. Wood is the main source of CH_4 emissions within this sector. It showed a steep rise after 2008 to reach 0.016 MMT CO_2e in 2009, until declining back down in 2015. With respect to the other fuel types, CH_4 emissions from natural gas were significant, and petroleum-related CH_4 consumption doubled from 2015 to 2018 when compared to its 2014 value.

For the commercial sector's stationary combustion N_2O contribution, petroleum is the all-time main source, presenting its steepest rise between 2014 and 2015. One explanation for the steep rise in petroleum consumption is the reduced use of wood by commercial users. Emissions from the other fuel types remain steadily low.

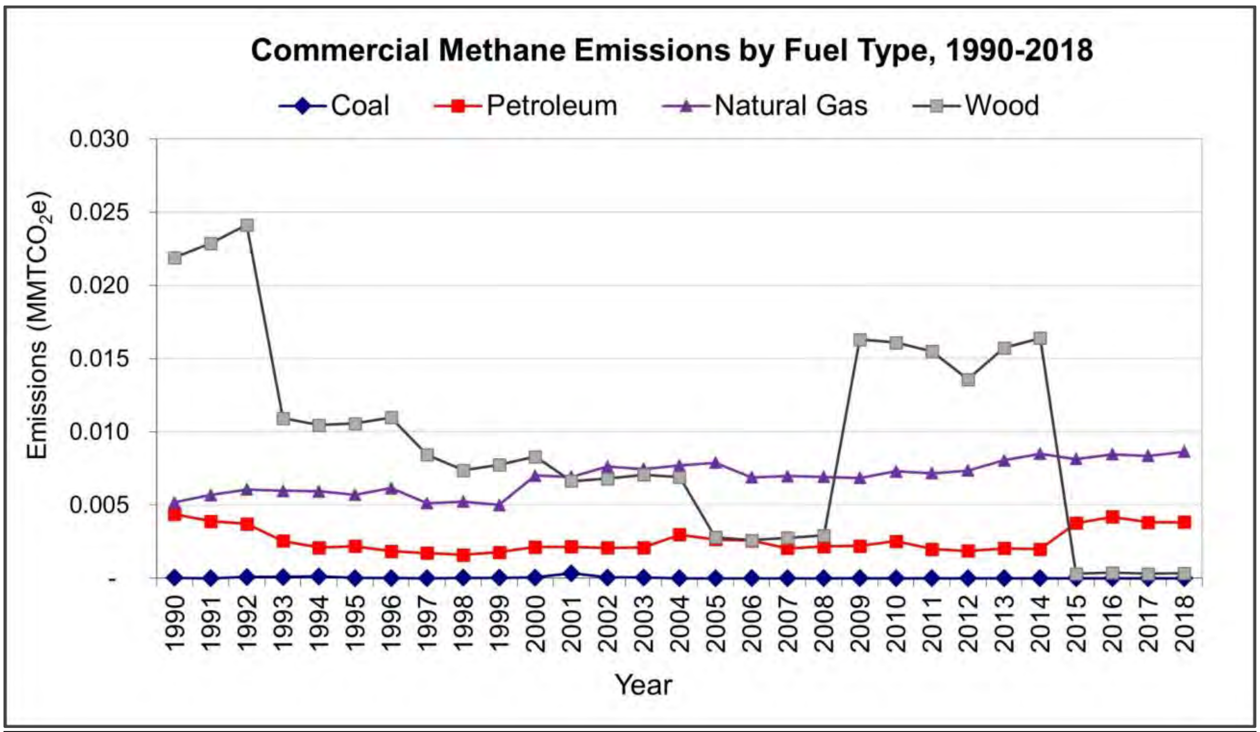

Figure B-2a: Stationary Combustion - Emissions for CH_4 by fuel type in the commercial sector.

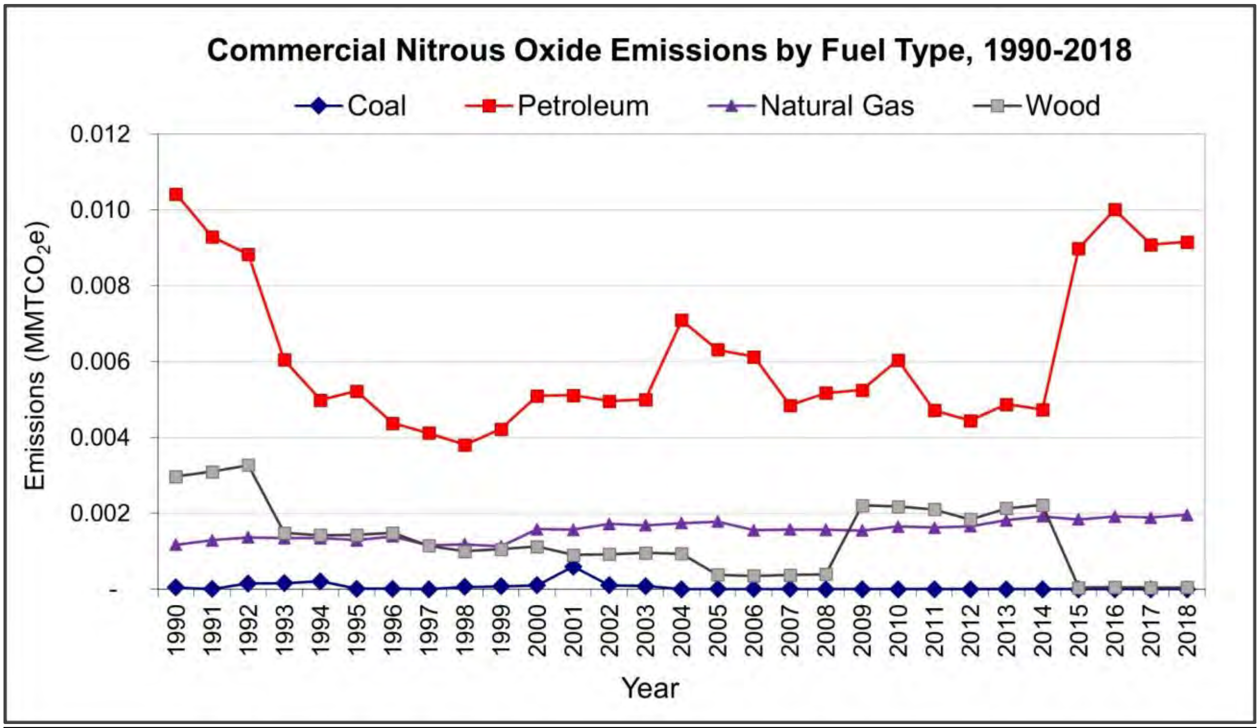

Figure B-2b: Stationary Combustion - Emissions for N_2O by fuel type in the commercial sector.

Industrial Sector:

Figures B-3a and B-3b display the CH_4 and N_2O emissions (MMT CO_2e) for Florida's industrial sector. These sector calculations consider non-energy consumption estimated with the SIT. For this sector's CH_4 emissions, wood is found as the major emitter compared to other less significant fuel sources. Wood's contribution is almost consistently double the sum of other fuels' CH_4 emissions. The average CH_4 emissions are 0.071 MMT CO_2e for wood as a fuel source. On the other hand, petroleum, natural gas, and coal have some but little weight on CH_4 emissions.

Regarding the N_2O contribution from the industrial sector, the majority of the emissions come from wood fuel, with average emissions totaling 0.1 MMT CO_2e. Petroleum and coal respectively take second and third place as emitters.

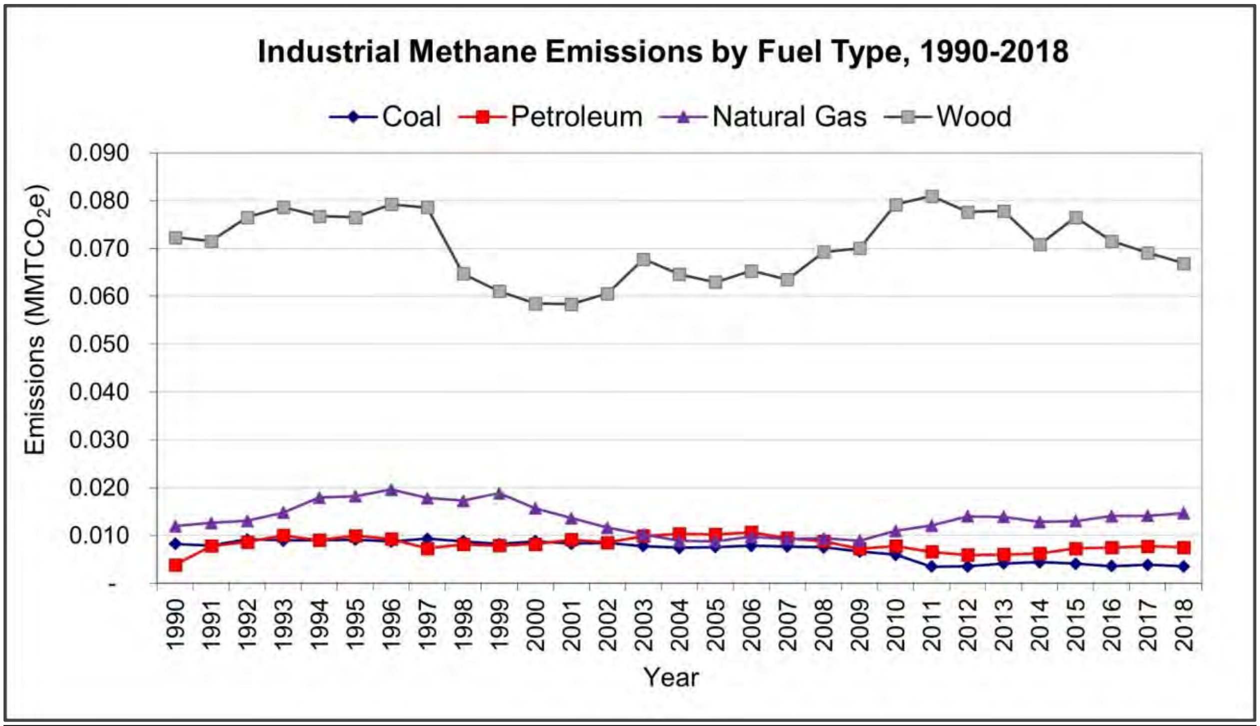

Figure B-3a: Stationary Combustion - Emissions for CH_4 by fuel type in the industrial sector.

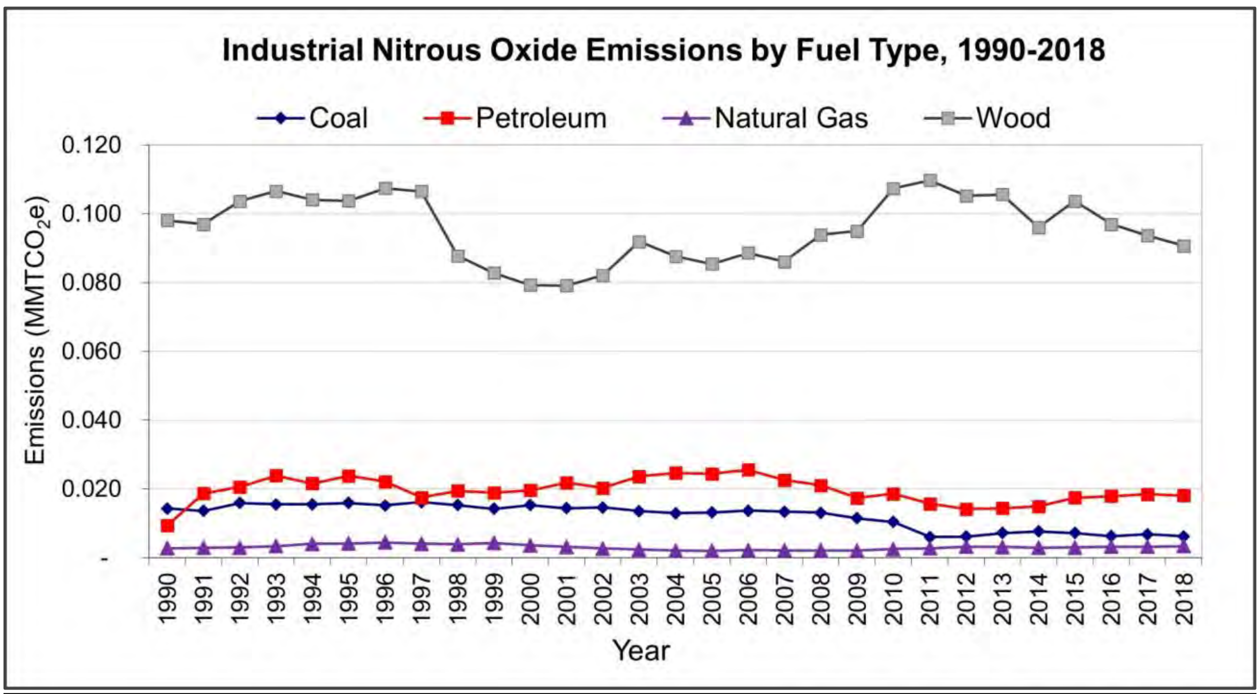

Figure B-3b: Stationary Combustion - Emissions for N_2O by fuel type in the industrial sector.

Electric Power Sector:

Figures B-4a and B-4b display the emissions of CH_4 and N_2O, in MMT CO_2e, for the electric power sector in Florida. In this sector, CH_4 and N_2O emissions are dominated by coal, with coal being a very cheap fuel option. However, coal-generated CH_4 and N_2O have been reduced by more than half from 1990 to 2018, with about 0.17 to 0.09 MMT CO_2e for CH_4, and about 0.29 towards 0.15 MMT CO_2e for N_2O. The second-largest source of both CH_4 and N_2O emissions in this sector is petroleum fuel, which has also shown a significant decline after 2005.

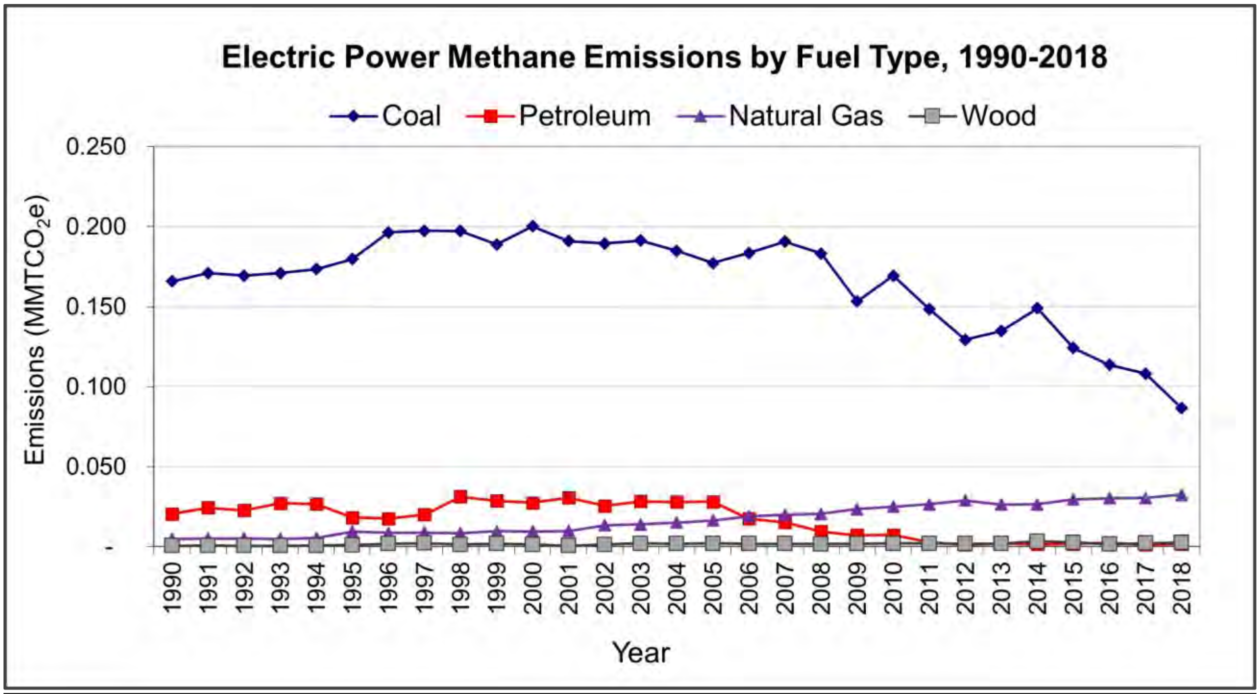

Figure B-4a: Stationary Combustion - Emissions for CH_4 by fuel type in the electric power sector.

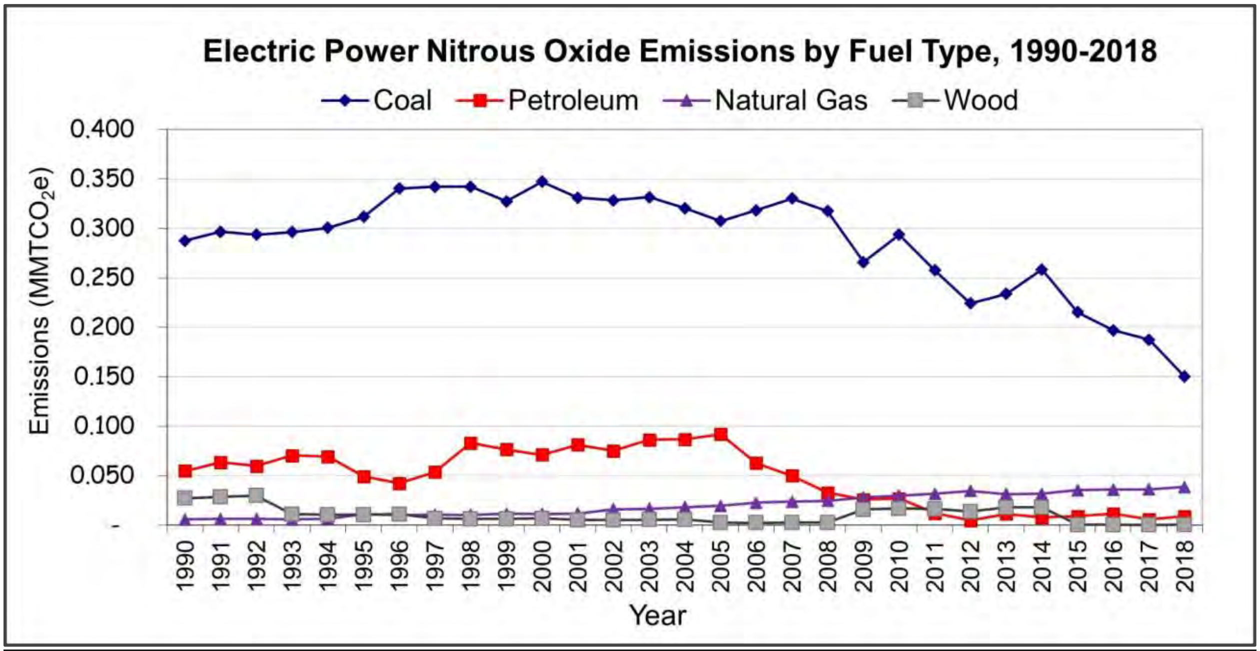

Figure B-4b: Stationary Combustion - Emissions for N_2O by fuel type in the electric power sector.

Emissions by Sector and Fuel Type:

Figures B-5a and B-5b show CH_4 and N_2O's total emissions by sector for all fuel types. The electric power sector dominates both gases' emissions as the largest emitting source. In the case of CH_4, the residential sector occasionally took significant weight among emissions across the time series, even surpassing the electric power sector from 1990 to 1992. Additionally, the industrial sector proves to be the residential sector's competitor for second place with CH_4 emissions, most prevalently between 1993 and 2008 as well as after 2014. The industrial sector does claim the second-largest emitter for N_2O across the entire time series.

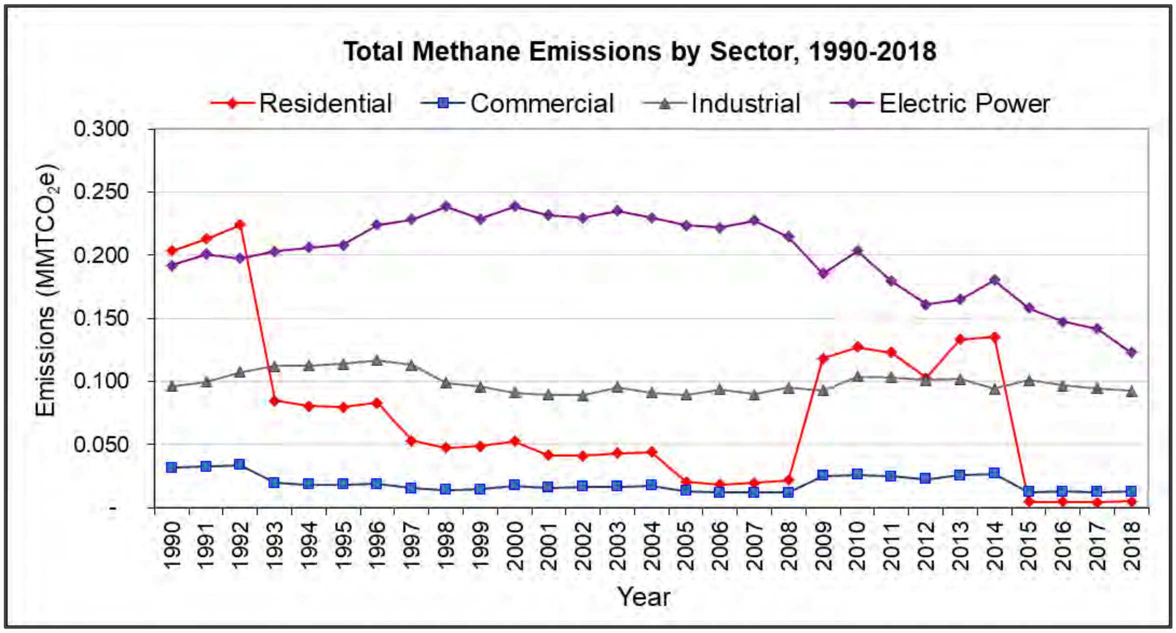

Figure B-5a: Stationary Combustion - Historical CH_4 emissions by sector.

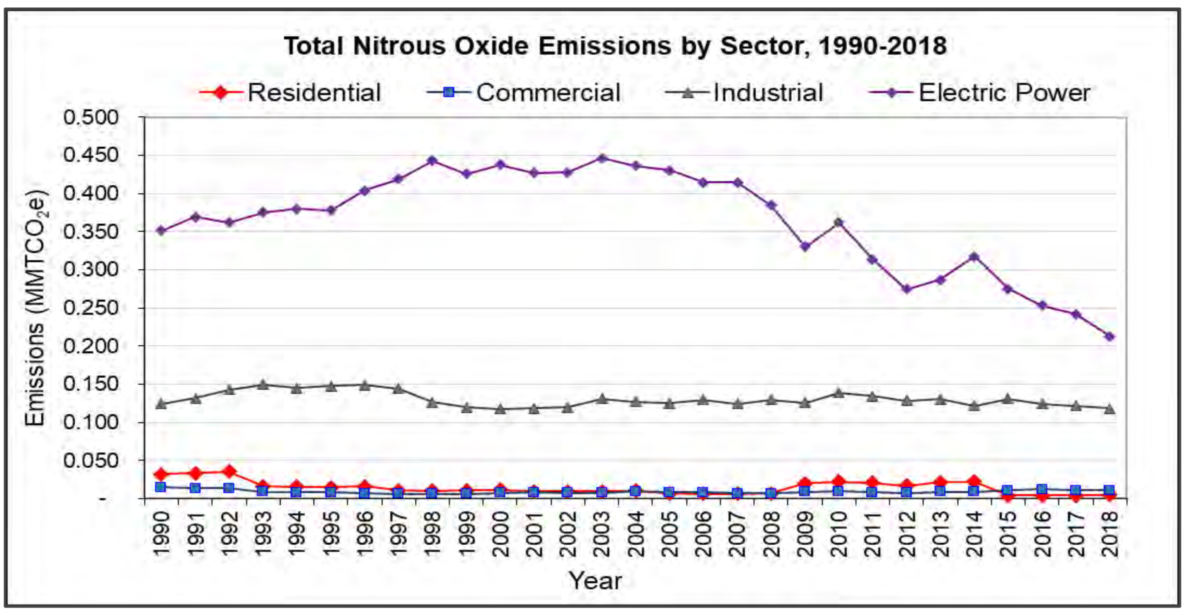

Figure B-5b: Stationary Combustion - Historical N_2O emissions by sector.

Figures B-6a and B-6b show CH_4 and N_2O's total emission by fuel type from all sectors. Overall, coal is the major contributor to CH_4 and N_2O, followed by wood and petroleum. More specifically for CH_4, coal and wood fluctuate as top emitters, but coal takes the top spot more consistently and for a longer period of time. Natural gas does dominate petroleum for total emissions, starting in 2006 for CH_4 and 2011 for N_2O.

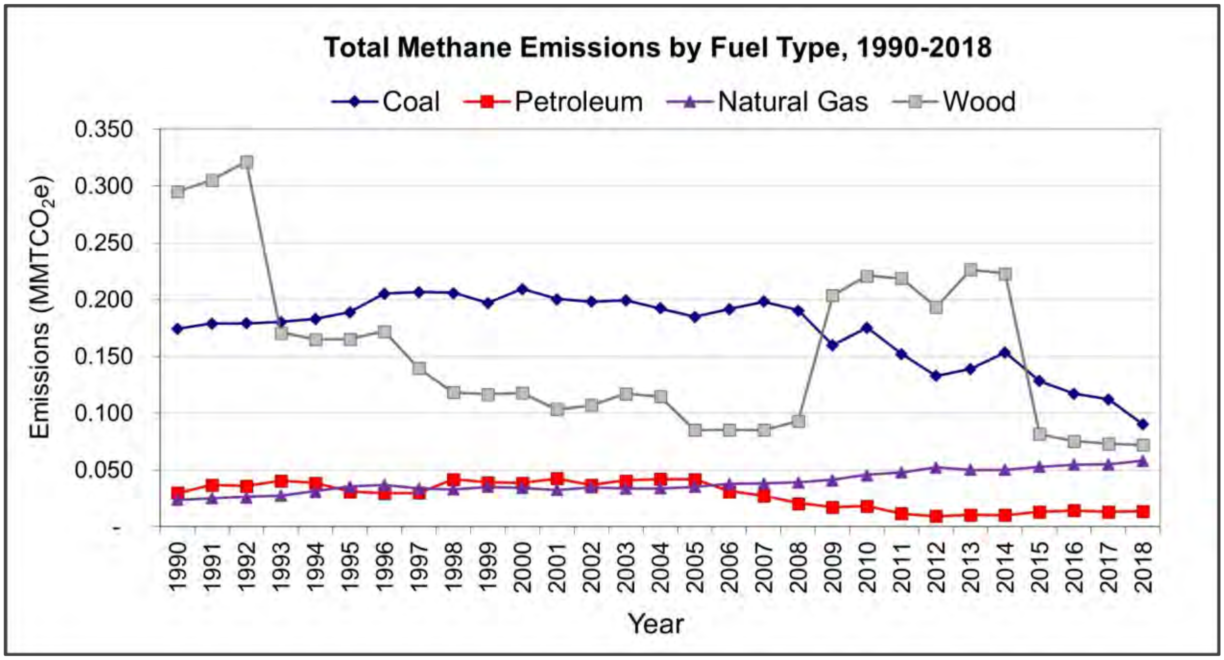

Figure B-6a: Stationary Combustion - Historical CH_4 emissions by fuel type from all sectors.

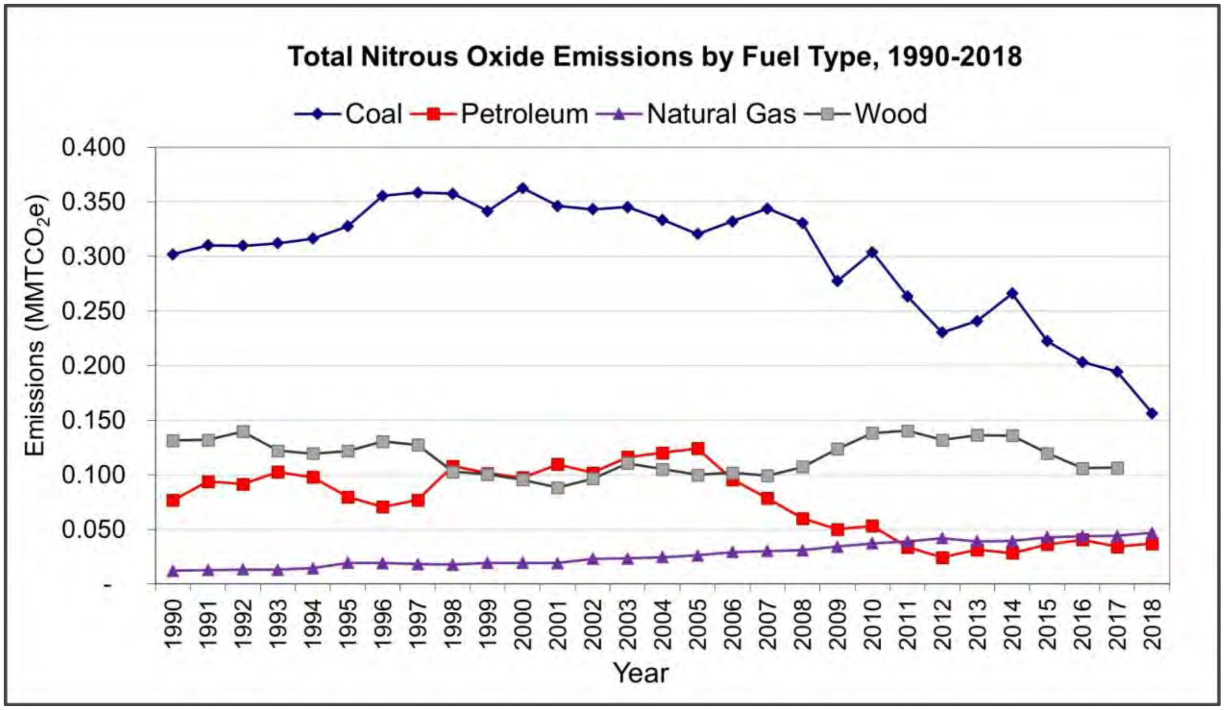

Figure B-6b: Stationary Combustion - Historical N_2O emissions by fuel type from all sectors.

Figure B-7 shows the sector-wide combined total emissions of CH_4 and N_2O in CO_2e. Emissions from electric power are the highest among these sectors and it shows a declining trend over the last several years. The second major contributor is the industrial sector which is very much consistent and emits an average of 0.23 MMT CO_2e per year. The industrial sector was only surpassed by the residential sector from 1990 to 1992. In summing up all the sectors' data, it can be concluded that for stationary combustion, Florida is having a downward slope of CH_4 and N_2O emission profile.

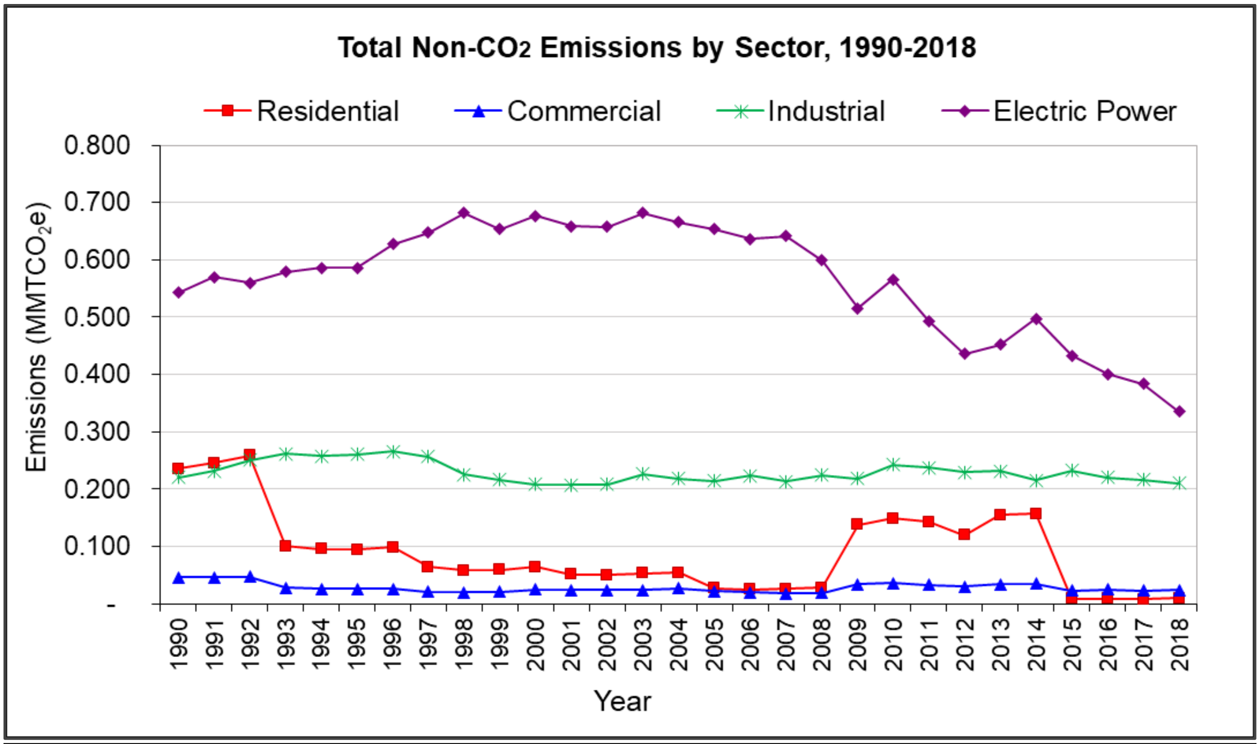

Figure B-7: Stationary Combustion - Historical cumulative emissions of CH_4 and N_2O by sectors.

A summary of the emissions from stationary combustion by sector, gas, and year is provided in Table B-1.

$MMTCO_2e$	1990	1995	2000	2005	2010	2015	2018
Residential	**0.235**	**0.095**	**0.064**	**0.027**	**0.149**	**0.009**	**0.01**
N_2O	0.032	0.015	0.011	0.007	0.022	0.004	0.005
CH_4	0.203	0.08	0.053	0.02	0.127	0.005	0.005
Commercial	**0.046**	**0.026**	**0.025**	**0.022**	**0.036**	**0.023**	**0.024**
N_2O	0.015	0.008	0.008	0.008	0.01	0.011	0.011
CH_4	0.031	0.018	0.017	0.013	0.026	0.012	0.013
Industrial	**0.221**	**0.261**	**0.209**	**0.214**	**0.243**	**0.232**	**0.211**
N_2O	0.124	0.147	0.118	0.125	0.139	0.131	0.118
CH_4	0.096	0.114	0.091	0.09	0.104	0.101	0.093
Electric Power	**0.543**	**0.586**	**0.676**	**0.654**	**0.566**	**0.433**	**0.336**
N_2O	0.351	0.378	0.438	0.43	0.362	0.275	0.213
CH_4	0.192	0.208	0.238	0.224	0.204	0.158	0.123
TOTAL	**1.045**	**0.969**	**0.975**	**0.918**	**0.993**	**0.697**	**0.580**

Table B-1: Stationary Combustion - Historical emission totals of CH_4 and N_2O by sector.

Key Uncertainties

As opposed to national data, state-specific emission factor data can have some uncertainties. Additionally, the total consumption data has some uncertainties when allocating data according to sector (residential, commercial, industrial, and electric power) for CH_4 and N_2O, because the efficiency of the users' equipment has an impact on the amount of emissions (e.g. combustion efficiency, carbon content coefficients, etc.). Because these are not known, the SIT's default data is instead used. Non-energy consumption is estimated based on default values provided by SIT, meaning that this can have some level of uncertainties for Florida values.

References

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EPA (2020). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018. Annex 2 (Methodology for estimating CO_2 emissions from fossil fuel combustion), Table A-43. U.S. Environmental Protection Agency, Washington, DC. U.S. EPA #430-R-20-002 (PDF). Available at https://www.epa.gov/sites/default/files/2020-04/documents/us-ghg-inventory-2020-main-text.pdf

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Appendix C

Mobile Combustion

Overview

While there are many factors that contribute to Florida's 2018 ranking as third-largest carbon dioxide emitter in the nation, transportation accounts for about 40% of those emissions, according to the Energy Information Administration (EIA). Thus, making the transportation sector the largest contributor of greenhouse gases in Florida. The transportation sector includes energy used by highway vehicles, planes, boats and vessels, locomotives, alternative fuel vehicles, and other sources. These vehicles produce carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) greenhouse gas emissions during mobile combustion.

To accurately estimate greenhouse gas emissions, the Mobile Combustion module of the State Inventory Tool (SIT) was used in conjunction with EPA's Emissions Inventory Improvement Program (EIIP). The SIT's methods use the data collected from various data sources to estimate the amount of CO_2, CH_4, and N_2O produced by different vehicle types and associated miles traveled.

From this module, the CH_4 and N_2O values are included in the total emissions estimates. The CO_2 emission from this module is an alternative calculation to know the contributions from each vehicle type. The CO_2 emission estimated from this module is not included in the total emissions for the state. The amount included in the inventory is based on CO_2 emissions from the transportation sector estimated by the module CO_2 emissions from Fossil Fuel Combustion (CO_2FFC).

Methodology

The Mobile Combustion module of the SIT calculates mainly methane (CH_4) and nitrous oxide (N_2O). It also includes an option to calculate carbon dioxide (CO_2) emissions from highway vehicles, aviation, boats and vessels, locomotives, other non-highway sources, and alternative fuel vehicles. This module estimates these emissions from mobile sources using activity data, information on the combustion technologies used, and information on the type of emission control technologies employed during and after combustion.

The general mobile combustion equation is as follows:

$$\textbf{Emissions (MMT } \boldsymbol{CO_2e}\textbf{)} = \Sigma\ (EF_{abc} \times Activity_{abc})$$

Where,

EF = Emissions Factor
Activity = activity level measured in appropriate units
a = fuel type
b = vehicle type
c = emission control type (if any)

Highway Vehicles:

For highway vehicles, CH_4 and N_2O emission factors are calculated for eight types of control technologies: three-way catalyst, early three-way catalyst, oxidation catalyst, non-catalyst, low-emission vehicle, advanced, moderate, and uncontrolled. It also calculates based on seven classes of vehicles: heavy-duty diesel vehicles, heavy-duty gas vehicles, light-duty diesel trucks, light-duty diesel vehicles, light-duty gasoline trucks, light-duty gasoline vehicles, and motorcycles.[6] The CH_4 and N_2O emission factors are calculated as grams of GHG/km traveled. The default data provided by the SIT module are correct according to the EPA's Greenhouse Gas Inventory Guidance: Direct Emissions from Mobile Combustion Sources report.

Activity level for highway vehicles is measured by vehicle miles traveled (VMT) for each vehicle type, by year. Total annual VMT data for the years 1990 through 2018 were collected from the U.S. Department of Transportation Federal Highway Administration's (FHWA) Highway Statistics report. The total annual default VMT data in the SIT match the values collected from the Highway Statistics report. However, upon searching the FDOT sources, VMT data per vehicle type is not collected for Florida, therefore default data values remain in the module.[7]

The module converts VMT data for use with CH_4 and N_2O emission factors associated with each control technology and vehicle class. However, to account for changes over time in the control technologies used by highway vehicles, estimates of VMT by vehicle type are distributed across vehicle model years. The SIT does this by distributing data based on vehicle age (0 - 30 years old) and annual age-specific mileage accumulation. The default vehicle age and annual age-specific mileage accumulation data in SIT were replaced with updated values from the EPA's Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018. Furthermore, data for the distribution of emissions control equipment by vehicle model year for all vehicle types was also obtained from EPA's Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018 report.

Aviation:

For aviation, emissions are calculated by obtaining data on fuel consumption for aircraft and converting the fuel consumption data with existing emission factors and energy contents. In this sector, three aviation fuel types are highlighted: kerosene jet fuel, naphtha jet fuel, and aviation gasoline. Energy contents, measured in kg/Million BTU, for these three fuel types are found in EIA's Monthly Energy Review, July 2021 edition. While CH_4 and N_2O emission factors

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[6] Using the Federal Highway Administration's (FHWA) vehicle classifications.

[7] VMT data per vehicle information provided by Joey Morgan, Transportation Data & Analytics Office, Florida Department of Transportation.

associated with each fuel type were obtained from EPA's Inventory of Greenhouse Gas Emissions and Sinks: 1990 - 2018 report.

Unlike measuring activity levels for highway vehicles through VMT, aircraft measure activity levels by estimating jet fuel consumption. Florida's kerosene and aviation gasoline consumption estimates, measured in BTU, for the years 1960 to 2019 were found in the EIA's State Energy Consumption Estimates report. In this report, kerosene jet fuel consumption estimates were recently revised for 2010 through 2018; thus, these values are used to replace the SIT default data values. Moreover, the default data values for aviation gasoline matched those found in the State Energy Consumption Estimates report.

Conversely, the EIA notes that beginning in 2004, naphtha-type jet fuel is no longer included under the "Jet fuel" variable, but instead included under the umbrella "Miscellaneous Products,"[8] along with many other petroleum products including absorption oils, ram-jet fuel, petroleum rocket fuels, synthetic natural gas feedstocks, and specialty oils. Because of this change, naphtha jet fuel does not have any recorded values following the year 2004. Furthermore, upon connecting with a representative from the EIA[9], it was found that the U.S. product supplied data, obtained from SEDS, for naphtha-type jet fuel was negative between 1998 and 2003. Thus, the estimated consumption values for naphtha jet fuel between the years 1998 to 2003 are shown as either negative or zero in the inventory data.[10]

Boats and Vessels:

The EIA defines vessel bunkering as an energy-consuming sector that consists of commercial or private boats, such as pleasure craft, fishing boats, tugboats, and ocean-going vessels, including vessels operated by oil companies. This definition excludes vessels sold to the U.S. Armed Forces. Using EIA's vessel bunkering definition, GHG emissions from boats and vessels are calculated by obtaining state data on fuel consumption for boats, then converting the fuel consumption data with existing emission factors and density factors. The existing emission and density factors for boat fuels: residual, distillate, and motor gasoline, are found in EPA's Inventory of U.S. GHG Emissions and Sinks.

For consumption data regarding the commercial marine sector, annual consumption values were obtained, in gallons, for residual and distillate fuels using the EIA's Petroleum and Other Liquids Data for Florida. The EIA's Petroleum and Other Liquids Data for Florida has two data reports estimating these values: "Sales of Distillate Fuel Oil by End-Use" and "Sales of Residual Fuel Oil by End-Use." Within both reports, Florida vessel bunkering estimates are provided for 1990 to 2019.

Consumption data regarding the private boat sector, also recognized as boats using motor gasoline, was obtained from FHWA's Highway Statistics annual report.

Locomotives:

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[8] EIA defines Miscellaneous Petroleum Products as "including all finished products not classified elsewhere."

[9] Information regarding naphtha-type jet fuel provided by Yvonne Taylor, Office of Energy Demand & Integrated Statistics, U.S. Energy Information Administration.

[10] U.S. product supplied measures the disappearance of petroleum products from primary sources and is used to approximate U.S. consumption of petroleum products.

GHG emissions from rail vehicles are calculated by obtaining state data on fuel consumption for locomotives, then converting the fuel consumption data with existing emission factors and density factors. The existing emission and density factors for locomotive fuels: residual, diesel, and coal, are found in EPA's Inventory of U.S. GHG Emissions and Sinks.

For Florida diesel fuel railroad consumption estimates, in gallons, the data was obtained through EIA's "Florida Sales of Distillate Fuel Oil by End-Use" data set.

However, Florida has reported no information for residual fuel and coal consumption regarding locomotives.

Other Non-Highway Vehicles:

This category of the Mobile Combustion module includes density and emission factors and fuel consumption data for farm equipment, construction, and other non-highway vehicles (industrial and snowmobiles).

Historical gasoline farm equipment and gasoline construction consumption data are found in FDOT's annual Highway Statistics report. Historical diesel farm equipment and diesel construction consumption data is found in the EIA's "Sales of Distillate Fuel Oil by End-Use" data report.

Default emission factors and consumption values for other non-highway vehicles (industrial and snowmobiles) are used within this sector.

Alternative Fuel Vehicles:

For alternative fuel vehicles (AFV), the methodology is similar to highway vehicles where an emission factor is multiplied by the VMT of each type of vehicle, based on the fuel used. However, AFVs only use three vehicle types: light-duty vehicles, heavy-duty vehicles, and buses, and five vehicle fuel types are methanol, ethanol, compressed natural gas (CNG), liquified petroleum gas (LPG), and liquified natural gas (LNG) (used for heavy-duty vehicles only).

For this module, CH_4 and N_2O emission factors are found in the EPA's Inventory of U.S. GHG Emissions and Sinks report. AFV VMT data split by different vehicle and fuel types has not been recorded in the state of Florida, so the default values used were taken from the EPA's Inventory of GHG Emissions and Sinks: 1990-2018.

Data Sources

Data were drawn from various sources to accurately develop Florida-specific GHG inventory data from transportation emissions. These are briefly summarized below:

- *CH_4 and N_2O Emission Factors for On-Road Vehicles.* This is based on Table B-1 of Appendix B in the EPA's Greenhouse Gas Inventory Guidance: Direct Emissions from Mobile Combustion Sources. The data in this report is based on The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (GHG Protocol) developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD).
- *State Vehicle-Miles of Travel (VMT), by functional system.* This is based on Table VM-2 of the U.S. Department of Transportation Federal Highway Administration's Highway

Statistics report. Highway data for these annual reports are submitted by the states and compiled by the Office of Highway Policy Information.

- *Annual Average Vehicle Mileage Accumulation per Vehicle.* This is based on Table A-103 in Annex 3 of the EPA's Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2018 report.
- *Age Distribution by Vehicle/Fuel Type for On-Road Vehicles.* This is based on Table A-102 in Annex 3 of the EPA's Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2018 report.
- *Control Technology Assignments for Diesel On-Road Vehicles and Motorcycles.* This is based on Table A-109 in Annex 3 of the EPA's Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2018 report.
- *Control Technology Assignments for Gasoline Passenger Cars.* This is based on Table A-106 in Annex 3 of the EPA's Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2018 report.
- *British Thermal Unit Conversion Factors*. This is found in EIA's Monthly Energy Review of October 2021. The table is used to determine CH_4 and N_2O energy contents for aircraft.
- *Emission Factors for Non-Road Mobile Combustion.* This is based on Tables A-113 and A-114 in Annex 3 of the EPA's Annexes to the Inventory of U.S. GHG Emissions and Sinks: 1990-2018 report. The table is used to determine CH_4 and N_2O emission factors for aviation, boats, locomotives, and farming equipment.
- *Florida Energy Consumption Estimates*. This is based on Table CT7 of the EIA State Energy Consumption Estimates (1960 - 2019). This table is used to determine aviation fuel (kerosene and aviation gasoline) consumption in the state of Florida.
- *Florida Total Residual Sales/Deliveries to Vessel Bunkering Consumers.* These values are compiled by the EIA and used to determine the annual residual fuel oil consumption for boats and vessels in Florida.
- *Florida Total Distillate Sales/Deliveries to Vessel Bunkering Consumers.* These values are compiled by the EIA, and used to determine the annual distillate fuel oil consumption for boats and vessels in Florida.
- *Boating, Agriculture, and Construction Gasoline Consumption.* This is based on Table MF-24 of the U.S. Department of Transportation Federal Highway Administration's Highway Statistics report. The table is entitled "Private and Commercial Non-Highway Use of Gasoline." Highway data for these annual reports are submitted by the states and compiled by the Office of Highway Policy Information.
- *Florida Total Distillate Sales/Deliveries to Railroad Consumers.* These values are compiled by the EIA, and used to determine the annual distillate fuel oil consumption for locomotives in Florida.
- *Agriculture and Construction Diesel Consumption.* These values are compiled by the EIA and used to determine the annual distillate fuel oil consumption for various vehicles in Florida, including Farm and Non-Highway vehicles.
- *Emission Factors for Alternative Fuel Vehicles.* This is based on Table A-111 and A-112 in Annex 3 of the EPA's Annexes to the Inventory of U.S. GHG Emissions and Sinks:

1990-2018 report. These tables are used to determine CH_4 and N_2O emission factors for Alternative Fuel Vehicles.

Results

As shown in Figure C-1, gasoline highway vehicles account for the largest portion of total CH_4 and N_2O emissions in Florida. In 1990, gasoline highway vehicles accounted for 86% of total CH_4 and N_2O emissions, at 2.26 MMT CO_2e. The total emissions from gasoline highway vehicles peaked in 1997 at approximately 2.83 MMT CO_2e, accounting for nearly 89% of total CH_4 and N_2O emissions. In 2018, highway vehicles still constituted the largest portion of transportation GHG emissions; yet emissions from this source had fallen by 82% since 1997. The second-largest contributor of CH_4 and N_2O emissions in Florida are boats and aircraft, which have been on a relatively consistent increase since 1990. As shown in Figure C-2, by 2018, aviation has increased CH_4 and N_2O emissions by 68% and marine has increased these emissions by 47% since 1990.

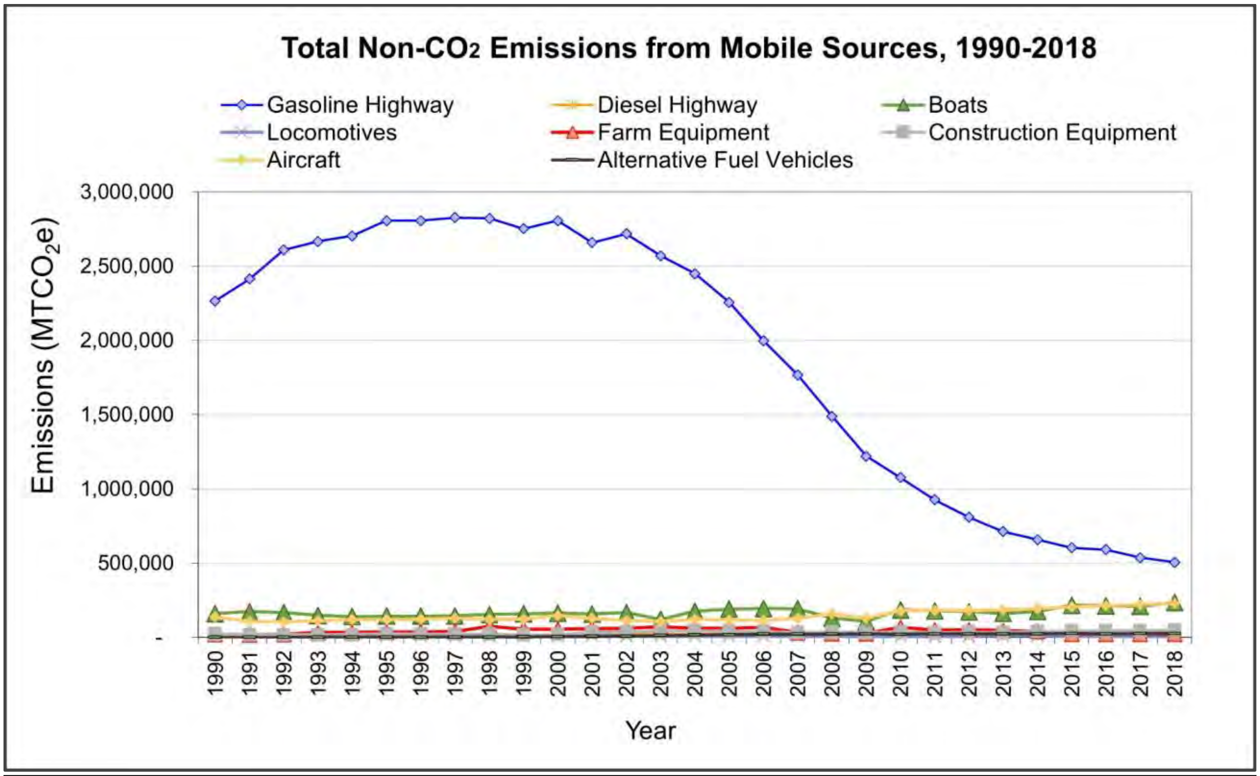

Figure C-1: Mobile Combustion - Total CH_4 and N_2O emissions from mobile sources by transport mode/vehicle type.

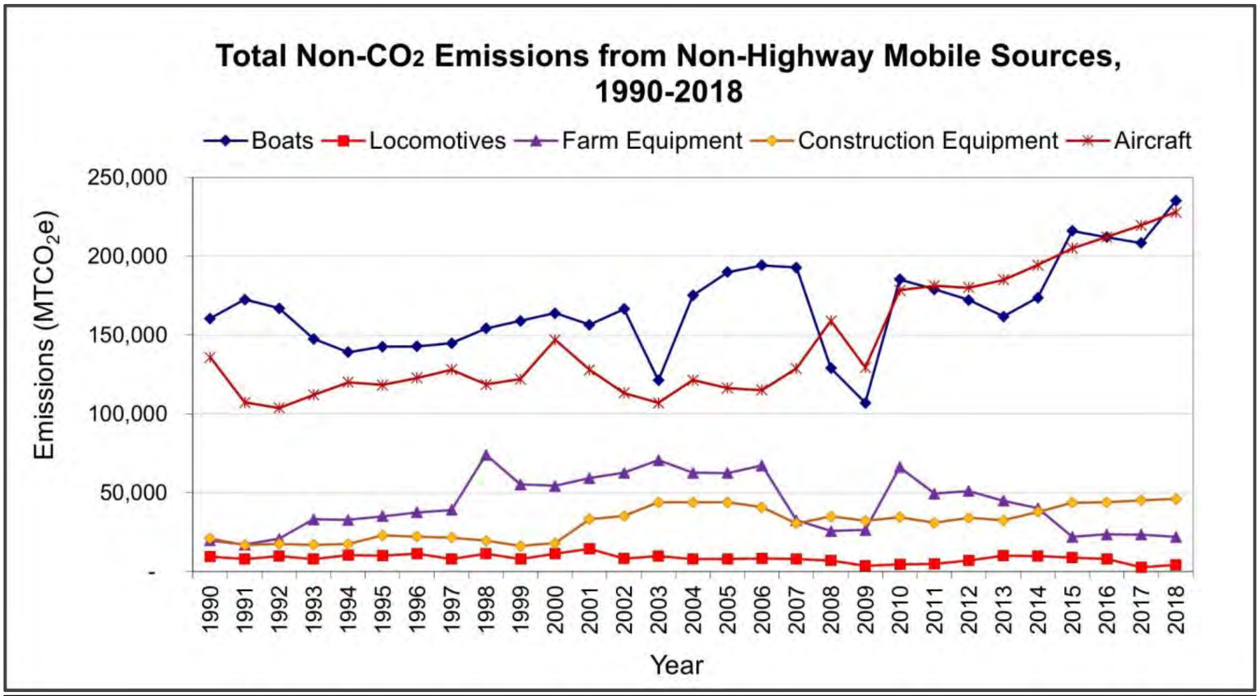

Figure C-2: Mobile Combustion - Total CH_4 and N_2O emissions from non-highway mobile sources.

As mentioned earlier, this module offers an emissions summary for carbon dioxide (CO_2), though these values are not considered in this module's emissions totals to avoid double-counting against the CO_2FFC module which considers CO_2 emissions from the transportation sector. Table C-1 and Figure C-3 refers to the total CO_2 emissions from mobile sources by vehicle type in Florida. The results show that in 2018 gasoline and diesel highway vehicles account for the largest portion of total carbon dioxide emissions, followed by aviation. From 1990 to 2018, the CO_2 emissions from gasoline highway vehicles increased 60%, while total CO_2 emissions increased by 78%.

Source	1990	1995	2000	2005	2010	2015	2018
Gasoline Highway	47.41	51.24	59.17	77.55	65.09	69.02	75.96
Diesel Highway	10.2	12.62	15.18	24.63	30.35	30.16	30.34
Aviation	13.08	11.49	14.6	11.46	17.90	20.58	22.86
Boats	6.99	6.68	7.75	9.16	8.53	8.53	9.58
Locomotives	0.89	0.96	1.09	0.79	0.43	0.84	0.41
Other	2.30	2.7	2.88	3.89	4.12	4.92	5.08
AFV	.006	.006	.012	.04	.036	.044	.043
TOTAL	**80.88**	**85.69**	**100.67**	**125.24**	**126.66**	**134.09**	**144.26**

Table C-1: Mobile Combustion - Total carbon dioxide emissions (MT CO_2e) by vehicle type.

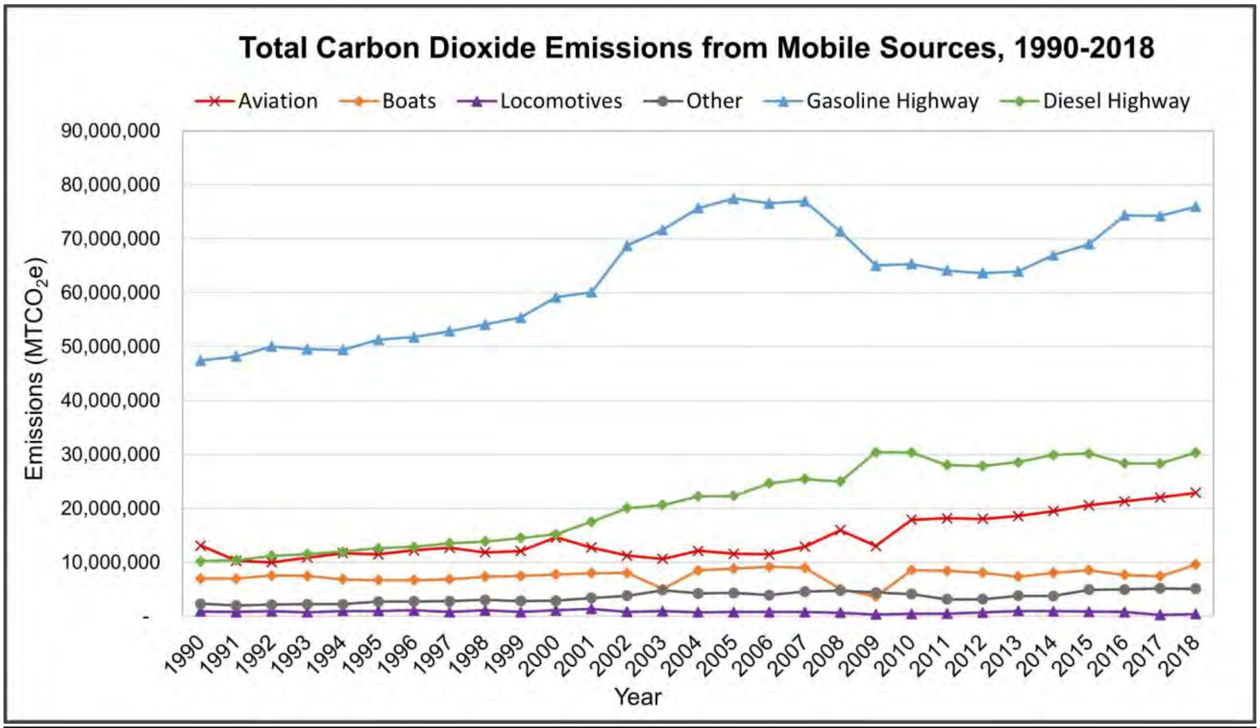

Figure C-3: Mobile Combustion - Total CO_2 emissions ($MTCO_2e$) by transport mode/vehicle type.

Key Uncertainties

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

Uncertainties in Highway Vehicles:

A key uncertainty within this analysis is the input values for activity data measured by VMT. VMT estimates are collected by the FHWA based on the information provided by each state. The methods each state uses to collect VMT data can vary, and may include the use of data sources including tax records for fuel sales or various sampling techniques. Upon discussion with the FDOT, it is understood that VMT data per vehicle type is not collected for Florida, therefore default data values remain in the module (this also includes VMT data for Alternative Fuel Vehicles). However, the total annual VMT data from 1990 to 2018 is assumed to be accurate because default totals are identical to FHWA data and Florida 2008 - GHG Inventory and Reference Case Projections report.

Another uncertainty within this sector is the information regarding annual vehicle mileage accumulation (recorded in miles) and age distribution (given by percentages) data per vehicle type and model year. This data is not recorded by Florida, so the input values for these data tables are collected as national averages based on EPA's Inventory of Greenhouse Gas Emissions and Sinks: 1990 - 2018 report.

Uncertainties in Aviation and Marine Fuel Consumption:

Within both of these sections, emission estimates are driven by activity data. Activity data from 1990 to 2018, categorized by fuel type, was gathered from EIA's SEDS. SEDS data includes both domestic and international bunker values.[11] However, the SIT software specifically flags international bunker values as irrelevant to the calculation and should be subtracted from fuel consumption estimates to accurately calculate the amount of fuel consumed by domestic aircraft and boats.[12] After speaking with a representative from the EIA, it was found that Florida does not have estimates that separate these two values. So, the activity data input values include both international bunker and domestic fuel consumption values.

Uncertainties in Marine, Locomotive, Farm Equipment, and Construction Vehicles Fuel Consumption:

Fuel consumption data for distillate and residual fuel types are collected from EIA's Petroleum and Other Liquids consumption reports. The EIA collects consumption data for these reports in two ways: "Sales by end-use" and "Adjusted Sales by end-use." The unadjusted version, or "Sales by end-use," comes from the survey EIA-821 and the additional information they collected (e.g., highway diesel uses from the Federal Highway Administration and fuel consumption for power generation from another EIA survey). The adjusted version aligns the unadjusted values so that they match EIA's product supplied. For our calculation, we used the unadjusted values as inputs for activity data, also known as fuel consumption data for distillate and residual fuel types.

Uncertainties in Other Non-Highway Fuel Consumption:

Under the umbrella of other non-highway factors and fuel consumption, vehicles such as farm equipment, construction vehicles, and other non-highway vehicles (industrial and snowmobiles) are included. For other non-highway vehicles (industrial and snowmobiles), Florida did not have any activity data for the given fuel types: Gasoline HD Utility, Gasoline Small Utility, Diesel HD Utility, and Gasoline Snowmobiles. Thus, the default values estimated from the EPA's Inventory of Greenhouse Gas Emissions and Sinks: 1990 - 2018 report remain in the calculation.

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[11] Emissions resulting from fuel used for international transportation.

[12] The SIT software follows the reporting guidelines set by the IPCC Guidelines for the preparation of GHG inventories and the UNFCCC reporting guidelines on annual inventories which outline that international bunker fuel emissions should be excluded from national totals and reported separately.

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FHWA. Policy and Governmental Affairs Office of Highway Policy Information: Highway Statistics Series. Table VM-2. United States Department of Transportation Federal Highway Administration. Available at https://www.fhwa.dot.gov/policyinformation/statistics.cfm

Appendix D

Coal Mining Extraction and Distribution

Overview

The Coal Mining inventory, within the subsection of Fossil Fuel Extraction and Distribution Industry of the energy sector, includes methane (CH_4) emissions from coal mining activities associated with: surface mining activities, surface post-mining activities, underground mining activities, underground post-mining activities, and abandoned coal mines.

Coal mining and its resulting emissions is not relevant to Florida because there is no active coal mining within the state, nor has there been during the entire analyzed time series (1990-2018).

Data Sources

- ➢ Information on the absence of coal mining activity in the state of Florida was pulled from the EIA's Florida State Profile and Energy Estimates Profile Analysis.
- ➢ Florida-specific information can be accessed from the Center for Climate Strategies' 1990-2025 Greenhouse Gas Inventory and Reference Case Projections.

Results

The state of Florida does not emit CH_4 due to its complete absence of coal mining activities.

References

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Appendix E

Natural Gas and Oil Systems

Overview

The inventory for this module of the Fossil Fuel Extraction and Distribution Industry includes fugitive methane (CH_4) and carbon dioxide (CO_2) emissions from the variety of components that make up the natural gas and petroleum systems present. According to the EPA, fugitive emissions are defined as "those emissions which could not reasonably pass through a stack, chimney, bent or other functionally-equivalent opening" (EPA 1999). Specifically, this module calculates the total greenhouse gas (GHG) emissions from the production, transmission, venting and flaring, and distribution of natural gas in Florida, as well as from the production and transport of oil within the state.

Methodology

Fugitive emissions were calculated by imputing activity data for each component into the SIT, which were then multiplied by their respective emission factors (EFs) to get total emissions for each year. The activity data, EFs, and GHGs calculation method for each system is described below.

Natural Gas Systems emissions equations:

- ➢ *For production, transmission, and distribution:*

  Emissions (MMT CO_2e) *= Activity Data × Emission Factor (MT CH_4/unit activity data) × 25 (GWP)*

- ➢ *For venting and flaring:*

  Emissions (MMT CO_2e) *= Activity Data (BBtu) × Emission Factor (MT CO_2/BBtu) × % flared ÷ 106 (MT/MMT)*

Petroleum Systems emissions equations:

Emissions (MMT CO_2e) *= Activity Data ('000 barrels) × Emission Factor (kg CH_4/'000 barrels) ÷ 1,000 (kg/MT) × 25 (GWP) ÷ 106 (MT/MMT)*

Natural Gas Production:

The GHGs emitted from wells during the production of natural gas is CH_4. The total number of gas-producing wells is entered into the SIT for each year which is then multiplied by a predetermined EF of 11.87 metric tons of CH_4 per well per year. This results in the total estimated amount of CH_4 released for natural gas production for that year. This value is then multiplied by CH_4's Global Warming Potential (GWP) of 25 and then divided by 10^6 to convert total emissions to MMT CO_2e. Within the module exists data cells for the number of shallow and deep-water offshore platforms in the Gulf of Mexico and the Pacific Ocean, of which Florida has none. The EIA starts to report the total number of Florida natural gas and gas condensate wells in the year 2011.

Natural Gas Transmission:

Emissions from natural gas transmission usually originate from leaks, compressor fugitives, exhaust vents, and pneumatic devices. To find the total amount of emissions from natural gas transmission systems, the total miles of gathering pipeline, number of gas processing plants, number of liquified natural gas (LNG) storage compressor stations, miles of transmissions pipeline, number of gas transmission compressor stations, and gas storage compressor stations were entered into the SIT. Each value was multiplied by its respective yearly source-specific CH_4 EF and converted to MMT CO_2e. The sums of these values were reported as the total amount of emissions for this section for each year.

The US Department of Transportation's (USDOT) Pipeline and Hazardous Materials Safety Administration (PHMSA) data was used to determine the total number of LNG storage compressor stations, miles of gathering pipeline, and miles of transmission pipeline. The PHMSA supplied Florida specific miles of gathering and transmission pipeline data for all years from 1990 to 2018. LNG storage compressor station annual data only existed as far back as 2010, however for all unreported years, the number of LNG storage compressor stations is assumed to be zero.

With the inability to locate data for the number of gas processing plants for each year, these values had to be estimated. Energy Information Administration (EIA) statistics were used to calculate the annual gas processing rate of an average gas processing plant within the United

States. EIA statistics showed that in 2017, out of the 510 processing plants that were recorded, an average value of 53.3 billion cubic feet (Bcf) of natural gas was processed per day. Multiplied by 365 days in a year, it can be estimated that the 510 plants processed around 19,454.5 Bcf of natural gas in that year. Divided by the total number of processing plants (510), it can be estimated that the average plant processes around 38.15 Bcf of natural gas a year. This value was then divided by the yearly EIA data amounts of natural gas that was processed in Florida each year to get the total number of gas processing plants in the state.

Data containing the total number of gas transmission and storage compressor stations for each year in Florida was unable to be identified. To fill in this data for all years, the SIT used the total number of miles of transmission pipeline reported to calculate an estimated default value for the number of compressor stations within the state.

Natural Gas Distribution:

Emissions from natural gas distribution usually originate from leaks, meters, regulators, and mishaps. All required natural gas distribution data was obtained from the PHMSA. Required activity data included: number of cast iron distribution pipelines, miles of unprotected steel distribution pipeline, miles of protected steel distribution pipeline, miles of plastic distribution pipeline, and total number of end services. Additionally considered was how many of those services were unprotected and protected steel services. Each activity data point was multiplied by its specific EF to calculate yearly metric tons (MT) of CH_4 emissions and then were converted to MMT CO_2e. These values were then summed up for each year to estimate the total amount of natural gas distribution system emissions.

Natural Gas Vented and Flared:

Emissions from natural gas venting and flaring comes from the direct release and burning of surplus natural gas into the air. EIA and default SIT data was used to determine the total billion BTU (BBtu) of natural gas that is vented in Florida, and what percent of it is flared for all years. EIA data provided how many million metric cubic feet (MMcf) of natural gas is vented and flared in Florida each year. This number was multiplied by a yearly conversion factor and then converted to BBtu. The yearly BBtu values were multiplied by an emission factor to get yearly MT of CO_2 emissions. These emissions were then multiplied by a SIT default flaring percent and converted to total yearly emissions of MMT CO_2e.

Oil Production:

Emissions from the production of oil can occur in a variety of ways during normal operations, routine maintenance, and during periodic system upsets and accidents of normal oil production facilities. Total emissions are estimated by using yearly EIA oil production data for Florida and multiplying the number of thousand barrels of oil produced by an EF to estimate the yearly kilograms of CH_4 emissions per year per 1,000 barrels of oil produced. This value is then converted to calculate total yearly emissions of MMT CO_2e. EIA data was available for all required years.

Oil Refining:

Emissions for this section are not computed due to the fact that the state of Florida does not have any active oil refineries, nor has there been during the entire analyzed time series.

Oil Transportation:

Data for the total amount of oil transported in Florida each year was unable to be located. To accommodate for this, it is assumed that the annual total amount of oil produced in Florida is what is transported in Florida. This value is multiplied by its own EF and converted to estimate yearly emissions of MMT CO_2e.

Data Sources

- *Natural Gas Production:* To determine the total number of natural gas producing wells in Florida for each year, data was taken from the EIA for the number of gas and gas condensate wells. Available data begins in 2011.
- *Natural Gas Transmission:* To determine the total number of miles of natural gas gathering and transmission pipeline along with the total number of Liquid Natural Gas compressor stations for each year, data was taken from the "Gas Transmission and Gathering Annual Data" and "Liquified Natural Gas (LNG) Annual Data" files provided by the USDOT's PHMSA.
    - Data that explicitly provided yearly totals of gas processing plants in Florida were unable to be identified. Instead, data on the yearly totals of natural gas processed in Florida and data to determine the average national processing rate of a processing plant was pulled from the EIA to estimate this data requirement.
    - Data on the total number of natural gas transmission and storage compressor stations were unable to be identified. The SIT's default values were used.
- *Natural Gas Distribution:* To determine the total number of miles of distribution pipeline and end services, data was taken from the "Gas Distribution Annual Data" files provided by the PHMSA. The files contained information pertaining to the different types of pipelines and services (protected and unprotected) as well as the different materials they were composed of.
- *Natural Gas Vented and Flared:* To determine the total BBtu of Florida natural gas vented and flared, yearly data was taken from the EIA that listed the total MMcf vented and flared. This data was multiplied by a thermal conversion factor provided by the EIA and then converted to BBtu. This data is only available up until 1995 because Florida wells no longer produce enough natural gas to vent in order to break the threshold required for reporting. Additionally, natural gas is usually pumped back down into the ground rather than vented.
- *Oil Production:* To determine the total number of thousand barrels of oil that are produced each year, data was taken from the EIA which provided values for Florida's yearly field production of crude oil.
- *Oil Refining:* For the years being measured, EIA data shows that Florida does not possess any oil refineries. This fact results in an amount of zero for thousand barrels of oil refined in Florida throughout the entire time series.

- *Oil Transportation:* No data was able to be located with respect to the amount of oil that is transported within the state. Therefore, this value is assumed to be the same as the total amount of oil produced in the state.

<u>*Results*</u>

Figure E-1 shows the total GHGs emitted from natural gas and oil activities between 1990 and 2018 in MMT CO_2e. It is apparent that oil activities hold little weight on total emissions when compared to natural gas activities, the main emitter. However, emissions from natural gas heavily fluctuated from 1990 to 2004, which then after, became quite steady. It is worth noting that these fluctuations seen in the graph could be the result of gaps and estimates of data. On the other hand, oil activities stay low and consistent throughout the entire time series. The total CH_4 emissions from natural gas and oil activities, including the production, transmission, and distribution of natural gas, are displayed in Figure E-2 in MT CH_4.

Table E-1 displays the estimated emissions from natural gas and oil systems for all years between 2005 and 2018. All data points are rounded to the nearest hundredth of a decimal from those calculated by the SIT. In 2018, emissions from this sector totaled an estimated 1.95 MMT CO_2e, with natural gas activities making up almost 99% of that total with 1.93 MMT CO_2e and oil activities only contributing 0.02 MMT CO_2e. In 2005, natural gas activities contributed 1.69 MMT CO_2e of emissions, and oil activities contributed 0.05 MMT CO_2e, equaling a cumulative total of 1.74 MMT CO_2e.

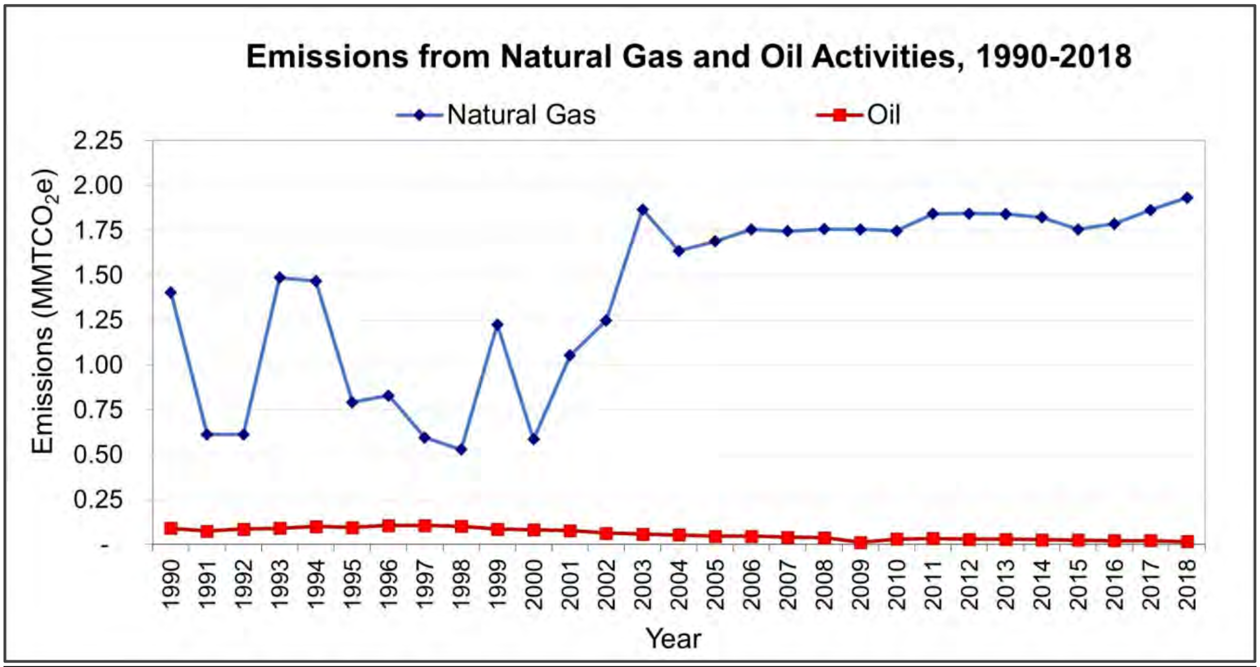

Figure E-1: Natural Gas & Oil - Total emissions from all activities in MMT CO_2e.

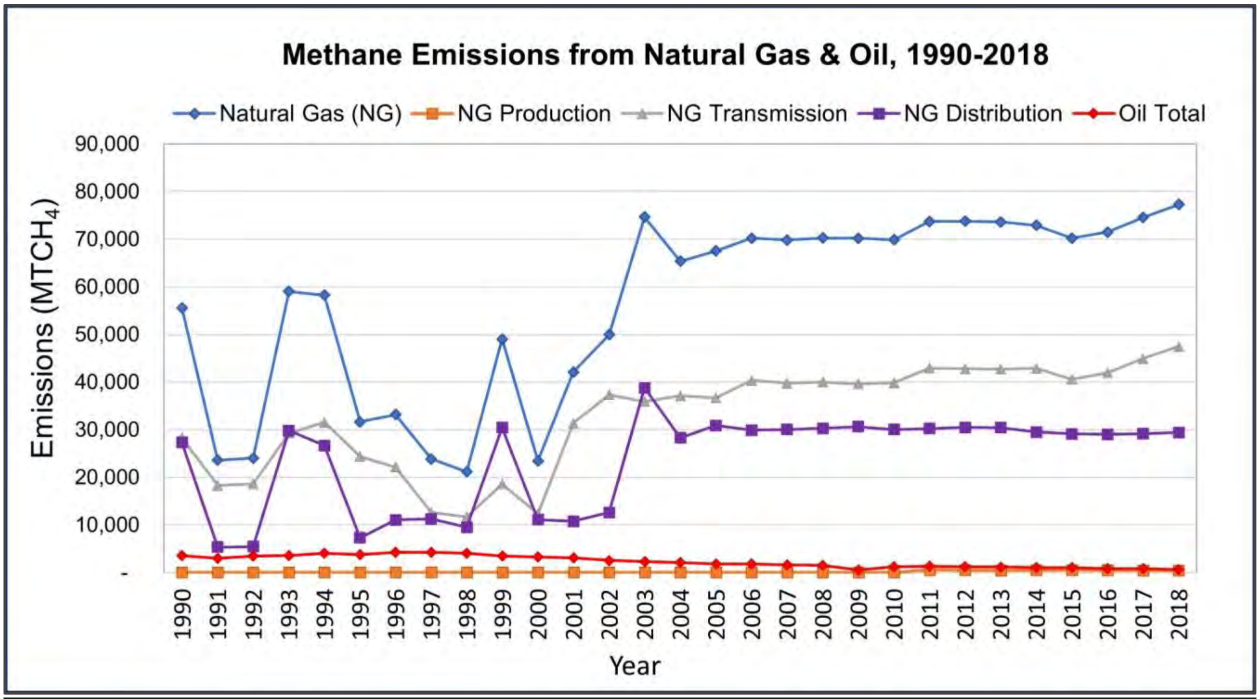

Figure E-2: Natural Gas & Oil - Total CH_4 emissions from all activities in MT CH_4.

(MMT CO_2e)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Cumulative Total	**1.74**	**1.80**	**1.79**	**1.80**	**1.76**	**1.78**	**1.87**	**1.87**	**1.87**	**1.85**	**1.77**	**1.81**	**1.88**	**1.95**
Natural Gas Total	**1.69**	**1.75**	**1.75**	**1.76**	**1.75**	**1.75**	**1.84**	**1.84**	**1.84**	**1.82**	**1.75**	**1.79**	**1.86**	**1.93**
Production	0	0	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Transmission	0.92	1.01	0.99	1.00	0.99	1.0	1.07	1.07	1.07	1.07	1.01	1.05	1.12	1.19
Distribution	0.77	0.75	0.75	0.76	0.77	0.75	0.76	0.76	0.76	0.74	0.73	0.73	0.73	0.73
Flaring	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oil Total	**0.05**	**0.05**	**0.04**	**0.04**	**0.01**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.02**	**0.02**	**0.02**	**0.02**

Table E-1: Natural Gas & Oil - Total GHG emissions from 2005-2018.

The EPA SIT did not include post-meter CH_4 emissions in the Natural Gas and Petroleum analysis. These values were calculated separately and the total post-meter CH_4 emissions from these units from 2018 were about 0.66 MMT CO_2e. The post-meter CH_4 emissions from each sector were as follows: residential buildings (0.24 MMT CO_2e), commercial buildings (0.03 MMT CO_2e), industrial facilities (0.03 MMT CO_2e), electric power generation facilities (0.36 MMT CO_2e) and alternative fuel vehicles (~0 MMT CO_2e). Emissions from the residential sector were calculated using information from the American Housing Survey (AHS) and the IPCC emission factor of 4 kg per appliance, with a consideration of 2.2 appliances per house that uses natural gas. For the commercial sector, estimates were made based on the proportion to the national value. For industrial and electric power generation, natural gas consumption was obtained from the EIA database and the IPCC emission factor of 11,326.7 kg CH_4/BCF natural gas consumption was applied. The number of alternative fuel vehicles was extracted from EIA alternative fuel vehicle data and considered the IPCC emission factor of 0.33 kg per vehicle.

According to Alvarez et al. (2008), measurement-based estimates of methane emissions from natural gas and petroleum activities are roughly 50% higher than what has been presented through the latest GHG inventory, suggesting a probable underestimation of methane emissions in this report.

Key Uncertainties

Due to the nature of how EFs have been calculated by the SIT, uncertainties may exist regarding their validity. The module explains how calculating EFs is a process of aggregating various measurements from different equipment types and survey methodologies. Inevitable inaccuracies may exist which can lead to variability in emission estimation data. Additional uncertainties may exist with regard to the use of national EFs and calculations compared to state-specific estimates. Some factors are based on national averages, and may over- or under-estimate the true value of Florida emissions. As production and industry practices differ by state, this may lead to uncertainties in emission calculations, most notably with petroleum systems.

More specific uncertainties may arise due to steps taken to estimate the number of natural gas processing plants in Florida based on national processing plant averages. Because no hard data was located that specified exact numbers of processing plants, estimations had to be made, and inaccuracies might arise with regards to the legitimate number of processing plants. Especially in the case of Florida where in later years the number estimated was below 1 at times. This is accepted when correlating Florida's processing capacity to national averages and EFs. Likewise, because hard data was not able to be located which listed the number of natural gas compressor stations in Florida, and the SIT had to estimate based on transmission pipeline miles, uncertainties may arise regarding the actual number of each type of compressor station.

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INDUSTRIAL PROCESSES & PRODUCT USE SECTOR

Appendix F

Industrial Processes

Overview

The inventory for the Industrial Processes and Product Use includes emissions from an array of industries and consist of non-combustion process emissions of various greenhouse gases (GHGs). Different GHGs and their sources covered in this module include:

- ➢ Carbon Dioxide (CO_2) from:
    - ○ Clinker production in cement making
    - ○ Lime production
    - ○ Limestone and Dolomite consumption
    - ○ Soda Ash consumption
    - ○ Iron and Steel production
    - ○ Ammonia production
    - ○ Urea consumption
    - ○ Phosphoric Acid production (*estimated separately as it is not included in the SIT*)
- ➢ Nitrous Oxide (N_2O) from:
    - ○ Nitric Acid and Adipic Acid production
- ➢ Sulfur Hexafluoride (SF_6) from:
    - ○ Electric Power Transmission and Distribution Systems
- ➢ Hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs)
    - ○ Consumption of Ozone Depleting Substances (ODS)
- ➢ Combination of HFCs, PFCs, and SF_6 from:
    - ○ Semiconductor Manufacturing

<u>Methodology</u>

Process emissions were calculated by imputing activity data for each component into the SIT, which were then multiplied by their respective emission factors (EFs) to get total emissions for each year. The activity data, EFs, and GHGs calculation method for each system is described below.

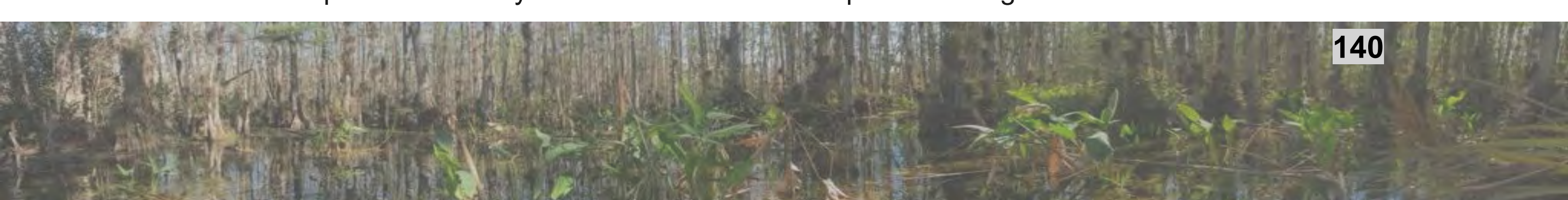
Cement Clinker Production:

CO_2 is emitted during the cement production process when calcium carbonate (CaCO3) is heated in a cement kiln. This calcination process forms lime and CO_2. To estimate cement process GHG emissions, the total production quantity of clinker produced during this process is multiplied by an EF to get total CO_2 emissions. This value is then summed with a total value of emissions from cement kiln dust and then converted to MT CO_2e. The module's emissions equation is as follows:

Emissions (MT CO_2e) *= Production (metric tons) × Emission Factor (t CO_2/t production) + Emissions from Cement Kiln Dust (MT CO_2)*

Lime Production:

Emissions from lime manufacture are estimated by combining emissions from high-calcium and dolomitic lime production. However, lime used in sugar refining leads to the reabsorption of atmospheric CO_2. The amount of lime used in sugar refining can be subtracted from total lime production to estimate total net CO_2 emissions. Default data was provided by the SIT for high-calcium and dolomitic lime production for the years 2008 through 2018. However, USGS lime production data existed as far back as 2003 and estimations had to be made to calculate Florida-specific lime production values for the years 2003-2007. Firstly, within USGS data both quicklime and hydrated lime values are reported for high-calcium and dolomitic lime.



The weight value of hydrated lime needs to be corrected for its total weight of water and added to the separate dry high-calcium and dolomitic lime values. Then percent values of total high-calcium and dolomitic lime production weights were determined based on national and state production ratios for each year, and Florida-specific lime production values were reported.

The total amount of lime used in sugar refining had to be subtracted from lime production values to determine net emissions. The total average weight of lime used to refine one metric ton of sugar was determined and multiplied by the annual refined sugar production amount in Florida for each year. This value estimated the total amount of lime used in Florida for sugar refining for each year. This total amount of lime used in sugar refining was multiplied by a factor that estimated CO_2 reabsorption from the sugar refining process. The net production values were then multiplied by an emission factor and then converted to estimate the total emissions of MT CO_2e.

Within the SIT tool exists a distinction for the input of values between high-calcium and dolomitic lime use in sugar refining. Resources that specified the different quantities of each type used in sugar refining were unable to be located. All values for lime used in sugar refining were assumed to be from high-calcium lime use due to the added magnesium content of dolomitic lime. The module's emissions equation is as follows:

Emissions (MT CO_2e) *= [Production (MT) - Sugar Refining and Precipitated Calcium Carbonate Production (MT) × CO_2 Reabsorption Factor (80%)] × Emission Factor (MT CO_2/MT production)*

Limestone and Dolomite Consumption:

Emissions from the industrial consumption of limestone and dolomite exist as CO_2 which is emitted as a by-product from the reaction of limestone or dolomite impurities and fuels heated in a blast furnace. The module provided default data for industrial limestone and dolomite consumption. Total limestone and dolomite consumption values were used for Florida from USGS Crushed Rocks Yearbooks and were rationed to determine the amount consumed for industrial use based on national industrial consumption factors. This total industrial consumption value was multiplied by specific limestone and dolomite emission factors to estimate CO_2 emissions. This value was then converted to estimate total emissions of MT CO_2e. The module's emissions equation is as follows:

Emissions (MT CO_2e) *= Consumption (MT) × Emission Factor (MT CO_2/MT production)*

Total consumption values for both limestone and dolomite were not reported for 1990-1993, as well as 2010-2014 for dolomite alone. Therefore, an interpolation method was used to calculate the totals by using the linear trendline equation. For limestone's missing values, the linear analysis was based on known values for 1994 through 1999. Estimates for dolomite's two gaps of missing values were produced by linear analysis based on known values for 1994 through 2009, while excluding outlier years of 1999 and 2007 to present a more accurate trend.

Soda Ash Consumption:

Emissions from soda ash consumption come in the form of CO_2 which is released when soda ash is consumed in products such as glass, soap, and detergents. Total soda ash consumption was calculated by the SIT by the proportional distribution of the total national soda ash consumption by the total state population of Florida. Estimated consumption values were multiplied by an emission factor to calculate total CO_2 emissions. This value was then converted to estimate total emissions of MT CO_2e. The module's emissions equation is as follows:

Emissions (MT CO_2e) *= Manufacture/Consumption (MT) × Emission Factor (MT CO_2/MT production)*

Iron and Steel Production:

Default data was provided by the SIT for Iron and Steel production in Florida for the years 1997-2018. Data was taken from the American Iron and Steel Institute (AISI Annual Statistics Report) to calculate the different values of iron and steel that were produced through various production methods. Each production method was assigned its own emission factor and this emission factor was multiplied by the total production values to estimate CO_2 emissions. This value was then converted to estimate total emissions of MT CO_2e.

The AISI Annual Statistics Report sums Florida iron and steel production with that of six other states. The SIT estimated Florida's individual production values by dividing the group's total production by the number of states in the grouping.

The module's emissions equation is as follows:

Emissions (MT CO_2e) *= Manufacture/Consumption (MT) × Emission Factor (MT CO_2/MT production)*

For the years 2011 through 2018, default data provided by the SIT mimicked 2010 reported values. AISI statistics for these specific years were unable to be obtained. In order to more accurately depict production, the value used for every year 2011 through 2018, was the average of the previous two years (2009 and 2010).

The SIT did not provide 1990-1996 default data for iron and steel production, nor were these values reported by AISI. Therefore, an interpolation method was used to calculate the totals by using the linear trendline equation for these years. The linear analysis was based on confident values for 1997 through 2009 to produce individually unique totals for the missing period.

Ammonia Production and Urea Consumption:

Emissions of CO_2 from ammonia production are estimated by subtracting the emissions from the total metric tons of urea that is applied to soils in Florida due to ammonia production data. Default production data was determined by the SIT by comparing USGS ammonia production capacity reports for the state of Florida to national capacity and production totals. Urea consumption data was estimated for Florida by the SIT using national and state consumption ratios. Both values were multiplied by their specific emissions factor to get total CO_2 emissions. CO_2 emissions from urea consumption was subtracted from CO_2 emissions due to ammonia production and the difference was converted to estimate total emissions of MT CO_2e for both industries. The module's emissions equations are as follows:

➢ *Ammonia Production emissions equation:*

Emissions (MT CO_2e) *= Production of Ammonia (MT) × Emission Factor (MT CO_2/MT activity) - Emissions from Urea (MT CO_2e)*

➢ *Urea Consumption emissions equation:*

Emissions (MT CO_2e) *= Consumption of Urea (MT) × Emission Factor (MT CO_2/MT activity)*

Phosphoric Acid Consumption:

Emissions from the production of phosphoric rock come in the form of CO_2. CO_2 is emitted when the inorganic carbon (in the form of calcium carbonate) components of phosphoric rock are washed with sulfuric acid during the chemical process that produces phosphoric acid. Emissions from phosphoric acid are not included in the SIT and hence a separate calculation was prepared to include it in the total emissions. To estimate the total yearly process emissions of phosphoric acid production, national usable phosphoric rock production data was taken from USGS Minerals Yearbooks for phosphoric rock. A statistic supplied by the Florida Polytechnic Institute was used to determine Florida's share of the total national production values. This statistic noted that approximately 75% of all phosphoric rock and acid is produced in Florida. Florida production values were set to equal 75% of yearly national production values. This value was then multiplied by the total percent of inorganic carbon in the form of CO_2 that was unique to Florida. This value, which was supplied by the Florida Industrial and Phosphate Research Institute (FIPRI), was approximated to be 3.55% of Florida phosphoric rock consisting of calcium carbonate. The product of these values, Florida production values and percent of calcium carbonate, made up the estimated emission values from this process. The data was converted to estimate total emissions of MT CO_2e.

Nitric and Adipic Acid Production:

Emissions from the production of nitric and adipic acid come in the form of N_2O. N_2O is released during nitric acid production as a by-product of the oxidation of ammonia. In adipic acid production, N_2O is released in the oxidation process of cyclohexane and a ketone-alcohol. Two methods for determining GHG emissions as specified within the SIT were either finding production data (in metric tons) of both acid types and using emission factors and gas conversions to estimate total emissions of MT CO_2e, or by utilizing the EPA's Greenhouse Gas Reporting Program Facility Level Information on GreenHouse Gases Tool (FLIGHT) application which tracks process emissions reported by large production facilities. Annual production data was unable to be located for Florida for these two processes, so the EPA reporting system was used to estimate total emissions. EPA data only existed for the years 2010-2018. The module's emissions equations are as follows:

- *Nitric Acid Production emissions equation:*

  Emissions (MT CO_2e) *= Production of Nitric Acid (MT) × Emission Factor (MT N_2O/MT production) x Percent N_2O Released after Pollution Control x GWP N_2O*

- *Adipic Acid Production emissions equation:*

  Emissions (MT CO_2E) *= Production of Adipic Acid (MT) × Emission Factor (MT N_2O/MT production) x Percent N_2O Released after Pollution Control x GWP N_2O*

Electric Power Transmission and Distribution Systems:

Emissions from electric power transmission and distribution systems come in the form of SF_6 which is emitted when it is used as an insulator in electrical technologies like gas-insulated high-voltage circuit breakers, substations, transformers, and transmission lines. Emissions are calculated in the SIT by multiplying the amount (in metric tons) of SF_6 consumed by a specific emission factor to calculate the estimated metric tons of SF_6 emitted by these systems. These SF_6 emissions are then multiplied by the GWP of SF_6 and converted to estimate the total emissions of MT CO_2e.

The SIT provided default values for SF_6 consumption for all years. The SIT calculated SF_6 consumption in Florida by comparing electricity sales in Florida to the ratio of total national SF_6 consumption and total national electricity sales for each year. The module's emissions equation is as follows:

Emissions (MT CO_2e) *= SF_6 Consumption (MT SF_6) × Emission Factor (MT SF_6/MT Consumption) x GWP of SF_6*

Consumption of Ozone Depleting Substances:

Emissions from the consumption of ODSs come in the form of HFCs and PFCs. These GHGs are emitted from the use of ODS in a variety of industrial applications. These applications include their use in refrigeration and air conditioning equipment, aerosols, solvent cleaning, fire extinguishing, foam blowing, and sterilization. Emissions are calculated by multiplying the total national compound emissions emitted by ODS (in metric tons of CO_2e as reported by the 1990-2018 US Inventory) by the population of the state of Florida, and then dividing the product by the national population. From this calculation, a total value of Florida apportioned emissions (in MT CO_2e) can be estimated. The module's emissions equation is as follows:

Emissions (MT CO_2e) *= [National ODS Substitute Emissions (MT CO_2e) × State Population]/ National Population*

Semiconductor Manufacturing:

Emissions from the manufacture of semiconductors come in the form of HFCs, PFCs, and SF_6s. These GHGs are emitted during the plasma etching and chemical vapor deposition processes of semiconductor manufacturing. Emissions were calculated by multiplying the total national emissions of metric tons CO_2e by a Florida to US ratio of semiconductor shipments dollar values. The total national emissions in MT CO_2e were determined by the 2019 US Inventory. These calculations were used and converted to estimate the total value of Florida apportioned emissions (in MT CO_2e) for this sector. The SIT provided default data for all years of this section.

The module's emissions equation is as follows:

Emissions (MT CO_2e) *= [National Semiconductor Manufacture Emissions (MT CO_2E) × Value of State Semiconductor Shipments]/ Value of State Semiconductor Shipments*

<u>Data Sources</u>

- *Cement clinker process data:* Clinker production data for the total metric tons of clinker produced in Florida for all years was able to be retrieved from different linked files from the United States Geological Survey (USGS) Cement Minerals Yearbook website.
- *Lime Production:* For calculating net emissions from lime manufacture in Florida, two different values needed to be determined: first the amounts of high-calcium and dolomitic lime that is produced each year in Florida, and second the amount of lime used in sugar refining in Florida. Lime production releases CO_2 emissions and the use of lime in sugar refining negates CO_2 emissions. Yearly lime production data was able to be determined

using the USGS Lime Minerals Yearbook. Sources were not able to be identified which directly listed the amount of lime that is used each year in Florida to refine sugar, so this had to be estimated for each year based on other information. The average amount of lime statistic was taken from a report done by the National Lime Association and yearly sugar production data for Florida was taken from the United States Department of Agriculture databases for Florida sugar Production.

- *Limestone and Dolomite Consumption:* Specific Florida Limestone and Dolomite consumption data was taken from the USGS Crushed Stone Yearbooks. Industrial consumption data was then determined by the SIT using national limestone and dolomite industrial consumption ratios.
- *Soda Ash Consumption:* Florida specific data with regards to the state's yearly consumption of soda ash was unable to be located. Default values were provided and calculated by the SIT based on National Inventory data.
- *Iron and Steel Production:* The SIT provided default data for iron and steel production in Florida using the American Iron and Steel Institute Annual Statistics Report.
- *Ammonia Production:* The SIT provided default data for ammonia production based on ammonia production capacity data from the USGS Nitrogen Minerals Yearbooks.
- *Urea Consumption:* The SIT provided default data for total urea consumption based off of national ratios and data taken from LULUCF Spreadsheet "Urea_1990-2018_PR_FINAL_FR," on the "Urea Consump Calendar Yr" worksheet.
- *Phosphoric Acid Production:* Emission estimate calculations for this sector were not included in the SIT and had to be incorporated later. To calculate process emissions from the production of phosphoric acid, data on the total amount of phosphate rock consumed in Florida, as well as its inorganic carbon content (as CO_2), need to be known to calculate CO_2 emissions. USGS data was used to determine national phosphate rock consumption for phosphoric acid production, and statistics from Florida Polytechnic Institute were taken to determine the total percent of national phosphate rock consumption within Florida. The Florida Industrial and Phosphate Research Institute (FIPRI) provides statistics for total inorganic carbon as (CO_2) content within phosphate rock in Florida, which were then used to calculate emissions.
- *Nitric and Adipic Acid Production:* To identify emissions from nitric and adipic acid production in Florida, the EPA FLIGHT application was used to input GHG emission data for these two processes using data reported by required facilities.
- *Electric Power Transmission and Distribution Systems:* SF_6 emissions from electric power transmission and distribution systems for Florida is provided in the SIT as default data. The SIT calculated emissions using EIA data for the total retail sales of electricity by state and emissions ratios based on total national US electricity sales.
- *Consumption of Ozone Depleting Substances:* To find total estimated GHG emissions from the consumption of ODSs, default data was provided by the SIT for all years for Florida. Emissions were calculated using national emission totals from the 1990-2018 US Inventory and state population data from the United States 2010 Census.
- *Semiconductor Manufacturing:* Default data was provided by the SIT for GHG emissions from semiconductor manufacturing in Florida for all years. Emissions were estimated by

the SIT using national and Florida values for total semiconductor shipments as well as national emissions estimates. National emissions estimates were taken from the 2019 US Inventory and shipment values were taken from U.S. Economic Census data for semiconductor manufacture.

Results

Figure F-1 shows the total emissions for all relevant activities within industrial processes and product use from 1990 to 2018. The figure shows that emissions were on a steady increase from 1990 with 5.4 MMT CO_2e up until 2007 with 13.3 MMT CO_2e, and then had a minor decline in 2008 and 2009. After that point, emissions quickly increased and almost doubled from 2007 to 2011. It continued to drop then rise up to 2018, staying well above 18 MMT CO_2e during this period.

Table SF-6 displays values per activity for all years between 2005 and 2018. All data points are rounded from those calculated by the SIT. Zooming into the baseline years of 2005 and 2018, CO_2e emissions from this sector totaled 12.6 MMT and 27.05 MMT, respectively. Following behind 2018 as the year with the highest emissions, 2011 totaled to 23.8 MMT CO_2e landing it as the second-highest emitting year.

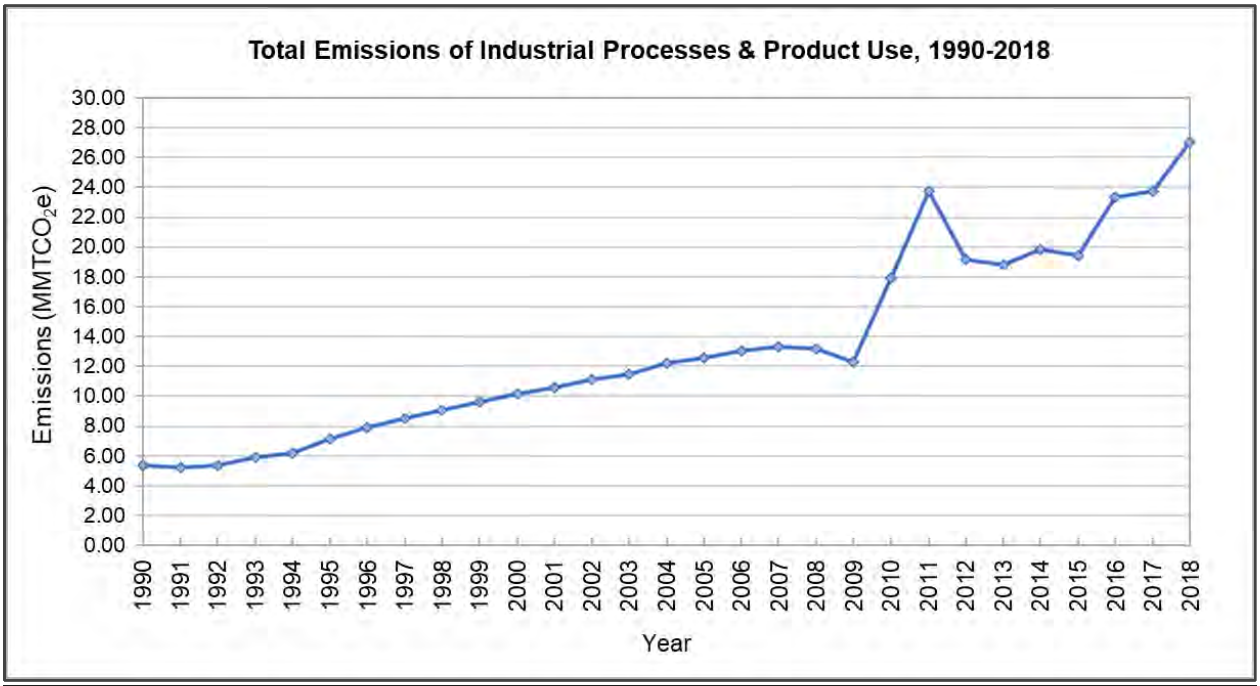


Figure F-1: IPPU - Total emissions from all activities in MMT CO_2e.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cumulative Total (MMT CO_2e)	**12.60**	**13.07**	**13.32**	**13.20**	**12.33**	**17.95**	**23.75**	**19.18**	**18.80**	**19.83**	**19.40**	**23.34**	**23.72**	**27.05**
Total Emissions of CO_2	**5.56**	**5.63**	**5.48**	**4.86**	**3.40**	**3.92**	**3.74**	**4.11**	**4.74**	**4.93**	**5.02**	**5.23**	**5.30**	**5.40**
Cement	2.73	2.91	2.70	2.46	1.54	1.71	1.57	1.96	2.42	2.58	2.70	2.86	2.98	3.19
Lime	0.13	0.13	0.10	0.13	0.09	0.11	0.09	0.06	0.05	0.03	0.02	0.03	0.04	0.04
Limestone and Dolomite	0.55	0.61	0.64	0.43	0.41	0.48	0.45	0.49	0.63	0.74	0.72	0.75	0.71	0.68
Soda Ash	0.15	0.15	0.15	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.14	0.13	0.13
Iron and Steel	1.03	1.02	1.05	0.92	0.56	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
Ammonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urea	.0007	.0006	.0008	.0003	.0006	.0007	.0004	.0005	.0008	.0007	.0005	.0009	.0010	.0010
Phosphoric Acid	0.96	0.80	0.83	0.77	0.68	0.75	0.76	0.73	0.77	0.71	0.70	0.71	0.70	0.62
Total Emissions of N_2O	**0**	**0**	**0**	**0**	**0**	**4.57**	**10.33**	**5.25**	**4.08**	**4.54**	**3.66**	**7.14**	**7.36**	**10.45**
Nitric Acid	0	0	0	0	0	0.71	0.62	0.64	0.67	0.60	0.62	0.70	0.62	0.60
Adipic Acid	0	0	0	0	0	3.86	9.71	4.61	3.41	3.94	3.04	6.44	6.75	9.85
Total Emissions of HFC, PFC, NF_3, and SF_6	**7.04**	**7.44**	**7.84**	**8.35**	**8.92**	**9.45**	**9.68**	**9.82**	**9.98**	**10.36**	**10.72**	**10.97**	**11.06**	**11.20**
ODS Substitutes	6.50	6.99	7.46	7.97	8.55	9.09	9.30	9.50	9.68	10.04	10.45	10.68	10.77	10.92
Semiconductor Manufacturing	0.03	0.02	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Electric Power Transmission & Distribution Systems	0.51	0.44	0.38	0.37	0.37	0.35	0.35	0.29	0.27	0.29	0.24	0.26	0.26	0.25

Table F-1: IPPU - Total and specific GHG (CO_2, N_2O, HFC, PFC, NF_3, and SF_6) emissions.

Key Uncertainties

Due to the nature of how emission factors have been calculated by the SIT, uncertainties may exist regarding the validity of the emission factors. With regards to uncertainties of individual industrial processes the SIT outlines major areas of uncertainty it has identified. These uncertainties are as follows:

The largest variable area of uncertainty regarding calculating emissions from cement manufacture is the variance in the portion of calcinated cement kiln dust and percentage of clinker constituted by lime.

Different chemical compositions of lime being produced by different manufactures can lead to variable emission data. Additional uncertainties when calculating lime emissions can originate from inaccuracies in production estimates based on available data as well as variability in the amount of lime used to refine sugar by different refineries in Florida.

The variable compositions of limestone and dolomite can lead to uncertainties in emission estimates.

Variance in emissions from the end-use of soda ash can lead to low uncertainty in emission estimations.

Uncertainties that may arise when calculating process emissions of phosphoric acid will predominantly exist when using the same national percent value for Florida production for all years. Different years may have yielded different national ratios. Additionally, the percent composition of calcium carbonate within phosphate rock in Florida may be variable from year to year.

Uncertainties in the total amount of GHGs emitted from adipic and nitric acid production can exist using the EPA's tool. Process emissions are only reported by facilities large enough to be required to report.

Since the SIT estimates Florida's iron and steel production values as an average share of a seven-state total reported by the AISI, uncertainties in the true production value can arise. Additionally, uncertainties may arise since the SIT makes assumptions about Florida's iron and steel production method mix based on national averages.

Since the use of national emission rates, national and state population data, and national and state dollar values were used to disaggregate Florida emissions from national totals, uncertainties may arise in the calculations of emissions from ODS, electric power, and semiconductor manufacturing data.

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AFOLU SECTOR

Appendix G

Agriculture

Overview

The Agriculture sector is made up of several activities that produce greenhouse gas emissions. The activities captured in the greenhouse gas calculations include enteric fermentation, manure management, agriculture soils, rice cultivation, liming agricultural soil, urea fertilizer, and agricultural residue burning. The total greenhouse gas emissions in the agriculture sector were made up of three gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Agriculture emissions combine for approximately 3% of the total greenhouse gas emissions in the state of Florida.

Methodology

Enteric Fermentation:

Enteric fermentation is the decomposition of plant material in the digestive tract of animals; the process causes the expulsion of by-products such as methane gas which are exhaled by the animal into the atmosphere (FAO, 2021). SIT accounts for GHGs caused by enteric fermentation for specific animal types and recorded populations to produce the total methane (CH_4) emission rate per year. The calculation for enteric fermentation uses the total number of dairy cattle (dairy cows and dairy replacement heifers), beef cattle (beef cows, beef replacement heifers, heifer and steer stockers, feedlot heifers and steer, and bulls), and other livestock (sheep, goats, swine, and horses) for years 1990 through 2018. Data on livestock was obtained through default data on the SIT data tables and compared to the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS) and Florida Department of Agriculture and Consumer Services (FDACS) census and statistical data. The module's emissions equation is as follows:

Emissions (MMT CO_2e) *= Animal Population ('000 head) × Emission Factor (kg CH_4/head) × 25 (GWP) ÷ 1,000,000,000 (kg/MMT CO_2e)*

Manure Management:

This section refers to the handling of livestock manure. Depending on the handling process, manure decomposition can produce a combination of methane, carbon dioxide (CO_2), and nitrous oxide (N_2O) gas. The calculation for manure management uses the total number of livestock similar to the enteric fermentation activity, including the number of dairy cattle (dairy cows and dairy replacement heifers), beef cattle (beef cows, beef replacement heifers, heifer and steer stockers, feedlot heifers and steer, and bulls), and other livestock (sheep, goats, swine, and horses), however, this section also includes poultry (chickens and turkeys). Data on livestock was obtained through default data on the SIT data tables and compared to the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS) and Florida Department of Agriculture and Consumer Services (FDACS) census and statistical data. For turkeys specifically, values were only available for 2008-2018, therefore linear regression was used to extrapolate the missing values for 1990-2007.

- The module's CH_4 emissions equations are as follows:
  - ***VS[13] Produced**$_{\text{Cattle, excluding calves}}$ = Animal Population ('000 head) × 1,000 × VS (kg/head/yr)*
  - ***VS Produced**$_{\text{Calves and all other livestock}}$ = Animal Population ('000 head) × TAM[14] ×*
  - *VS (kg/1,000 kg animal mass/day) × 365 (days/yr)*
  - ***Emissions (MMT CO_2e)** = VS Produced (kg) × B_o[15] (m^3 CH_4/kg VS) × MCF × 0.678 kg/m^3 × 25 (GWP) ÷ 1,000,000,000 (MMT CO_2e)*

- The module's N_2O emissions equations are as follows:
  - ***K-Nitrogen[16] Excreted**$_{\text{Cattle, excluding calves}}$ = Animal Population ('000 head) × 1,000 × K-Nitrogen (kg/head/day)*
  - ***K-Nitrogen Excreted**$_{\text{Calves and all other livestock}}$ = Animal Population ('000 head) × TAM × K-Nitrogen (kg/1,000 kg animal mass/day) × 365 (days/yr)*
  - ***Emissions (MMT CO_2e)** = K-Nitrogen Excreted × Emission Factor (liquid or dry) × 298 (GWP) ÷ 1,000,000,000 (kg/MMT CO_2e)*

Agricultural Soils:

Agricultural soils emit nitrous oxide naturally because of the decomposition of organic matter. The activity includes emissions calculations from three subactivities: the decomposition of plant residues, synthetic and organic fertilizers, and droppings from pastured animals and livestock. Estimates for plant decomposition in agricultural soils included volume of crop production from the following crops: Alfalfa, Corn for Grain, All Wheat, Barley, Sorghum for Grain, Oats, Rye, Millet, Rice, Soybeans, Peanuts, Dry Edible Beans, Dry Edible Peas, Austrian Winter Peas, Lentils, Wrinkled Seed Peas, Red Clover, White Clover, Birdsfoot Trefoil, Arrowleaf Clover, and Crimson Clover. Calculations for the manure of pastured animals and livestock included the list used for manure management.

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[13] VS: "Volatile Solids"
[14] TAM: "Typical Animal Mass"
[15] B_o: "Maximum Potential CH_4 Emissions"
[16] K-Nitrogen: "Kjeldahl Nitrogen"

Data for both sub-activities were obtained from default data on the SIT data tables and compared to the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS) and Florida Department of Agriculture and Consumer Services (FDACS) census and statistical data. Calculations for plant fertilizers included synthetic and organic fertilizers. Organic fertilizers were further divided into categories, including dried blood, compost, dried manure, activated and other sewage sludge, tankage, and other forms of organic fertilizer. Data for fertilizers was obtained through the SIT data tables and compared to Commercial Fertilizer data provided by the Association of American Plant Food Control Officials (AAPFCO) and The Fertilizer Institute (TFI). The module's N_2O emissions equations are as follows:

- Direct N_2O emissions:
    - ***Emissions (MMT CO_2e)*** *= Total N × fraction unvolatilized (0.9 synthetic or 0.8 organic) × 0.01 (kg N_2O-N/kg N) × 44/28 (Ratio of N_2O to N_2O-N) × 298 (GWP) ÷ 1,000,000,000 (kg/MMT CO_2e)*
- Indirect N_2O emissions:
    - ***Emissions (MMT CO_2e)*** *= Total N × fraction volatilized (0.1 synthetic or 0.2 organic) × 0.001 (kg N_2O-N/kg N) × 44/28 (Ratio of N_2O to N_2O-N) × 298 (GWP) ÷ 1,000,000,000 (kg/MMT CO_2e)*

Rice Cultivation:

The crop cultivation of rice in Florida is part of the sugarcane production cycle and occurs on fallow sugarcane land (UF IFAS, 2019). Most of the sugarcane in Florida is commercially produced on flooded soils around Lake Okeechobee (Baucum, 2006; Schueneman 2000). The sugarcane is harvested annually, and the sugarcane ratoon is left to grow in its place. Typically, a sugarcane field will go three years before it is replanted (Baucum, 2006).

The choice to grow rice between the replanting of sugarcane depends if the last harvest is early in the calendar year (Baucum, 2006; Schueneman 2000). During the growing period of cultivation, methane is released by both the rice plant and the bacteria in flooded soil.

Calculations for emission of this activity consider the area harvested of primary and ratoon rice crops to produce CH_4 emission rates. To obtain the GHGs from rice cultivation, the formula uses the total annual area harvested and multiplies that by an emissions factor developed from the US EPA. The result is then converted from kg CH_4 to MMT CO_2e.

Three sources were considered for data use on rice cultivation, the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS) Quick Stats tool. Values for rice crop production were only available for 1997, 2002, 2007, and 2017. Interpolations and extrapolations were conducted to estimate all other years (1990-1996, 1998-2001, 2003-2006, 2008-2016, and 2018). The module's emissions equation is as follows:

Emissions (MMT CO_2e) *= Area Harvested ('000 acres) × 1/2.471 (ha/acre) × Emission Factor (kg CH_4/ha-season) × 25 (GWP) ÷ 1,000,000,000 (kg/(MMT CO_2e)*

Liming Agricultural Soil:

Liming agricultural soil is a practice used to increase the pH of agricultural soils. The components used in the liming process include limestone and dolomite, the amounts of which are used in the emissions calculations for this activity. Data on limestone and dolomite application were obtained through default data on the SIT data tables. The module's emissions equation is as follows:

Emissions (MMT CO_2e) *= Total Limestone or Dolomite Applied to Soil (1,000 metric tons) × Emission Factor (tons C/ton limestone or dolomite) × 44/12 (ratio of CO_2 to C) ÷ 1,000,000*

Values for total applied to soil of both limestone and dolomite were not reported for 1998 or 2009. Therefore, an interpolation method was used to calculate the total by taking the average of the totals reported for the previous and following years. The average of 1997 and 1999 was used to determine the 1998 total, as was the 2008 and 2010 average to determine the 2009 total.

Urea Fertilizer:

Urea fertilizer is a product applied to agricultural soils to increase nitrogen levels available for plant uptake. The calculation for this section includes the total amount of urea fertilizer applied to agricultural soils. Data on urea fertilizer was obtained through the SIT data tables and compared to Commercial Fertilizer data provided by the Association of American Plant Food Control Officials (AAPFCO) and The Fertilizer Institute (TFI). The module's emissions equation is as follows:

Emissions (MMT CO_2e) *= Total Urea Applied to Soil (MT) × Emission Factor (tons C/ton urea) × 44/12 (ratio of CO_2 to C) ÷ 1,000,000*

Agricultural Residue Burning:

Agricultural residue burning is a process of land management used as a method to deal with crop residues. GHGs produced during crop residue burning include methane and nitrous oxide. The calculation uses crop production of barley, corn, peanuts, rice, soybeans, sugarcane, wheat, and other crops along with emissions factors such as the residue/crop ratio, fraction residue burned, dry matter refraction, burning efficiency, combustion efficiency, and carbon content to approximate both methane and nitrous oxide emissions. Data for crops were obtained from default data on the SIT data tables and compared to the United States Department of Agriculture National Agricultural Statistics Service (USDA NASS) and Florida Department of Agriculture and Consumer Service (FDACS) census and statistical data. The module's emissions equation is as follows:

Emissions (MMT CO_2e) *= Crop Production (MT) × Residue/Crop Ratio × Fraction Residue Burned Dry Matter Fraction × Burning Efficiency × Combustion Efficiency × C or N Content × Emission Ratio (CH_4-C or N_2O-N) × Mass Ratio (CH_4/C or N_2O/N) × GWP ÷ 1,000,000 (MT/(MMT CO_2e)*

The agricultural sector in Florida produces some of the highest yields for specific crops in the United States. These crops, including fresh market tomatoes, oranges, fresh market bell peppers, grapefruits, watermelons, fresh market sweet corn, squash, strawberries, fresh market cabbage, sugarcane, cucumbers, potatoes, and snap beans, make up a large portion of the crops produced in Florida. Most common management practices from commercial growers show that the residue from these crops are instantly destroyed to manage disease and pest. Because the residues were not integrated into the soils, these crops were not included in the agricultural residue calculations.

Data Sources

- ➢ Census data can be accessed from the USDA's Quick Stats Query Tool Database.
- ➢ Commercial fertilizer data was provided by AAPFCO and TFI through the 2014 report.
- ➢ Agricultural data can be accessed from the USDA'S CropScape Webtool.

Results

Figure G-1 displays the linear trends of 1990-2018 for each of the agricultural activities, as well as the cumulative total. The results of GHG calculations of the agricultural module show the total annual emissions range from 9.3 to 9.91 MMT CO_2e during the period 2005 to 2018, as seen in Table G-1. The average annual amount of emission from the agricultural sector in the state of Florida is 9.414 MMT CO_2e with a median of 9.41 MMT CO_2e. Zooming into the baseline years of 2005 and 2018, CO_2e emissions from the agriculture sector totaled to 9.3 MMT and 9.42 MMT, respectively.

The agricultural activity with the largest average emission was agricultural soils with an annual average of 4.79 MMT CO_2e across the entire time series of 1990-2018. Although this activity is the largest, it also had the largest decline of emissions through the 2005-2018 time period. The activity with the second-largest emissions was enteric fermentation, with 1990-2018 emission totals averaging to 3.36 MMT CO_2e. These two activities accounted for over 85% of the emissions in the agricultural sector through the 2005-2018 time period.

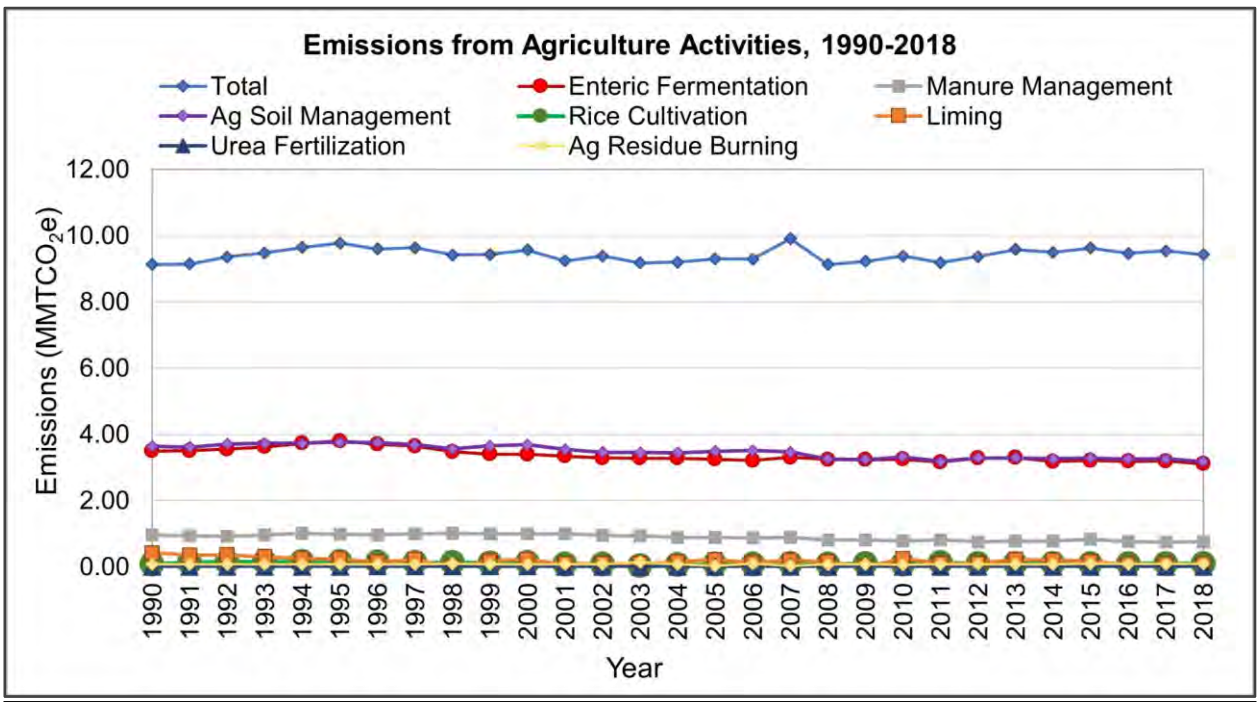

Figure G-1: Agriculture - Historical emissions (MMT CO_2e) from agricultural activity types.

$MMTCO_2e$	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Enteric Fermentation	3.25	3.21	3.30	3.24	3.23	3.25	3.16	3.28	3.29	3.18	3.21	3.18	3.19	3.11
Manure Management	0.89	0.87	0.89	0.81	0.80	0.77	0.81	0.75	0.78	0.78	0.83	0.77	0.74	0.75
Ag Soil Management	4.84	4.92	5.37	4.78	4.83	4.97	4.89	5.05	5.11	5.15	5.23	5.26	5.35	5.30
Rice Cultivation	0.07	0.07	0.10	0.08	0.09	0.08	0.13	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Liming	0.21	0.12	0.20	0.14	0.19	0.24	0.11	0.10	0.22	0.20	0.16	0.06	0.06	0.06
Urea Fertilization	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01
Ag Residue Burning	0.03	0.09	0.04	0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09
TOTAL	**9.30**	**9.29**	**9.91**	**9.13**	**9.22**	**9.38**	**9.18**	**9.37**	**9.58**	**9.49**	**9.63**	**9.46**	**9.54**	**9.42**

Table G-1:Agriculture - Total annual emissions (MMT CO_2e) from the agriculture sector.

Between 1990 and 2018, the largest GHG produced by agriculture activities on average was CH_4, portrayed in Figure G-2. This GHG accounted for more than half, 52%, of the sector's average annual CO_2e emissions. N_2O was the second-largest GHG in the sector contributing to 46% of average annual emissions, followed by CO_2 with a 2% contribution.

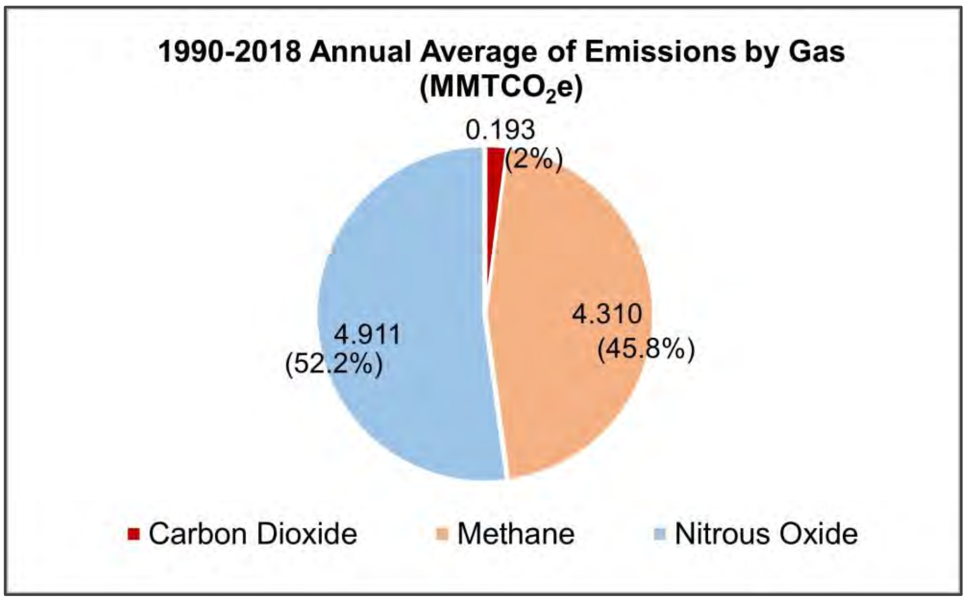

Figure G-2: Agriculture - Average annual emissions (MMT CO_2e) from 1990 to 2018, by gas type.

In 2018, CH_4 produced in the agriculture sector amounted to approximately 3.94 MMT CO_2e. The agricultural activities contributing to the CH_4 emissions include: enteric fermentation, manure management, rice cultivation, and agricultural residue burning. Two activities make up an average of 98% of the CH_4 emissions between 2005 and 2018. Enteric fermentation contributes to nearly 80% of those CH_4 emissions, the vast majority of the produced CH_4. The second activity, manure management, produces an average of about 18% of the sector's 2005-2018 CH_4 emissions. For this same time period, rice cultivation and agricultural residue burning average a combined CH_4 emission of 0.15 MMT CO_2e.

N_2O averaged an annual amount of 3.40 MMT CO_2e between 2005 and 2018, approximately 45% of the annual agriculture sector GHG emissions in this period. The agricultural activities that resulted in N_2O emissions include: manure management, agricultural soils, and agricultural residue burning. Of these activities, agricultural soils produced the most emissions with 97% of the N_2O produced from this activity. The other two activities, manure management and agriculture residue burning combined produce approximately 0.10 MMT CO_2e of N_2O.

Figure G-3 shows the direct N_2O emissions from agricultural soil management activities across the entire time series. Emissions are highest from livestock, which stays relatively consistent at around 7,000 MT of N_2O between 1990 and 2018. However, livestock activities emissions are surpassed in 2017 and 2018 by crop residue activities, which has been on a steady incline since 1990. Figure G-4 shows the indirect N_2O emissions from agricultural soil management activities for 1990-2018. Here, leaching and runoff activities are the highest emitting source, which is then followed by livestock.

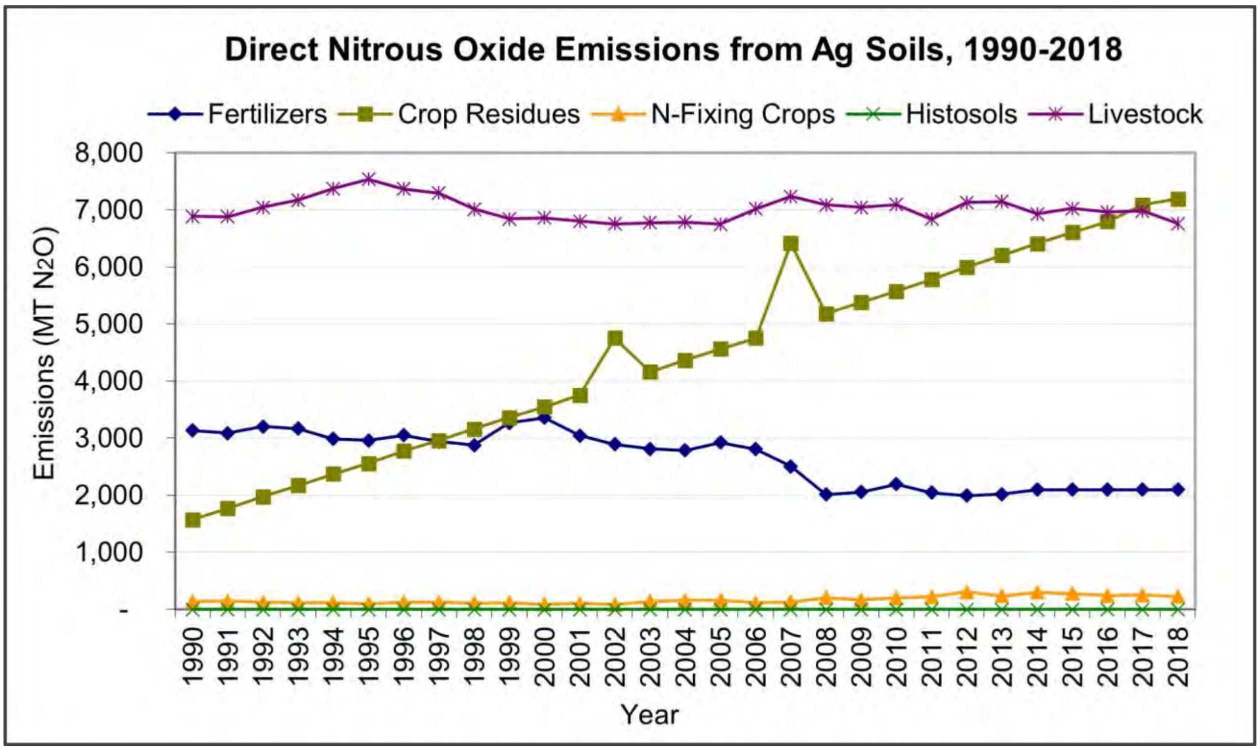

Figure G-3: Direct Nitrous Oxide Emissions from Agriculture Soils (1990-2018).

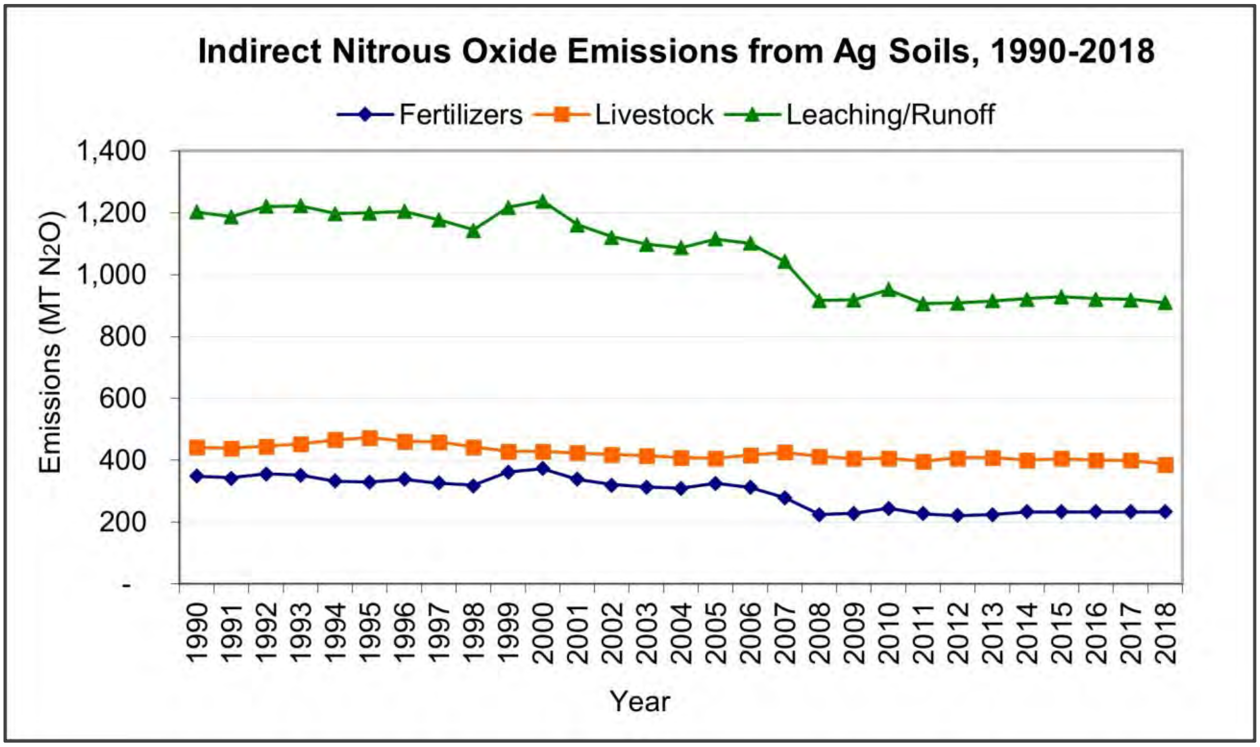

Figure G-4: Indirect Nitrous Oxide Emissions from Agriculture Soils (1990-2018).

The final GHG, CO_2, amounts to less than a fifth of a percent of the total GHG emissions of the agriculture sector. The agricultural activities that produce CO_2 directly are: liming, and urea fertilization. Emissions from liming made up 89% of the CO_2 produced from the agriculture sector. On average, liming produced about 0.15 MMT CO_2e between 2005 and 2018. Urea fertilization produced about 0.05 MMT CO_2e on average during the same period.

Each of the GHGs has continued to decline between the period of 2005 and 2018. The most drastic change between the two years (2005 and 2018) in the amount was the reduction of N_2O at 0.47 MMT CO_2e. The second-largest change occurred in the reduction of CH_4 at 0.20 MMT CO_2e. Finally, CO_2 was reduced by 0.15 MMT CO_2e. However, CO_2 had the largest reduction by percentage at 67%. N_2O and CH_4 were at 9% and 5% reduction, respectively.

Table G-2 lays out the breakdown of emissions from agricultural soils, the largest emitter in the agriculture sector, primarily N_2O.

	MMT CO_2e			
GHG	**2005**	**2018**	**Δ%**	**#Δ**
CO_2	0.22	0.07	67%	0.15
CH_4	4.14	3.94	5%	0.20
N_2O	4.94	5.41	9%	0.47

Table G-2: Agriculture - Breakdown of emissions from agricultural soils.

Key Uncertainties

Uncertainty Associated with Animal Populations

Annual census checks of animal populations do not account for the fluctuation of the animal populations throughout the year. Therefore, the annual animal population total adds uncertainty to the precision of the emissions estimates. Additionally, some livestock categories do not have values for every year, such as turkeys which are only available for 2008-2018. In this case, values for 1990-2007 were extrapolated based on linear regression, and therefore adds uncertainty to the totals used.

There is uncertainty associated with the emission factors for animal populations. Emission factors vary depending on each animal's conditions including diet, genetics, and environment, and therefore introduce uncertainty with an average of an animal population. Emission factors for cattle populations were simulated by the EPA and did not follow the IPCC guidelines. Other animal populations' emission factors follow IPCC guidelines, though the uncertainty lies with the generalized values.

Emissions from Rice Crop Production

There is uncertainty associated with emissions from rice fields. Methane emissions vary significantly throughout the growing season due to temperature, fertilizer application, soil type, variety of rice grown, and agricultural practices such as seeding or direct planting.

There is uncertainty associated with census data of rice crops. Data is collected every five years, which creates a high uncertainty about ratooned yields. Rice crop production values were sources from USDA for years 1997, 2002, 2007, and 2017. Values for all other years were interpolated and extrapolated, leading to the uncertainty of integrated estimates.

Uncertainty from Agricultural Soil Management

The amount of nitrogen oxide in agricultural soil depends on many factors, including nitrogen, soil moisture content, soil temperature, pH, and soil amendments. N_2O concentration is highly variable throughout the year due to conditions not accounted for in the emissions calculations. The missing inputs and the variation due to location introduce a high level of uncertainty in agricultural soil management.

There is uncertainty associated with fertilizer data since it was limited to commercial fertilizer applications. Furthermore, urea fertilization's default emissions factor assumes that all of the carbon in urea applied to soils is ultimately emitted into the environment as CO_2. Non-fertilizer use, such as aircraft deicing, may be included in urea fertilization consumption totals, but the amount is likely minimal.

Uncertainty from Agricultural Residue Burned

The quantity of residue burned varies by management practice and crop type. A single annual data point is an estimate of the variation. Therefore the single point data creates an uncertainty in calculation inputs including the emissions factor, gas emissions, residue dry matter content, burning efficiency, and combustion efficiency.

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Appendix H

Land Use, Land-Use Change, and Forestry

Overview

The Land Use, Land-Use Change, and Forestry module, more commonly referred to by its acronym “LULUCF”, is responsible for the monitoring of Florida’s net carbon dioxide flux (CO_2) emanated from forest byproducts between the years 1990-2018. Other quantifiable data gathered from the state’s forestry section include methane (CH_4) and nitrous oxide (N_2O) emissions. The LULUCF Module delineates forest byproducts by organizing the section within two categories: *Forested Landscape,* and *Urban Forestry & Land Use*. *Forested Landscape* refers to an area that is covered by an array of vegetation, where the process of carbon flux occurs which includes net carbon sequestration, carbon stored in wood products, and emission rates from the burning of specified forests. *Urban Forestry and Land Use* highlights the process of carbon sequestration in calculated urban tree totals, carbon flux from landfills of yard trimmings and food scraps, and N_2O emissions from fertilizers applied in urban areas.

This module is composed of five sections:

- Forest Carbon Flux
  - Forest Land Remaining Forest Land/Land Converted to Forest Land/Forest Land Converted to Land
- Urban Trees
- Non-CO_2 Emissions from Forest Fires and Settlement Soils
- Landfilled Yard Trimmings and Food Scraps
- Agricultural Soil Carbon Flux

In addition to the activities presented by the SIT's LULUCF module, external calculations were conducted to determine the net removal of emissions from wetlands.

Methodology

Calculations of Florida's CO_2, CH_4, and N_2O emissions from its LULUCF activities were conducted with the aid of the Environmental Protection Agency's (EPA) State Inventory Tool (SIT). Required inputs for SIT's five subsections of LULUCF are provided below.

Forest Carbon Flux:

Forest carbon flux emissions are equated from the cumulative calculations of three land-use categories: forest land remaining forest land, land converted to forest land, and forest land converted to land. The category of 'land converted to forest land' includes: cropland converted to forest land, grassland converted to forest land, settlements converted to forest land, and other land converted to forest land. Similarly, the category of 'forest land converted to land' includes: forest land converted to cropland and forest land converted to settlements. The module's emissions equation for the entire forest carbon flux section is as follows:

> ***Emissions or Sequestration (MMT CO_2e)*** *= Sum of carbon fluxes from aboveground biomass, belowground biomass, dead wood, litter, mineral, and organic soils, drained organic soil, and wood products and landfills*

Urban Trees:

This section calculates the state's net carbon flux (CO_2) sequestration rates by combining the total urban area and percent of urban area with tree cover, along with a conversion ratio to produce its carbon sequestration factor. The module's emissions equation is as follows:

> ***Sequestration (MMT CO_2e)*** *= Total Urban Area (km^2) × Urban Area with Tree Cover (%) × 100 (ha/km^2) × C Sequestration Factor (metric tons C/ha/yr) × 44/12 (ratio of CO_2 to C) ÷ 1,000,000*

Non-CO_2 Emissions from Settlement Soils:

This portion of the SIT requires inputs of direct N_2O emission factors (EFs) for managed soils as a percentage and the total synthetic fertilizer applied to settlements measured in metric tons (MT) of nitrogen.

- The module's emissions equation for settlement soils is as follows:

__Emissions (MMT CO_2e)__ = Total Synthetic Fertilizer Applied to Settlement Soils (metric ton N) × Emission Factor (percent) × 0.01 (metric tons N_2O-N/metric ton N) × 44/28 (Ratio of N_2O to N_2O-N) × 298 (GWP) ÷ 1,000,000 (MT/MMT CO_2e)

Non-CO_2 Emissions from Forest Fires

The non-CO_2 emissions from forest fires represents CH_4 and N_2O emitted through the burning of forest biomass in both prescribed burns and wildfires. It requires the input of measured area burned, the combustion efficiency of multiple vegetation types in a percentage, and average biomass density. The Environmental Protection Agency (EPA) State Inventory Tool's (SIT) module estimates the emissions from the area burned by both types of fires and multiplies them by the biomass factors. The module generally analyzes the following forest types: primary tropical forests, secondary tropical forests, tertiary tropical forests, boreal forests, eucalypt forests, other temperate forests, shrublands, savanna woodlands (early dry season burns), and savanna woodlands (mid/late season burns).

The SIT module delineates emissions by forest type since the separated categorization of the combustion efficiency and EFs more accurately represent the level of emissions from forest fires. However, the available data dictated the use of a single, average set of combustion efficiency and EFs.

The annual acres burned for prescribed burns and wildfires were provided by the Florida Department of Consumer Services Florida Forest Services (FFS). FFS provided data in two forms, total acreage for both prescribed burns and wildfires as recorded from each reported incident, and a geographical overlay of each incident over each forest type. The total acres burned was the total acreage reported from the reported incidents, and the combustion efficiency and EF were derived from the GIS overlay data.

The acres burned by forest type were not used for a couple of reasons. First, the forest type data provided by FFS was not the same as the forest types listed in the tool, and as a result, did not align directly with the module's forest types. Additionally, the number of acres burned by each forest type was a small percentage of the acres recorded from each incident, since spatial data is not collected on every prescribed burn or wildfire.

Combustion efficiency and EFs were determined by comparing the forest type/combustion efficiency/EF data provided by the EPA with the data provided by FFS. The percentages of forest types associated with the fires was used to derive an average combustion efficiency (34%) and average EF (0.1 g/kg dry matter burned) used in the calculation.

- The module's emissions equation for forest fires is as follows:
    - *__CH_4 Emissions (MMT CO_2e)__ = Total Acres Burned (acres) x Average Biomass Density (145,215 kg d.m./ha) x Combustion Efficiency x Emission Factor (5.5 g/kg dry matter burned) x CH_4 GWP (25)*
    - *__N_2O Emissions (MMT CO_2e)__ = Total Acres Burned (acres) x Average Biomass Density (145,215 kg d.m./ha) x Combustion Efficiency x Emission Factor (0.1 g/kg dry matter burned) x N_2O GWP (298)*

Landfilled Yard Trimmings and Food Scraps:

Emission estimates for landfilled yard trimmings and food scraps requires the input of various land byproducts in a percentage format to analyze the amount of CO_2 flux emitted in

Florida. Data inputs required include: yard trimmings percent composition of grass, leaves, and branches; tons of yard trimmings; tons of food scraps landfilled; the initial carbon content percentage of yard trimmings and food scraps; the dry and wet weight ratio of yard trimmings and food scraps; the proportion of carbon stored from yard trimmings and food scraps; and the half-life of degradable carbon for yard trimmings and food scraps in years. The module's emissions equation is as follows:

$$\boldsymbol{LFC_{i,t}} = \Sigma\, W_{i,n} \times (1 - MC_i) \times ICC_i \times \{[CS_i \times ICC_i] + [(1 - (CS_i \times ICC_i)) \times e^{-k \times (t - n)}]\}_n$$

Where,

t = year for which carbon stocks are being estimated

$LFC_{i,t}$ = stock of carbon in landfills in year t, for waste i (grass, leaves, branches, food scraps)

$W_{i,n}$ = i represents the mass of waste disposed in landfills in year n, in units of wet weight

n = the year in which the waste was disposed, where 1960 < n < t

MC_i = moisture content of waste i

CS_i = proportion of initial carbon that is stored for waste i

ICC_i = initial carbon content of waste i

e = natural logarithm

k = first order rate constant for waste i, and is equal to 0.693 divided by the half-life for decomposition

Agricultural Soil Carbon Flux:

Agricultural soil carbon flux emissions/storage are calculated from four land use categories: cropland remaining cropland, land converted to cropland, grassland remaining grassland, and land converted to grassland. This section requires the inputs of mineral and organic soils on agricultural soils to determine the amount of carbon emitted per million metric tons (MMT). There is no module emissions equation for agricultural soil carbon flux because input for the values are in MMT CO_2e.

Wetlands:

According to the National Oceanic and Atmospheric Administration (NOAA) Office of Coastal Management, approximately 31% of Florida is wetlands. In coastal areas, wetland habitats are key ecosystems that provide an array of ecosystem services such as sediment retention, water purification, wildlife habitat, storm protection, and carbon sequestration, among others. Emissions and sequestration from coastal wetlands were included in the LULUCF calculations as an addition to the EPA's SIT values to add precision to the calculation of emissions and removals. Coastal wetlands emissions and sequestration calculations followed recommendations outlined in the 2013 IPCC Wetlands Supplement.

Coastal Change Analysis Program (C-CAP) land cover and land cover change data were provided by the NOAA. Land cover and land cover change data were provided as mineral and organic soils in coastal wetland areas in 5-year intervals from 1996 to 2016.

Wetland emissions and removals were calculated using both wetland and non-wetland land cover categories. The wetland land cover categories included, Palustrine Scrub/Shrub Wetland, Palustrine Emergent Wetland, Estuarine Forested Wetland, Estuarine Scrub/Shrub

Wetland, Estuarine Emergent Wetland, and Water. The non-wetland land cover categories included Settlement, Cultivated, Grassland, and Forest. The category Other was included to capture non-wetland land cover types not associated with the other non-wetland land cover categories.

The acreage of mineral and organic soils converted between each combination of land cover category were calculated between the 5-year intervals. The total land cover change was evenly divided among the five years of that time frame to provide annual land cover change data for each soil type. The land cover change for the four 5-year intervals (1996-2001, 2001-2006, 2006-2011, 2011-2016) were averaged and divided over a 5-year period to create land cover change values for each soil type for the years 1990 to 1995, and 2017 to 2018.

The changes between land cover categories were calculated between wetland types under three main classifications: Wetlands remaining Wetlands, Converted from Wetlands, and Conversions to Wetlands. A fourth minor classification, Wetlands and Water, included calculations of instances of Wetlands remaining Wetlands land cover categories, but specified the categories where water was converted to (caused by subsidence or erosion) or from (caused by the restoration or creation of) wetlands land cover categories. Annual acreage totals by land cover category for each soil type were derived from the provided C-CAP data from the years 1996, 2001, 2006, 2011, and 2016 combined with the annual land cover acreage change.

The equations used to externally calculate CO_2 and CH_4 emissions from wetlands are as follows:

- Wetlands Remaining Wetlands
  - ***Soil Carbon Accumulation (MMT CO_2e)*** = [Sum of Soils Acreage / Hectare conversion (2.471)] x Soil Carbon Removal (tons C $ha^{-1}yr^{-1}$) x ratio of CO_2 to C (3.67)
  - Methane Emissions (MMT CO_2e)
    - ***Methane Emissions for each category (T CH_4y^{-1})*** = *((Sum of Soils Acreage / Hectare conversion (2.471))/ kilograms to Metric Tons (1,000)) x kilograms of Methane emitted (kg of CH_4 $ha^{-1}yr^{-1}$)*
    - then, ***Methane Emissions to CO_2e*** = *[Sum of Categories (ΣT CH_4y^{-1})/ Millions Metric Tons conversion (1,000,000)] x GWP (25)*
- Conversions from Wetlands (Drainage)
  - ***Soil Carbon Emission (MMT CO_2e)*** *= [Sum of Soils Acreage / Hectare conversion (2.471)] x Soil Carbon Emitted (tons C $ha^{-1}yr^{-1}$) x ratio of CO_2 to C (3.67)*
- Conversions to Wetlands (Restoration)
  - ***Soil Carbon Accumulation (MMT CO_2e)*** *= [Sum of Soils Acreage / Hectare conversion (2.471)] x Soil Carbon Removal (tons C $ha^{-1}yr^{-1}$) x ratio of CO_2 to C (3.67)*
  - Methane Emissions (MMT CO_2e)
    - ***Methane Emissions for each category (T CH_4y^{-1})*** = *((Sum of Soils Acreage / Hectare conversion (2.471))/ kilograms to Metric Tons (1,000)) x kilograms of Methane emitted (kg of CH_4 $ha^{-1}yr^{-1}$)*
    - Then, ***Methane Emissions to CO_2e*** = *[Sum of Categories (ΣT CH_4y^{-1})/ Millions Metric Tons conversion (1,000,000)] x GWP (25)*

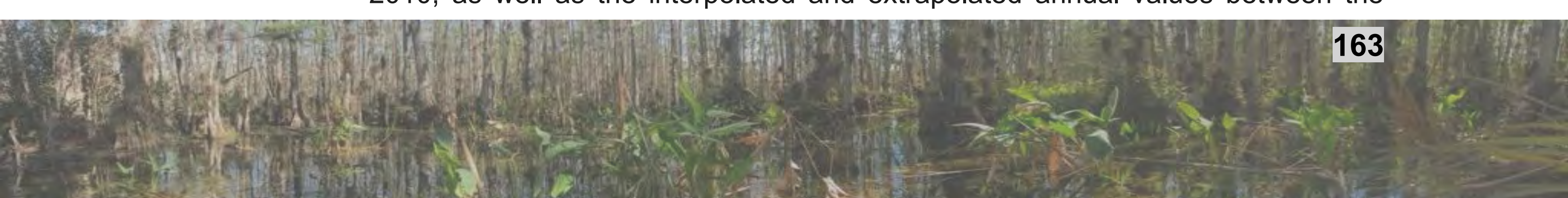
- Wetlands and Water
  - <u>Wetlands to Water</u>
    - ***Soil Carbon Emission (MMT CO_2e)*** *= [Sum of Soils Acreage / Hectare conversion (2.471)] x Soil Carbon Emitted (tons C $ha^{-1}yr^{-1}$) x ratio of CO_2 to C (3.67)*
  - <u>Wetlands from Water</u>
    - ***Soil Carbon Accumulation (MMT CO_2e)*** *= [Sum of Soils Acreage / Hectare conversion (2.471)] x Soil Carbon Removal (tons C $ha^{-1}yr^{-1}$) x ratio of CO_2 to C (3.67)*
  - <u>Methane Emissions (MMT CO_2e)</u>
    - ***Methane Emissions for each category (T CH_4y^{-1})*** *= [((Sum of Soils Acreage / Hectare conversion (2.471))/ kilograms to Metric Tons (1,000)) x kilograms of Methane emitted (kg of CH_4 $ha^{-1}yr^{-1}$))]/ Millions Metric tons conversion (1,000,000) x GWP (25)*
- **Total Soil Carbon Accumulation (MMT CO_2e) =**
  - Wetlands Remaining Wetlands *(+ Soil Carbon Absorption – Methane Emissions)*
  - Conversions from Wetlands *(- Soil Carbon Emissions)*
  - Conversions to Wetlands *(+ Soil Carbon Absorption – Methane Emissions)*
  - Wetlands and Water =
    - Wetlands to Water *(- Soil Carbon Emissions)*
    - Wetlands from Water *(+ Soil Carbon Absorption – Methane Emissions)*

Soil Carbon Removal (tons C $ha^{-1}yr^{-1}$) of *Wetlands remaining Wetlands, Converted from Wetlands, and Conversions to Wetlands* included the biomass for mangrove trees exclusively. Methane from *Wetlands remaining Wetlands* was calculated from two categories remaining the same: *Palustrine Scrub/Shrub Wetland and Palustrine Emergent Wetland*. Methane from *Conversions to Wetlands* included total conversions to non-wetland categories, *Settlement, Cultivated, Grassland, Forest, and Other.* Methane from *Wetlands and Water*: *Wetlands from Water* classification combines total acreage from categories total conversions of *Palustrine Scrub/Shrub Wetland and* total conversions of *Palustrine Emergent Wetland.*

<u>Data Sources</u>

Sources of data extraction used for the verification of inputted numbers were taken from the following locations:

- *Forest Carbon Flux*:
  - *Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2018. Appendix 1. National Estimates for Individual States, 1990-2018*.
- *Urban Trees:*
  - Urban Trees: Default data for the Total Urban Area (km2) and Percent of Urban Area with Tree Cover were based on values from the following sources: Nowak et al. 2005, Nowak and Greenfield 2012, and the U.S. Census. The SIT Tool included default data from the listed sources which included the years 1990, 2000, and 2010, as well as the interpolated and extrapolated annual values between the



decennial data from 1991 to 2018. The default data for the carbon sequestration factor was provided by Nowak et al. 2013.

- *Non-CO_2 Emissions from Forest Fires/Settlement Soils:*
  - Data required for the N_2O emissions for Settlement Soils was retrieved from *The AAPFCO (2017) Commercial Fertilizers 2014 Report*.
  - Forest fires data was collected from the Florida Department of Consumer Services Florida Forest Services. The data collected included wildfires from 1990 to 2018 and prescribed from 1993 to 2018. Linear Regression was used to determine the prescribed fire values from 1990 to 1992.
- *Landfilled Yard Trimmings, and Food Scraps:*
  - Default data for Landfilled Yard Trimmings, and Food Scraps were based on estimates drawn from the use of national and Florida specific landfilled, yard trimmings, and food scraps data. National estimates were generated from *The Environmental Protection Agency's (EPA) Advancing Sustainable Materials Management: Facts and Figures Reports* along with the *Florida Department of Environmental Protection's (FDEP) Annual Solid Waste Reports*.
- *Agricultural Soil Carbon Flux:*
  - Default data pertaining to carbon emissions/storage (CO_2) flux for Agricultural Soil Carbon Flux were based on national estimates that were aggregated to the state level. National Estimates were utilized from *The Environmental Protection Agency's (EPA) Inventory of Greenhouse Gas Emissions and Sinks: 1990-2018*.
  - Environmental Protection Agency (EPA) Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2019. (2021, April 14).
- *Wetlands*:
  - Land cover and land cover change data were provided by the National Oceanic and Atmospheric Administration (NOAA) Office of Coastal Management. Land cover and land cover change data were provided as mineral and organic soils in coastal wetland areas in 5-year intervals, for years 1996, 2001, 2006, 2011, and 2016.

Results

The LULUCF sector resulted in net carbon storage. However, the sector's activities were nearly evenly split between emissions and sinks. The LULUCF activity with the largest average emission was agricultural soils with an annual average of 20.22 MMT CO_2e across the entire time series of 1990-2018. The annual emissions from the agricultural soils activity provided a counterbalance for the carbon storage of the sector's largest repository, the forest land remaining forest land activity. Forest land remaining forest land annually averaged a net removal of 31.57 MMT CO_2e between 1990 and 2018. Figure H-1 shows the annual average emissions for all the LULUCF sector activities.

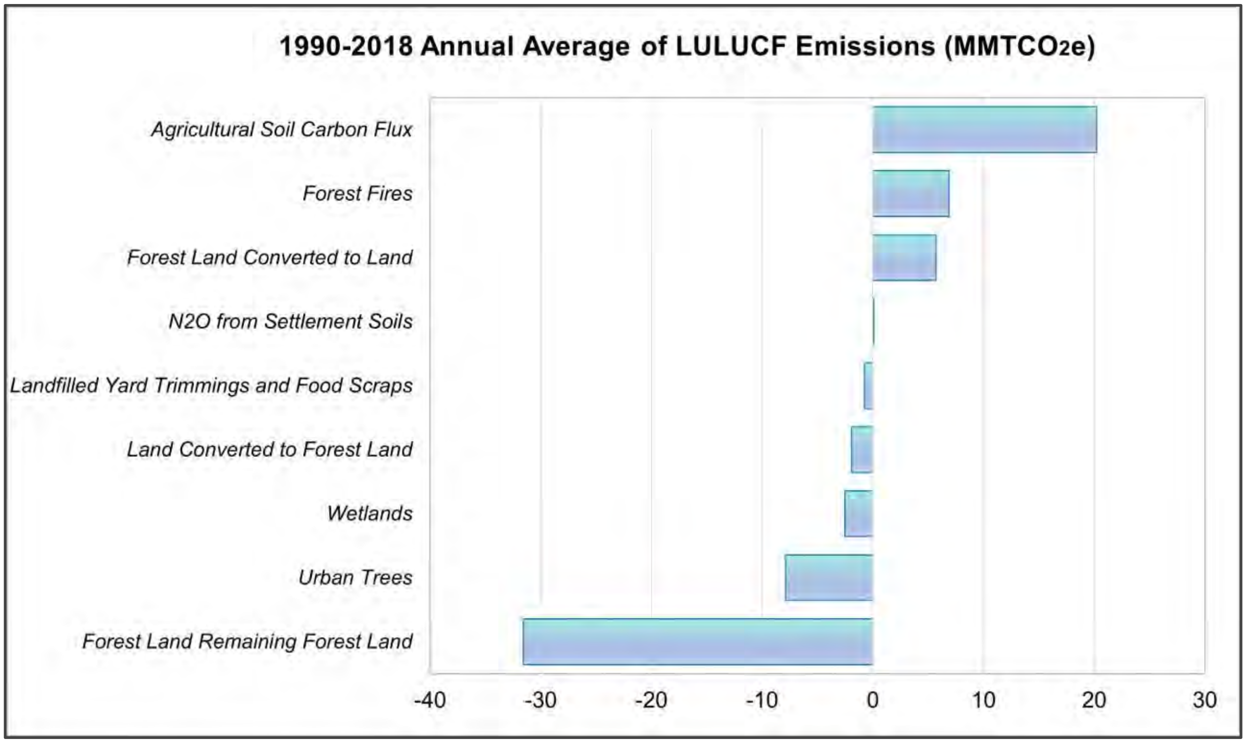


Figure H-1: Annual average of 1990-2018 emissions from activities within the LULUCF sector.

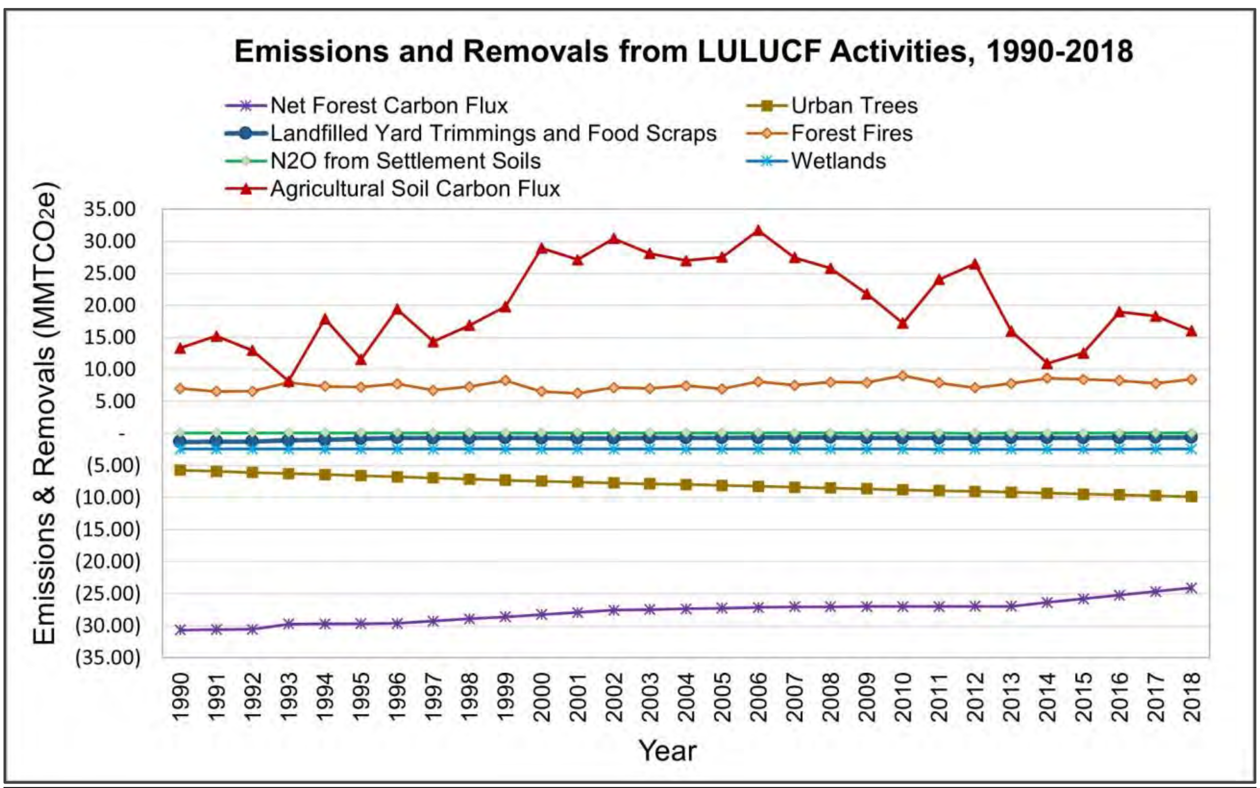


Figure H-2: LULUCF - Carbon E/R from forest management and land-use change activities.

Figure H-2 shows the annual carbon emissions and removals from forest management and land-use change activities from 1990 to 2018. The figure shows that there are significant differences in the amount of emissions and storage for each LULUCF activity. Net forest carbon flux (forest land remaining forest land) sequestered the greatest amount of carbon in 2018, storing approximately 24.1 MMT CO_2e. Other activities that sequestered carbon in 2018 included urban trees (9.8 MMT CO_2e), wetlands (2.42 MMT CO_2e), land converted to forest land (1.82 MMT CO_2e), and landfilled yard trimmings and food scraps (<1.0 MMT CO_2e). On the other hand, the agricultural soil carbon flux activity emitted the greatest amount of carbon in the LULUCF sector in 2018 with 16.1 MMT CO_2e. Other sectors that contributed to the LULUCF sector emissions included forest fires (8.45 MMTCO_2e), forest land converted to land (6.0 MMT CO_2e), and N_2O from settlement soil (<1.0 MMT CO_2e).

There was uniformity in most of the values for the LULUCF activities. The activity with the most consistent emissions in the LULUCF sector was the wetlands activity which remained at 2.4 MMT CO_2e between 1990 and 2018. Four other LULUCF activities had a range of emissions/storage below 1.0 MMT CO_2e during the same time period, including carbon emissions from N_2O from settlement soils (between 0.06 and 1.1 MMT CO_2e), the carbon sequestration of land converted to forest land (between 1.82 and 2.00 MMT CO_2e), the carbon sequestration of landfilled yard trimmings and food scraps (between 0.59 and 1.30 MMT CO_2e), and the carbon emissions of forest land converted to land (between 5.29 and 6.00 MMT CO_2e). Three other LULUCF activities had a variation of values that were less than 10.0 MMT CO_2e, including the carbon emissions of forest fires (between 6.30 and 9.03 MMT CO_2e), the carbon sequestration from urban trees (between 5.73 and 9.84 MMT CO_2e), and the carbon sequestration from forest land remaining forest land (between 24.09 and 30.65 MMT CO_2e). Note that no LULUCF activities alternated between emissions and sequestration between 1990 and 2018.

Conversely, the agricultural soils varied widely from year to year as shown in figure H-2. The carbon emissions from this LULUCF activity ranged between 8.13 and 31.74 MMT CO_2e between 1990 and 2018.

Conversion of land use in LULUCF resulted in net emissions for the sector. Land converted to forest land annually averaged 1.91 MMT CO_2e carbon removal while forest land converted to land resulted in 5.70 MMT CO_2e carbon emissions. Converting land back to forest in Florida during the 1990 to 2018 time period did not offset the emissions due to converting forest land to land. The disparity between the two was approximately 3.8 MMT CO_2e annually. Figure H-3 specifically lays out the carbon emissions and sequestration values from forest carbon flux in MMT CO_2e, depicting slight variations in the tabulated CO_2 flux rates. Within the section that analyzes forest carbon flux, the Forest Land Remaining Forest Land portion removed 28.3 MMT CO_2e in 2018. Similarly, Land Converted to Forest Land removed 1.8 MMT CO_2e based on carbon sequestration. On the other hand, Forest Land Converted to Land released 6.0 MMT CO_2e.

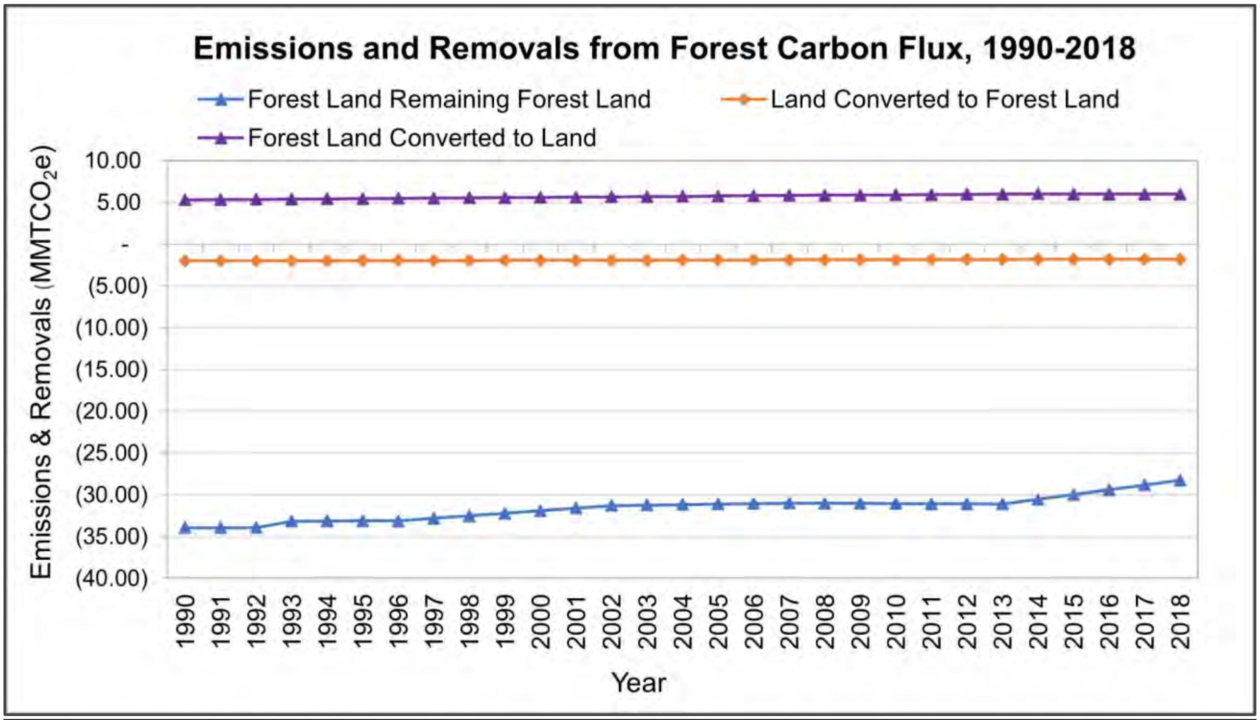


Figure H-3: LULUCF - Carbon E/R from changes in forest and land cover.

Figure H-4 presents the net removal of GHG emissions in carbon dioxide equivalent by Florida's wetlands from 1990-2018. Over the years, emission values slightly fluctuated by a mere 0.001 or 0.01 MMT CO_2e. In 2005 and 2018, net removals equated to 2.4 MMT CO_2e both years, being some of the lowest points across the twenty-eight-year time series. The highest valued removal of emissions by wetlands occurred in 2011 with a total of 2.5 MMT CO_2e.

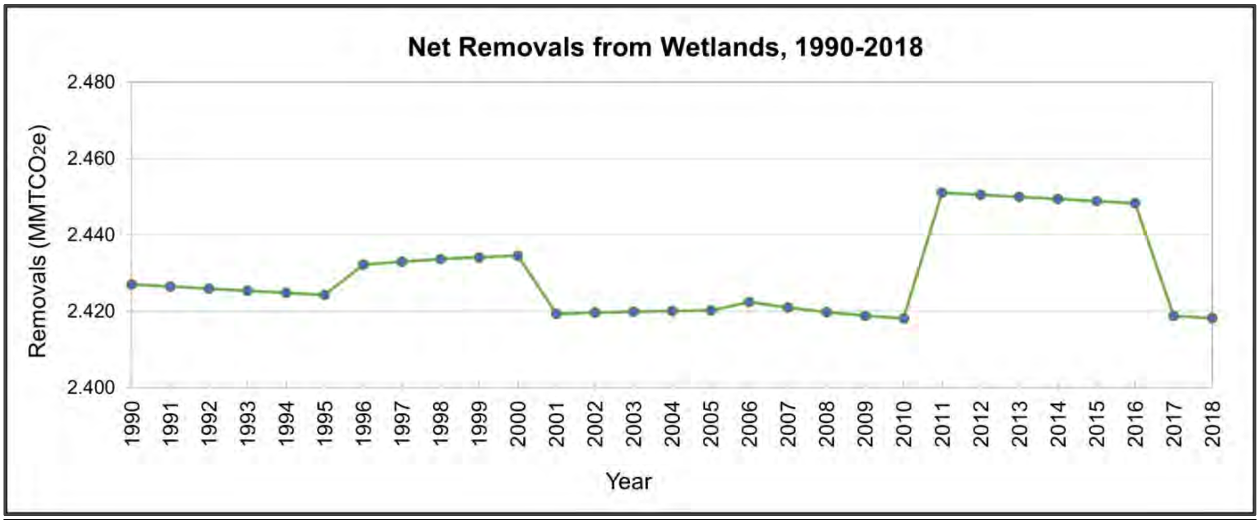


Figure H-4: LULUCF - Net removal of greenhouse gases by wetlands (MMT CO_2e).

Figure H-5 shows the non-CO_2 emissions from Florida's forest fires, measured in MMT CO_2e. The figure has individual historical trends for both CH_4 and N_2O emissions, as well as the combined total of both. Total combined emissions were estimated at 7.0 MMT CO_2e in 2005, and 8.5 MMT CO_2e in 2018. The year where forest fires emitted the most was in 2010 with a total of 9.0 MMT CO_2e. As the figure shows, N_2O emissions were not nearly as high as CH_4 emissions across the entire time series.

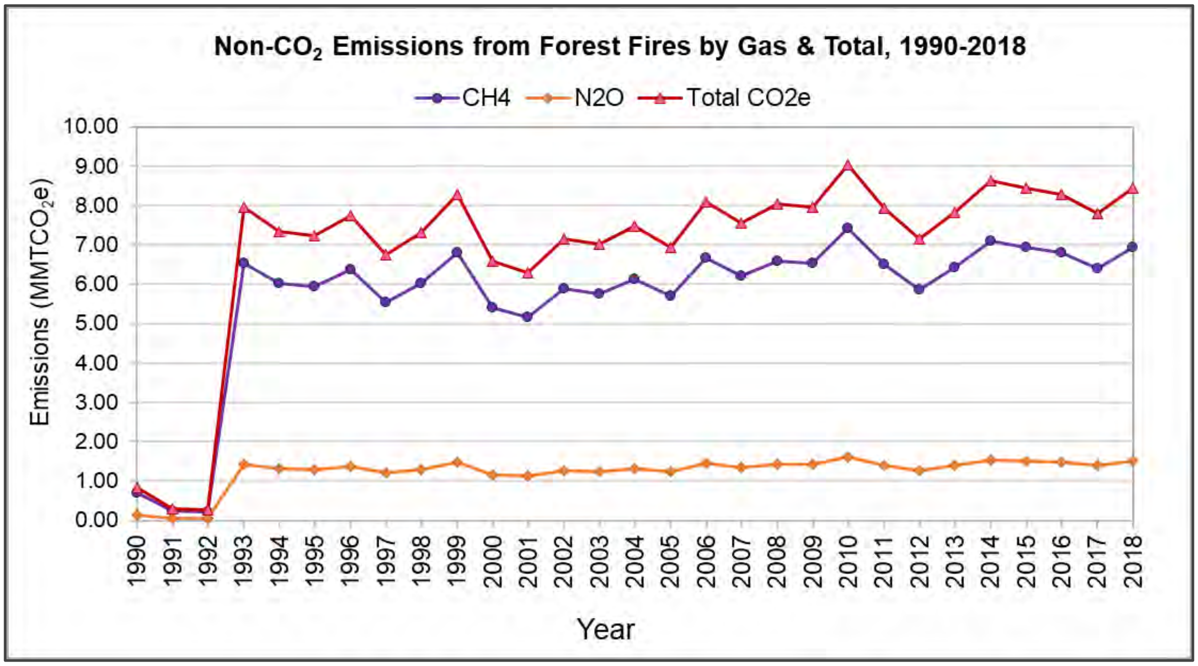


Figure H-5: LULUCF - CH_4 and N_2O emissions from forest fires, both individual and cumulative total.

Key Uncertainties

There's uncertainty with the combustion efficiency and EFs. The combustion efficiency and EF are average values derived by comparing Environmental Protection Agency (EPA) provided data to Florida Department of Consumer Services Florida Forest Services (FFS) forest fire by forest type. The total value of all the forest fires by forest types was much smaller than the reported incidents since spatial data is not collected on each authorized prescribed fire or most wildfires unless they are major events. The assumption was made that if the values of the forest fire by forest type were extrapolated to a total equivalent to the total reported incidents, the increase would be uniform across all forest types. There's also uncertainty on the number of acres burned. Prescribed wildfires are recorded when they are reported to the Florida Forest Service, and may not reflect every prescribed burn or wildfire.

Areas of land cover change were removed between categories that began as wetlands in 1996, changed, and reverted to wetlands by 2016. There is uncertainty with applied land cover change data for individual years. Land cover data were uniformly divided over each year within a 5-year interval. Land cover fluctuates throughout the year, for each year, and there is uncertainty about the amount of annual land cover change. There is also uncertainty for the years outside the 5-year intervals. Land cover data is derived from satellite imagery. There is uncertainty around the imagery resolution and accuracy of the identified vegetation per pixel.

Key uncertainties for the LULUCF module were largely centered around the accurate calculation of CO_2 flux estimates for Florida's forestry section when portions of data were not available for confirmation. According to *EPA's Inventory of U.S. Greenhouse Gas Emissions and*

Sinks 1990-2019 manual, a quantitative analysis placed bounds on verifiable CO_2 flux estimates using a sample-based and model-based approach, in which data was organized within a Lower Bound and Upper Bound Range, along with the use of the Monte Carlo Analysis. All five sections within the LULUCF Module utilized a Lower Bound, an Upper Bound Range, and a Monte Carlo Analysis for estimating values that were unable to identify a verifiable source. Within both the Lower and Upper Bound Ranges, data is promulgated based on its estimation with other verifiable data, and then converted to its appropriate MMT CO_2e emission rate. The Monte Carlo Analysis was useful in the projection of data points based on its possible results within both the Lower Bound and Upper Bound Ranges.

One section that presented difficulties in estimating rates was the calculation of fertilizers applied to soils. When calculating N_2O Emissions from N Additions to Forest Soils, a key uncertainty was the creation of a specific range for land receiving fertilizers per year. According to *EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2019* manual, fertilization rates were assigned a default level of uncertainty at +/50% and Areas Receiving Fertilizers were assigned a +/20% default level.

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FDEP. Solid Waste Management Annual Reports: Total Tons of Special Waste Materials Collected and Recycled in Florida By Descending Population Rank. Florida Department of Environmental Protection. https://floridadep.gov/waste/waste-reduction/content/recycling

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WASTE SECTOR

Appendix I

Solid Waste

Overview

The Solid Waste module calculates methane (CH_4) emissions associated with municipal solid waste (MSW). The module also estimates carbon dioxide (CO_2) and nitrous oxide (N_2O) emissions from the combustion of MSW. Organic waste in landfills decomposes aerobically, in the presence of oxygen, as well as anaerobically Non-methanogenic bacteria decomposes MSW anaerobically, converting organic matter to cellulose, amino acids, sugars, and fats. Methanogenic bacteria anaerobically decompose organic matter producing CH_4 and CO_2. The by-products of this process are broken down into gases and short-chain organic compounds such as H_2, CO_2, CH_3COOH, HCOOH, and CH_3OH. These compounds support the growth of methanogenic bacteria further contributing to this cycle. The fermented products are metabolized into stabilized organic materials and biogas. The resulting biogas consists of approximately 50% CO_2 and 50% CH_4 by volume.

In some cases, landfills burn the recovered landfill gas, converting the CH_4 portion of the gas to CO_2. The landfill gas can also be used for electricity production or for other energy uses. This process is also known as landfill-gas-to-energy projects (LFGTE). This module is composed of six sections:

- State MSW Combusted
- CO_2 from Plastics
- CO_2 from Synthetic Rubber
- CO_2 from Synthetic Fiber
- N_2O from MSW Combustion
- CH_4 from MSW Combustion

The module calculates the CH_4, CO_2, and N_2O emissions from specified byproducts found during combustion and landfilling. The completed data for CH_4, CO_2, and N_2O are quantified as MMT CO_2e. Common examples of inventoried products include clothes, plastic containers/water bottles, furniture, textiles, and tires, among others. Also required for the accurate portrayal of Florida's emissions was annual state population, annual disposal tons of landfill, as well as annual tons combusted and proportion of discarded waste (plastics, synthetic rubber, and synthetic fiber).

Methodology

The approach used to estimate emissions in the various categories of solid waste is described below.

CO_2 from Combustion of Plastics:

This section examines the amount of plastics discarded in Florida. The calculation for this section required the proportion of discards for a subcomponent of plastic, multiplied by that specific year's state MSW combusted (short tons), the plastics carbon content percentage, and plastics fraction oxidized. The values are then converted to MT Ce and MT CO_2e to produce CO_2 rates from plastic combustion.

The subcomponents of plastic include PET, HDPE, PVC, LDPE, PP, PS, and others. Default data is available for all the years but couldn't be confirmed. The data that was found and confirmed during the research is available from 1999 to 2018. For the years 1990-1998, default data is used to get the summary as there is no data available for these years online.

For the years 1999- 2018 the calculation of plastics is based on following formula:

- ***Tons of plastic discarded*** *= Tons of total plastic discarded - tones of plastic recycled*
- ***Percentage of plastic discarded*** *= Total plastic discarded (tons)/ Total amount of MSW landfilled (tons) X 100*

Due to the lack of state-level data for the specific subcomponents of plastic, the type of plastics used for Florida includes Florida Department of Environmental Protection's (FDEP) 'total tons of plastic bottles' as well as 'total tons of other plastic produced'. These two categories were added together, and the amount of plastic FDEP reported as 'recycled' was subtracted to get the total plastic discarded.

CO_2 from Combustion of Synthetic Rubber:

This section requires the proportion of discards of synthetic rubber products, multiplied by the state MSW combusted (short tons), the rubber carbon content percentage, and rubber fraction oxidized to calculate both the MT Ce and MT CO_2e rates. For the calculation of synthetic rubber in MSW, the module requires the proportion of discards categorized as durables and nondurables, clothing/footwear, other non-durables, and containers and packaging.

Data was not publicly available for all these categories, therefore the SIT default data was used for 1990-1995. For 1996-2018, the annual values of 'tires' were obtained from FDEP and used as 'durables' to compute the results for all synthetic rubber emissions.

For the years 1996-2018, the values of tires discarded were calculated as follows:

- ***Tons of tires discarded*** *= Tons of total tires discarded - tons of tires recycled*
- ***Percentage of tires discarded*** *= Total tons of tires discarded/ Total amount of MSW landfilled X 100*

CO_2 from Combustion of Synthetic Fiber:

This section of the module required the proportion of discards per year of synthetic fiber, multiplied by the state MSW combusted (short tons), the synthetic fiber carbon content percentage, and synthetic fiber fraction oxidized to calculate both the MT Ce and MT CO_2e rates. Data on the individual components of total synthetic fiber were not available online. Synthetic fibers are a durable component of textiles, therefore the FDEP total of textiles discarded is used to assume total emissions from all synthetic fibers. The data on textile production is available for the years 1999-2018. For the years 1990-1998, SIT default values have been used as there is no other data publicly available.

- ***Tons of textile discarded*** = *Tons of total textile discarded - tons of textile recycled*
- ***Percentage of textile discarded*** = *Total tons of tires discarded/ Total amount of MSW landfilled X 100*

The module's emissions equation for all three types of CO_2 combustion is as follows:

CO_2 Emissions (MT CO_2e) = *Material as Proportion of all Discards (%) × Total MSW Combusted (short tons) × Carbon Content (%) × Fraction Oxidized (%) × 44/12 (CO_2 to C ratio) × 0.9072 (short tons to metric tons conversion)*

N_2O from MSW Combustion:

The calculation of N_2O from MSW Combustion required the State MSW Combusted (short tons), multiplied by the Emission Factor (tons N_2O/ton MSW), by the N_2O GWP, Metric Tons / Short Ton, and C/CO_2, to receive its Emissions (MT Ce) and Emissions (MT CO_2e) rates. The waste combustion data is found for the year 1990-2018 from the FDEP. The module's emissions equation is as follows:

N_2O Emissions (MT CO_2e) = *MSW Combusted (short tons) × 0.00005 (emission factor in tons N_2O/ton MSW) × 298 (N_2O GWP) × 0.9072 (short tons to metric tons conversion)*

CH_4 from MSW Combustion:

The calculation of CH_4 from MSW Combustion required the State MSW Combusted (short tons) multiplied by its Emission Factor (tons CH_4/ton MSW), CH_4 GWP, Metric Tons / Short Ton, and its C/CO_2 to receive its emissions (MT Ce) and emissions rates (MT CO_2e). The waste combustion data is collected for the years 1990-2018 from FDEP. The module's emissions equation is as follows:

CH_4 Emissions (MT CO_2e) = *MSW Combusted (short tons) × 0.00002 (emission factor in tons CH_4/ton MSW) × 25 (CH_4 GWP) × 0.9072 (short tons to metric tons conversion)*

Landfilled Solid Waste:

The module's CH_4 emissions equation is adjusted by subtracting the amount of methane flared or used to produce energy in Landfill-Gas-To-Energy (LFGTE) plants, subtracted from the total amount of methane generated. This is done because flaring is not counted as anthropogenic activity and using landfill gas for energy reduces the final amount of methane emissions from the landfill.

The module's CH_4 emissions equation is as follows:

Preliminary Net CH_4 Emissions = *Total CH_4 Generated – CH_4 Flared or Recovered for Energy – CH_4 Oxidized in Landfill*

Data Sources

- The majority of data gathered in this module is collected from the Florida Department of Environmental Protection's (FDEP) website and the units for the numbers are in short tons.
    - Data on plastic bottles and other plastics, used to represent all *plastics,* for the years 1999-2018 can be accessed through the FDEP's Recycling website.
    - Tire data, used to represent *synthetic rubber,* for the years 1996-2018 can be accessed through the FDEP's Recycling website.
    - Textile data, used to represent *synthetic fibers,* for the years 1999-2018 can be accessed through the FDEP's Recycling website.
    - *State MSW Combustion* data for the years 1990-2018 can be accessed through the FDEP's Recycling website.

Results

Figure I-1 shows the GHG emissions resulting from both landfills and waste combustion by gas type. Cumulative GHG emissions from landfills and waste combustion for the years 2005 and 2018 are approximately 9.99 and 14.57 MMT CO_2e, respectively. For the same years, CH_4, N_2O, and CO_2 emitted from landfills and waste combustion individually resulted in 8.89, 0.05, 1.05 MMT CO_2e (2005) and 11.87, 0.07, 2.63 MMT CO_2e (2018). CH_4 emissions from the landfills (municipal waste and industrial waste) from 2005 and 2018 are 8.89 and 11.87 MMT CO_2e, respectively. Results show that CH_4 emissions have increased steadily over the years due to the rise in the amount of solid waste generated.

Figure I-2 presents GHG emissions from waste combustion, by both gas and activity type (MT CO_2e). The majority of emissions are CO_2, which result from the burning of plastics and synthetic fiber. In 2018, plastics contributed 2.14 MMT CO_2e while synthetic fibers contributed 0.42 MMT CO_2e.

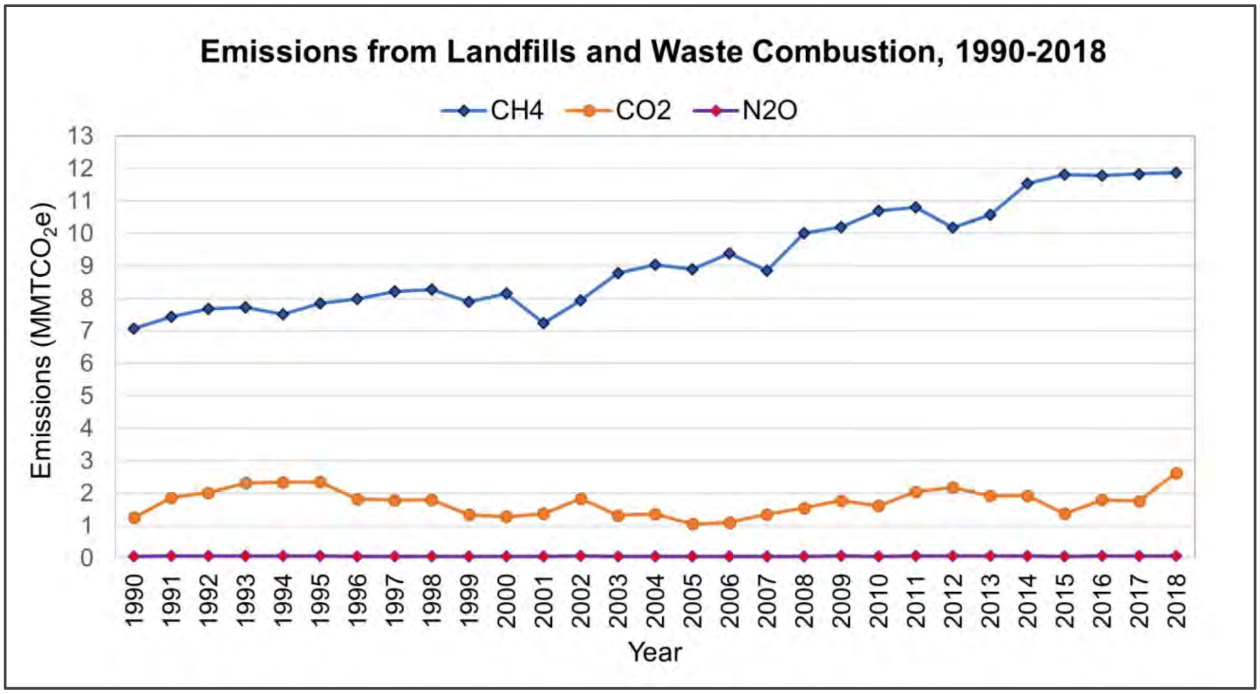

Figure I-1: GHG emissions from landfills and waste combustion, by gas type (MMT CO_2e). Note that N_2O values are not equal to zero, but range between 0.045 and 0.073.

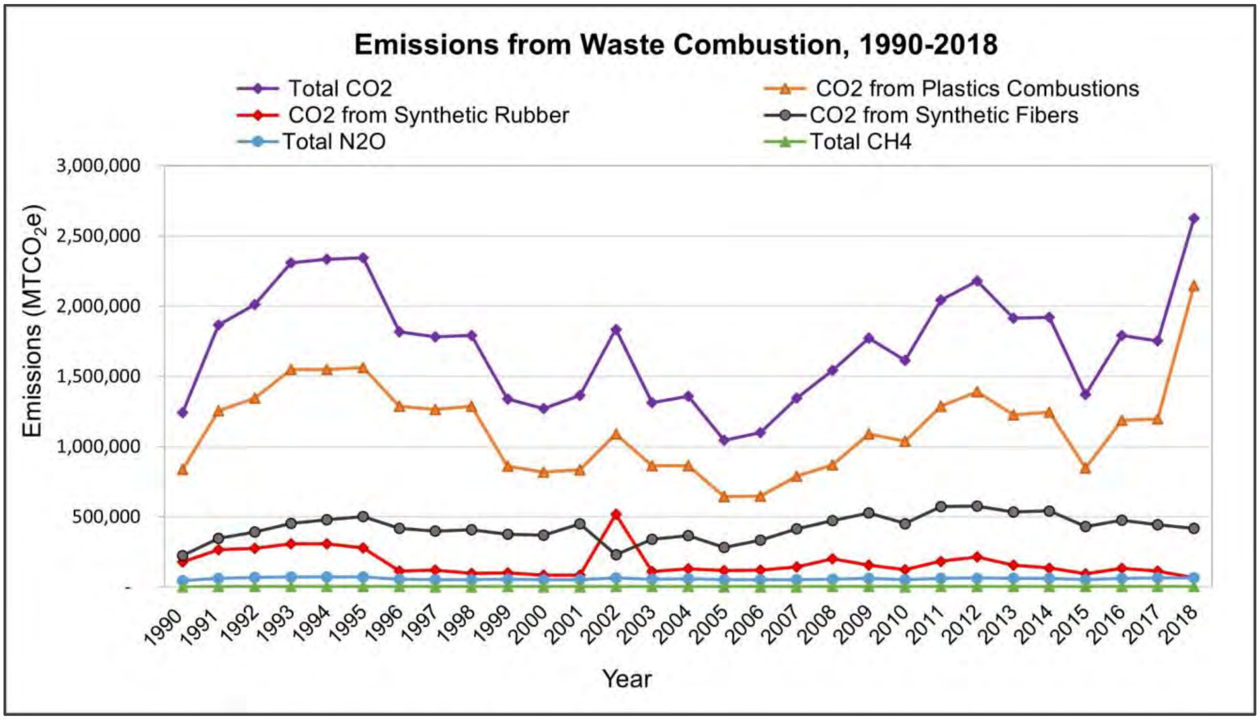

Figure I-2: GHG emissions from waste combustion, by gas and activity type (MT CO_2e).

Key Uncertainties

Complete discarded values for plastic categories, synthetic rubber totals, and synthetic fiber totals could not be obtained for Florida. As a substitute, total percent of plastic discarded has been used instead of different categories of plastic, values for tires have been used to represent total rubber discard percentage, and textiles values have been used to represent the percent of total fiber discarded. Therefore, plastic and synthetic rubber emissions are considered underestimates, and synthetic fiber emissions are considered overestimates.

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Appendix J

Wastewater

Overview

The Wastewater module calculates methane (CH_4) and nitrous oxide (N_2O) emissions associated with the treatment of municipal and industrial wastewater. Disposal and treatment of industrial and municipal wastewater creates CH_4 emissions resulting from the chemical treatment of organic material in the absence of oxygen (in an anaerobic environment). CH_4 is also produced from the degradation of untreated wastewater in the absence of oxygen. Nitrification and denitrification processes emit N_2O from both domestic and industrial wastewater containing nitrogen-rich organic matter. Nitrification is the process that converts ammonia to nitrate aerobically (in the presence of oxygen). While denitrification occurs anaerobically, converting nitrate to N_2O.

Human sewage and wastewater contain substances that produce N_2O emissions. Therefore, wastewater can be treated by using both aerobic and/or anaerobic technologies. This module considers municipal and industrial categories when calculating the GHG emissions from wastewater (Wastewater - EPA, 2017). Industrial wastewater emissions refer to the emissions associated with the processing of fruits and vegetables, red meat, poultry and pulp and paper. Under the Municipal wastewater module different sections refer to CH_4 emissions, direct emissions of N_2O, and N_2O emission from biosolids.

Methodology

CH_4 from Municipal Wastewater Treatment:

Municipal wastewater treatment emissions were calculated by using state population numbers through US census data, biological oxygen demand production (kg/day) and the EF. The module's emissions equation is as follows:

> ***CH_4 Emissions (MMT CO_2e)*** *= State Population × BOD_5 Production (kg/day) × 365 days/year × 0.001 (metric ton/kg) × Fraction Treated Anaerobically × Emission Factor (Gg CH_4/Gg BOD_5) × 10^{-6} (MMT/metric ton) × 25 (GWP)*

Direct N_2O from Municipal Wastewater Treatment:

This section was calculated by using state population numbers, fraction of population not on septic, and emissions factor (g N_2O/person/year). The module's emissions equation is as follows:

> ***Direct N_2O Emissions (MMT CO_2e)*** *= State Population × Fraction of Population not on Septic (%) × Emission Factor (g N_2O/person/year) × 10^{-6} (metric ton/g) × 10^{-6} (MMT/metric ton) × 298 (GWP)*

N_2O from Biosolids Municipal Wastewater Treatment:

This was calculated by using state population, protein consumption (kg/person/year), fraction of nitrogen not consumed, percentage of biosolids used as fertilizers, emission factor (kg N_2O-N/kg sewage N produced). The module's emissions equation is as follows:

> ***N_2O Emissions (MMT CO_2e)*** *= [State Population × Protein Consumption (kg/person/year) × $FRAC_{NPR}$ (kg N/kg protein) × Fraction of Nitrogen not Consumed 0.001 (metric ton/kg) – Direct N Emissions (metric tons)] × [1 – Percentage of Biosolids used as Fertilizer (%)] × Emission Factor (kg N_2O-N/kg sewage N produced) × 44/28 (kg N_2O /kg N) × 10^{-6} (MMT/metric ton) × 298 (GWP) + Direct N_2O Emissions*

CH_4 from Industrial Wastewater of Meat:

For the industrial processing of red meat, SIT default values were used for 1990-2018. These values were confirmed by the United States Department of Agriculture (USDA).

The module's emissions equation is as follows:

> ***CH_4 Emissions (MMT CO_2e)*** *= Production Processed (MT) × Wastewater Produced (m^3/metric ton) × 1,000 (L/m^3) × Organic Matter Content (g COD/L) × Emission Factor (g CH_4/g COD) × Percent Treated Anaerobically (%) × 10^{-12} (MMT/g) × 25 (GWP)*

CH_4 from Industrial Wastewater of Poultry:

State values for the production processed aggregate of poultry are not available, nor were default values provided by the SIT. As per calculation methods established by the EPA, wastewater emissions from poultry are based on the production processing of all poultry components, or represented by the total liveweight killed (LWK). For the national inventory poultry processing value, EPA used a combination of data on young chickens, mature chickens, and turkeys. Due to the lack of state-level data for these specific subcomponents of poultry, values on young chickens slaughtered (in pounds) were doubled and used to draw an estimated total for total poultry processing. These values were obtained from the USDA, for years 1990-

2003 and 2008-2018. For the missing values of 2004-2007, linear interpolation was used to develop estimates.

The module's emissions equation is as follows:

> ***CH_4 Emissions (MMT CO_2e)*** *= Production Processed (MT) × Wastewater Produced (m^3/metric ton) × 1,000 (L/m^3) × Organic Matter Content (g COD/L) × Emission Factor (g CH_4/g COD) × Percent Treated Anaerobically (%) × 10^{-12} (MMT/g) × 25 (GWP)*

CH_4 from Industrial Wastewater of Fruits & Vegetables:

State values for the production processed aggregate of fruits and vegetables are not available, nor were default values provided by the SIT. Therefore, annual totals (in metric tons) used to calculate emissions are a combination of Florida's: citrus totals, non-citrus totals, and principal fresh market vegetables.

Florida's citrus totals include values for processed production of grapefruit, oranges, tangerines, and tangelos for all years, as well as mandarins, temples, lemons, limes, and K-Early citrus fruit for some years. This data was acquired through USDA's annual Citrus Fruits Summary reports (for years 1990-2007), as well as their NASS Quick Stats tool (for 2008-2018).

Non-citrus totals only consider Florida's utilized production of blueberries processed, as other non-citrus fruits do not have their production values reported. The data on blueberries was also sourced from the USDA's annual reports, specifically their Noncitrus Fruits and Nuts summaries. Values here were only available for 1992-2001, 2010, and 2015. Linear interpolations and extrapolations were conducted to estimate missing totals for all other years (1990-1991, 2002-2009, 2011-2014, 2016-2018).

Vegetable totals specifically for processed production could not be obtained, therefore 'Principal Fresh Market Vegetable Utilized Production' for Florida was instead used. This data was acquired through USDA's annual Vegetables Summary reports (for years 1990-2008 and 2012-2018), as well as their NASS Quick Stats tool (for 2009-2011).

These values were converted from their reported units to metric tons, the unit required by SIT. All three categories were then summed annually for the SIT's required input of production processed in order to proceed with emission calculations. The module's emissions equation is as follows:

> ***CH_4 Emissions (MMT CO_2e)*** *= Production Processed (MT) × Wastewater Produced (m^3/metric ton) × 1,000 (L/m^3) × Organic Matter Content (g COD/L) × Emission Factor (g CH_4/g COD) × Percent Treated Anaerobically (%) × 10^{-12} (MMT/g) × 25 (GWP)*

CH_4 from Industrial Wastewater of Paper & Pulp:

- ➢ Data on Florida's production of processed paper and pulp could not be located, nor did the SIT provide default data. Because no Florida-specific values were found, this activity was not considered in total emissions estimates.

<u>*Data Sources*</u>

- ➢ *CH_4 from Industrial Wastewater of Meat:* Data of red meat production processed for 1990-2018 was sourced from the USDA's National Agricultural Statistics Service (NASS) Quick Stats tool.

- *CH_4 from Industrial Wastewater of Poultry:* Data related to and used for poultry production processed was sourced from the USDA's NASS Quick Stats tool. The data pulled was Florida's totals for young chickens slaughtered (live basis) in pounds. These values are available from 1990-2003 and 2008-2018. Interpolation by linear regression was done to estimate the values used for 2004-2007.
- *CH_4 from Industrial Wastewater of Fruits & Vegetables*: Data on Florida's production processed of fruits and vegetables was aggregated from USDA totals for:
    - Citrus fruit processed production
        - Values for the years 1990-2007 were obtained from annual Citrus Fruits Summary reports. Values for 2008-2018 were obtained from the NASS Quick Stats tool.
    - Non-citrus fruit processed production
        - Values for the years 1992-2001, 2010, and 2015 were obtained from annual NonCitrus Fruits and Nuts Summary reports. Values missing for 1990-1991, 2002-2009, 2011-2014, 2016-2018 were estimated by linear interpolations and extrapolations.
    - Principal fresh market vegetable utilized production
        - Values for the years 1990-2008 and 2012-2018 were obtained from annual Citrus Fruits Summary reports. Values for 2009-2011 were obtained from the NASS Quick Stats tool.

Results

Figure J-1 presents the overall cumulative total of emissions produced by wastewater in MMT CO_2e, from 1990-2018. Zooming into our baseline years of 2005 and 2018, CO_2e emission from wastewater totaled to 2.1 MMT and 2.4 MMT, respectively. Figure J-2 breaks down the total wastewater emissions by gas and sector. Wastewater emissions have had a steady increase for municipal CH_4 and municipal N_2O since 1990, with CH_4 emissions having a steeper incline. Industrial CH_4 emissions on the other hand remain relatively low and constant, with a minor decrease starting in 2004.

Figure J-2 presents CH_4 emissions from wastewater produced during processing of fruits and vegetables, red meat, and poultry for years 1990-2018. The emissions of CH_4 from meat processing are significantly low and consistent. Emissions from fruits and vegetables are the highest of all industrial wastewater categories, fluctuating heavily across the entire time series yet seeing a decline since 2008. The second highest-emitting category is poultry, with CH_4 emissions lowest in 2009 (about 0.02 MMT CO_2e) and highest in 1999 (almost 0.06 MMT CO_2e).

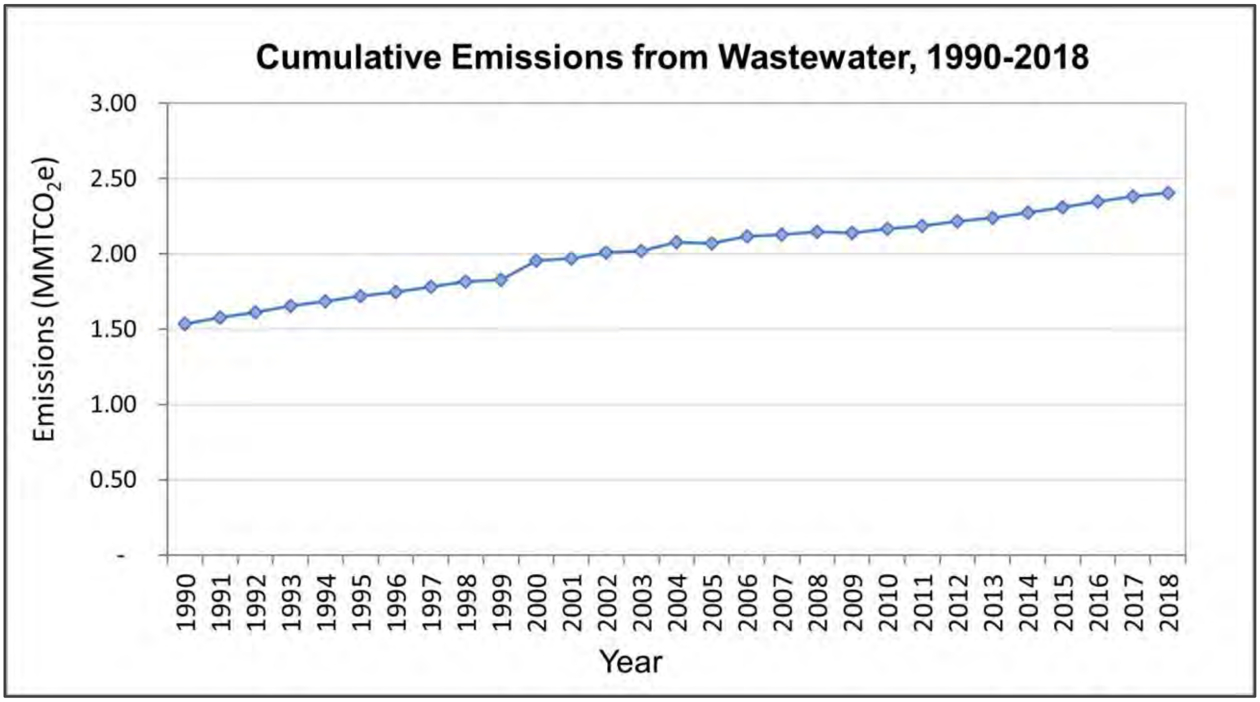

Figure J-1: Wastewater - Historical cumulative emissions in MMT CO_2e.

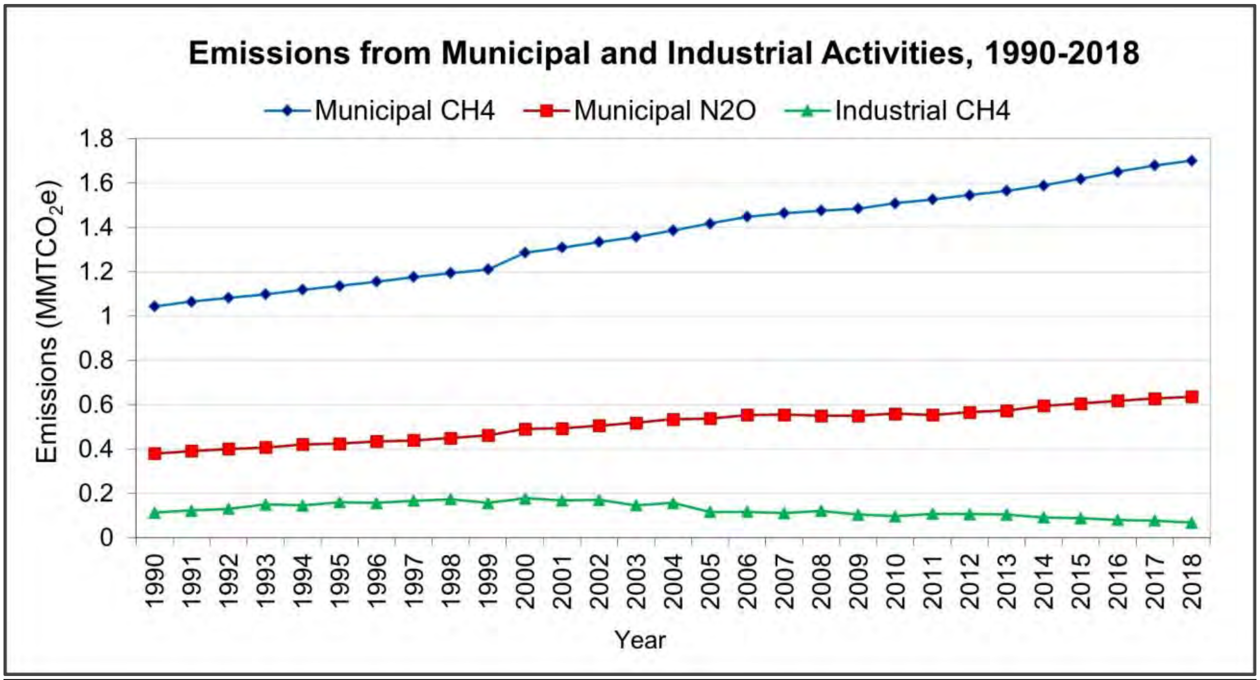

Figure J-2: Wastewater - Historical GHG emissions from municipal and industrial wastewater activities, by gas and sector.

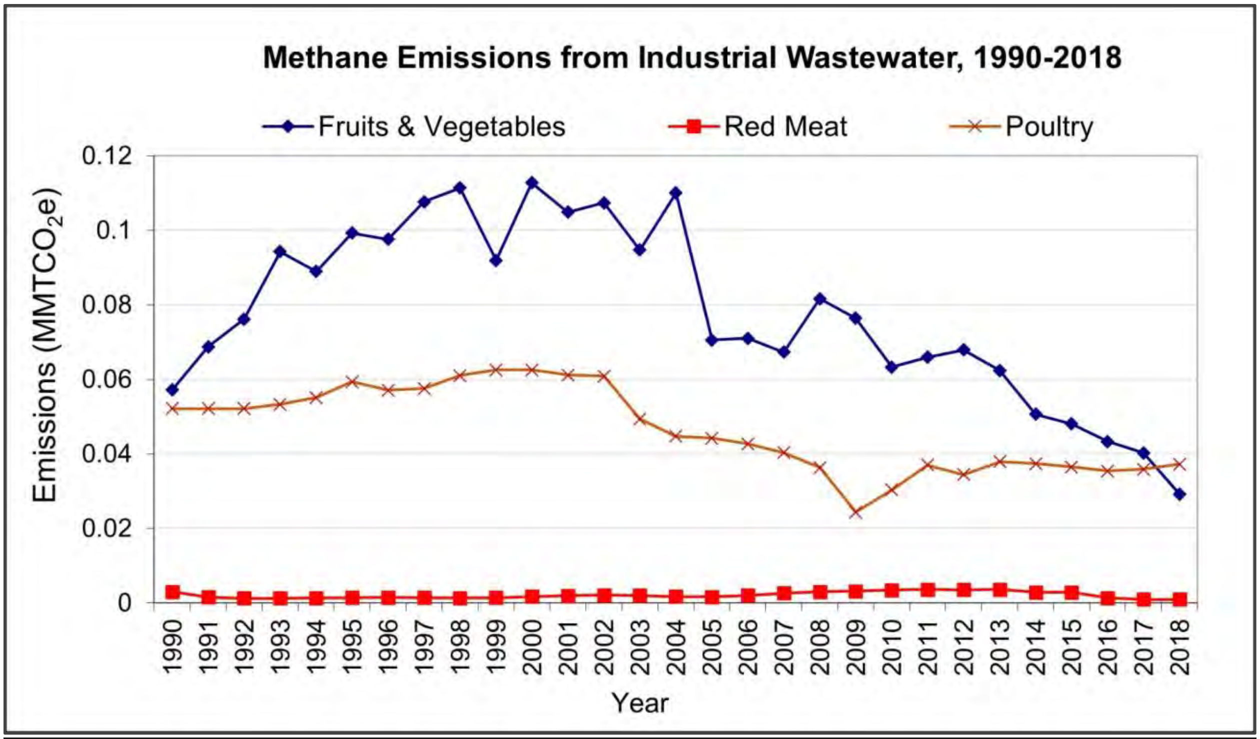

Figure J-3: Wastewater - CH_4 emissions produced during the processing of fruits and vegetables, red meat, and poultry.

Key Uncertainties

Uncertainties arise in the emissions estimated from poultry processing, centered around the lack of state-specific data. According to the EPA, which uses liveweight killed values, poultry would include values for young chickens, mature chickens, and turkeys. Because there is no explicit value for Florida's production processed weight of all poultry, only young chickens slaughtered data is taken into account. In the EPA's methodology, for states that lacked data for mature chickens, the values of young chickens were used for mature chickens. Therefore, Florida's value for young chickens was double to account for the missing mature chicken values. Turkey data was not available for Florida, therefore turkey processing was not considered in total emissions.

There are key uncertainties within emissions from fruits and vegetables processed for a few reasons. First, fruit totals do not consider all fruits, such as the noncitrus totals only accounting for blueberries (e.g., avocados and strawberries are also produced in Florida, but values are not reported by USDA). Some fruit values are only reported for the crop's seasonal year, which is not in line with the calendar year as the inventory analyzes. For example, the orange season for 1990-1997 started in December of the year prior, and from 1999-2018 started in October (i.e. December 1996-November 1997; October 2017-September 2018). Considering that the closing year of the season held the majority of months (e.g. 2017/2018 accounts for 3 months in 2017 and 9 months in 2018), the data was assigned to the later year of the season. Vegetable totals used are for fresh market vegetables and only include estimates for the selected crops in the NASS annual program. Additionally, the data used for vegetables are values for production, not values for production processed. Lastly, linear interpolations and extrapolations result in an additional layer of estimates embedded in these totals.

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INDIRECT CARBON DIOXIDE

Appendix K

Indirect CO_2 Emissions from Electricity Consumption

Overview

This annex displays indirect carbon dioxide (CO_2) emissions from electricity consumption in different use sectors. Direct emissions [estimated in the *CO_2 from Fossil Fuel Combustion (CO_2FFC)* module] result from the combustion of fossil fuels at the electricity generating station, whereas indirect emissions occur at the point of use (e.g., residential space heating electricity consumption). It can be stated that electricity consumption within a state for different users

[residential, commercial, industrial, and transportation (RCIT)] does not correspond to the electricity generated within that state, so emissions from consumption (indirect emissions) are not likely to be the same as emissions from generation (direct emissions).

The estimates for indirect emissions are not added to the total greenhouse gas (GHG) emissions for the state since the direct emissions are already included. Indirect emissions are useful to identify key electricity consumers and develop strategies based on such information. Indirect emissions along with direct emissions will also tell whether Florida is a net energy importer or exporter.

The general equation to calculate indirect CO_2 emissions from electricity consumption is shown below:

> ***Emissions (MMT CO_2e)*** *= {(Total State Consumption (kWh) × End-Use Equipment Consumption (%)) ÷ (1- Transmission Loss Factor (%))} × Emission Factor (lbs CO_2E/kWh) × 0.0005 short ton/lbs × 0.90718 (Ratio of Short Tons to Metric Tons) ÷ 1,000,000*

Methodology

The methodological steps used for estimating CO_2 emissions are divided according to activities tracked within the State Inventory Tool (SIT) of indirect CO_2 from electric power consumption. These activities are described below.

Electricity Emission Factor and Transmission Loss:

For every kWh of electricity consumed by each customer, there is a corresponding energy loss in the transmission lines. Therefore, estimation of emissions from electricity use includes emission factors (EFs) due to transmission losses. The state-specific loss is also called “grid loss”, and tabulated in survey data. This factor is a weighted average EF describing the average CO_2 emitted per unit of electricity sold by the grid to the state. EFs are available from the Environmental Protection Agency’s (EPA) Emissions and Generation Resource Integrated Database (eGRID) database at the state level for certain years. Default EFs and transmission loss are used in the years for which eGrid has no published data and linear interpolation were applied for the missing years.

Total Consumption per Sector:

State electric retail sales in million kWh values from 2001 to 2018 are provided for RCIT sectors in the Energy Information Administration’s (EIA) electricity database. Electric power sales data of the state is considered equal to the electric power consumption within the state. This is taken into account and compared to default data of the SIT module.The default values were closely matched with the available data; therefore, for the “not available” years in RCIT sectors, modules default data is considered correct and confidently used.

End-Use of Sector Consumption:

The indirect use of electricity at the consumer end is tracked by conducting user surveys on their equipment patterns and usage. With this in mind, the SIT’s default data is considered validated. However, for the unavailable survey years, linear interpolation was used.

Data Sources

- *Electricity Emission Factor and Transmission Loss (or Grid Gross Loss %):*
    - Florida-specific data is available in the EPA's eGRID database. For transmission loss, it is often named as grid loss which is used here. The majority of the state of Florida is within the Florida Reliability Coordinating Council (FRCC) region, an electricity market subregion recognized by the EPA's eGRID and the EIA. This regional data is also taken into account for the values of certain years.
    - The SIT's default data closely matched with yearly data found in the eGRID. Therefore, default values for EFs and transmission loss are used for the years in which eGRID had no published data. These years are: 1990-1995, 2001-2003, 2007-2008, 2011, 2015, 2017.
- *Consumption data:*
    - This data is based on state level consumption in kWh units. State-specific, sector-wise (RCIT) "Total State Consumption" in kWh (2001-2018) are drawn from the EPA's website.
- *Percent data:*
    - The use of total consumption varies by sector. The default usage percentage provided by the SIT was taken into account for state-specific consumption rate. The following sources were used to verify these default values.
    - *Residential*: EIA Residential Energy Consumption Survey -- Detailed Tables: 2001, 2005, 2009, 2015; Consumption and Expenditure Tables (last revised May 2018).
        - Included in this source: the physical characteristics of the housing units; the appliances used, including space heating and cooling equipment; the demographic characteristics of the household; the types of fuels used; and other information relating to energy use.
    - *Commercial*: The Commercial Buildings Energy Use Survey (CBECS) is a national sample survey that gathers data on the stock of commercial buildings at the state and national levels, as well as their energy-related building attributes, energy consumption, and expenditures. Commercial buildings are defined as any structure where at least half of the floorspace is used for a purpose other than residential, industrial, or agricultural. Additionally, these structures include building types that are not traditionally thought of as "commercial," such as schools, correctional institutions, and places of worship.
    - *Industrial*: The Manufacturing Energy Consumption Survey (MECS) is the federal government's comprehensive source of information on energy use by US manufacturers. The survey collects data on energy consumption and expenditures, fuel-switching capability, onsite generation of electricity, byproduct energy use, and other energy-related topics.
        - Table 5.7, End Uses of Fuel Consumption. Last revised October 2017.
    - *Transportation*: The National Transit Database (NTD) from the Federal Transit Administration (FTA) is a main source of data and statistics about national transit systems. The data in the 2017 National Transit Database (NTD) is one of three

publications that make up the Annual Report of the National Transit Database Program. This module incorporates state-level NTD data from 2007 to 2017, as well as proxies from 1990 to 2018.

Results

Residential Sector:

Figure K-1 displays the carbon emissions (MMT CO_2e) from the residential sector. In the case of Florida's residential sector, air conditioning was always a key consumption area of electricity. The average emissions from air conditioning is estimated at 14.69 MMT CO_2e. However, the other uses of electricity in residential users are the highest, ranging from 20.19 to 33.7 MMT CO_2e. The higher values in household appliances are attributed to the increased number of digital products in use.

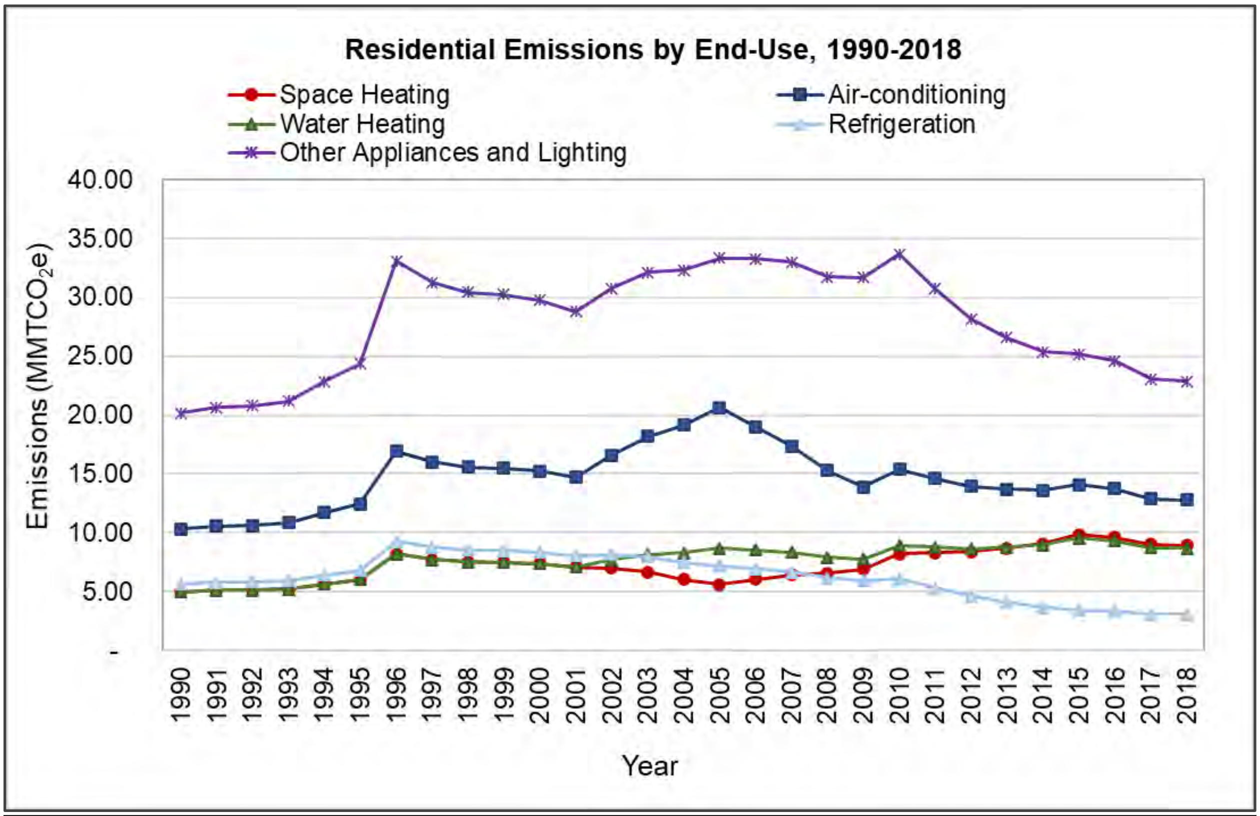

Figure K-1: Indirect CO_2 from Electricity Consumption - Emissions from the residential sector by use.

Commercial Sector:

Figure K-2 displays carbon dioxide equivalent (CO_2e) emissions from the commercial sector. The electric power usage for lighting was significantly the highest emitter before 2010. However, the evolution of energy-efficient light bulbs and LED bulbs caused this end-use to decline beginning in 2003 despite an increase in the number of users. Cooling on the other hand is the other major source of emissions in the commercial sector because of the increase in floor space cooling.

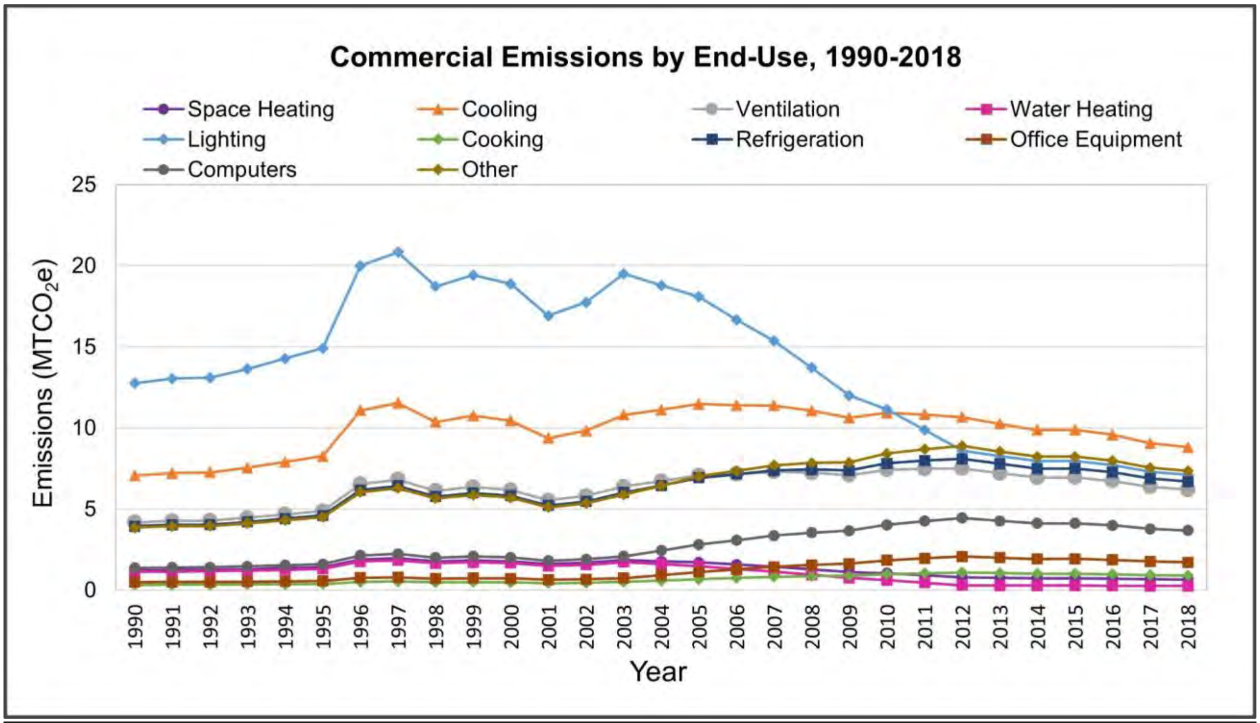

Figure K-2: Indirect CO_2 from Electricity Consumption - Emissions from the commercial sector by use.

Industrial Sector:

Figure K-3 displays emissions from the industrial sector, which is different from the other three sectors because industries might use their own generation in parallel to grid-supplied electricity. The majority of usage, and therefore the main emitting source, comes out of the grid-supplied electric power from direct uses (total process). This can include the primary processes to start operations before starting the key machines in industrial users. Direct uses peaked in 1997, with 12.6 MMT CO_2e when the energy efficiency was not much for the electricity-consuming equipment. Afterwards, this consumption gradually decreased to its lowest point of emissions in 2018 with 6.02 MMT CO_2e. The direct use for total non-process, the second-largest source of emissions, is consistent at around 1.8 MMT CO_2e, which can be related to the processing of byproducts of direct process. This is also replicating the profile of the total process and decreases over the years.

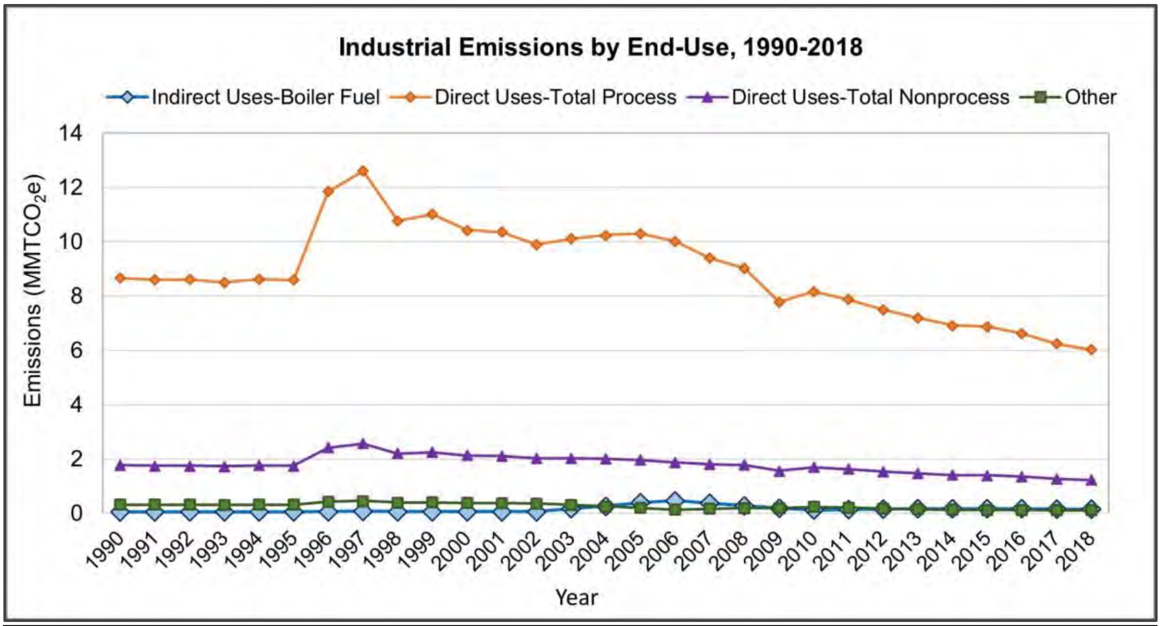

Figure K-3: Indirect CO_2 from Electricity Consumption - Emissions from the industrial sector.

Transportation Sector:

Figure K-4 presents the emissions (MMT CO_2e) from the transportation sector. Emissions are dominated heavily by heavy rail which includes railway and electric power rails, and is somewhat related to the economy of the state. Heavy rail saw a rise in emission up to a maximum of 0.06 MMT CO_2e in 2005, which then began to gradually decline to 0.03 MMT CO_2e in 2017. The other end-use sources are not significant emission contributors, which in some cases is because they are not relevant to or occur in Florida, such as the use of an inclined plane for transit up a mountain.

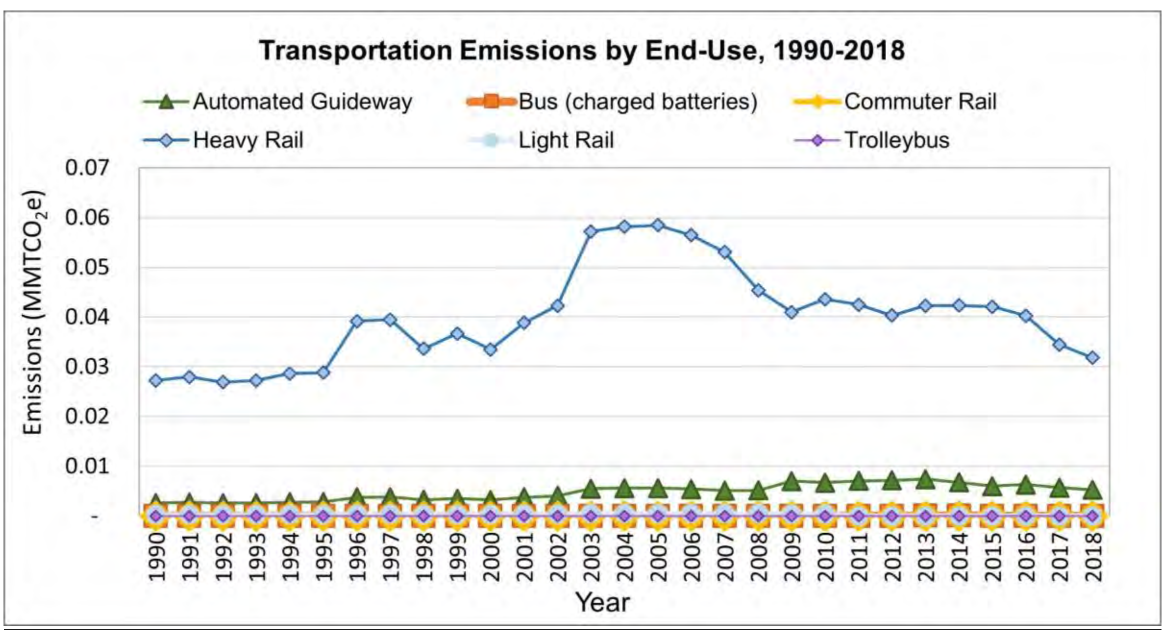

Figure K-4: Indirect CO_2 from Electricity Consumption - Emissions from the transportation sector by use.

Emissions by Sector:

The total indirect CO_2 emissions from the consumer end of different sectors can be seen in Figure K-5. This graph displays that, in Florida, the major contribution comes from two sources: the residential sector as the largest emitter and the commercial sector as the second-largest emitter. Table K-1 shows the total emissions and its sector breakdown across the entire time series in 5-year intervals, plus 2018. The profile of residential and commercial are similar, which is understandable considering the increase in the commercial floors, the population increases in the area, and the residential appliances and electricity consumption. The other two sectors, transportation and industrial, are more consistent than residential and commercial, with industrial topping transportation as an emissions contributor.

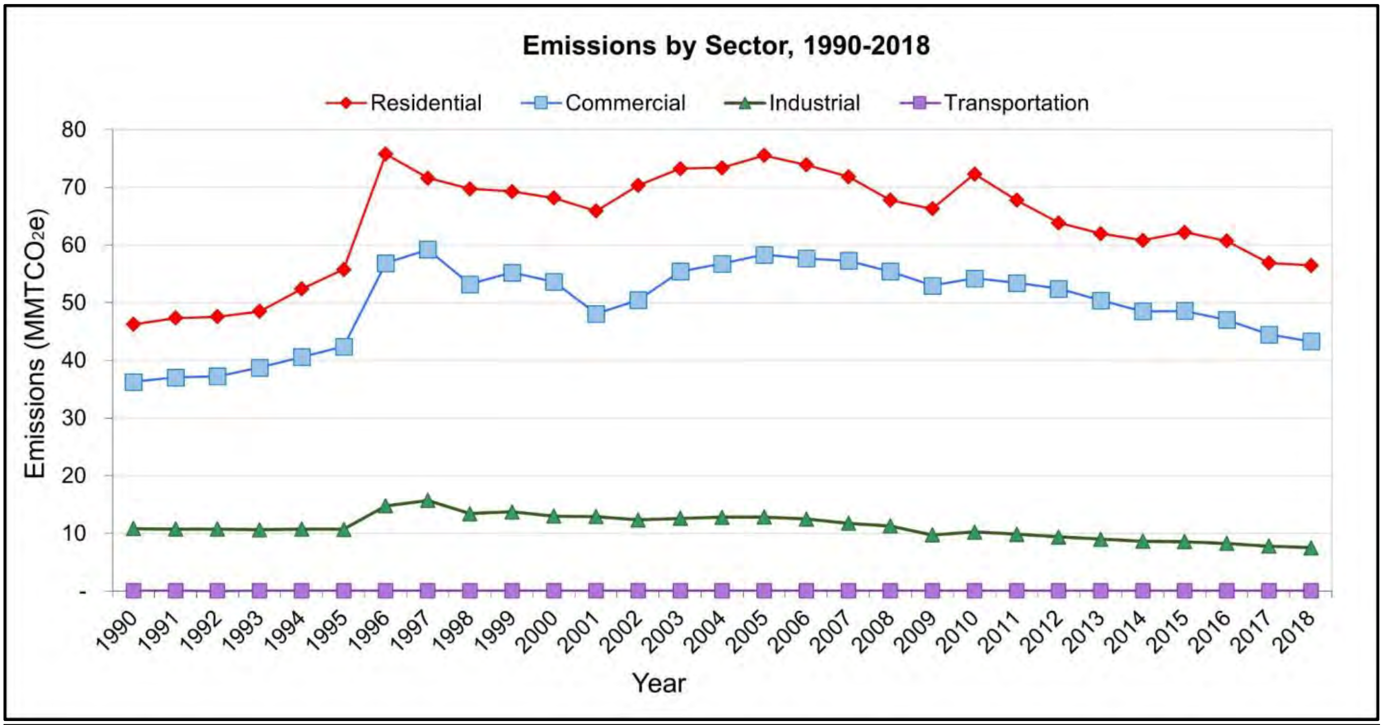

Figure K-5: Indirect CO_2 from Electricity Consumption - Emissions by sector. Note that transportation values are not equal to zero, but range between 0.03 and 0.06.

Sector	1990	1995	2000	2005	2010	2015	2018
Residential	46.23	55.75	68.14	75.54	72.30	62.20	56.45
Commercial	36.25	42.38	53.61	58.33	54.18	48.56	43.29
Industrial	10.79	10.71	13.00	12.84	10.21	8.56	7.50
Transportation	0.03	0.03	0.04	0.06	0.05	0.05	0.04
TOTAL	93.30	108.87	134.79	146.76	136.74	119.37	107.28

Table K-1: Indirect CO_2 from Electricity Consumption - Emissions by sector and total (MMT CO_2e).

Key Uncertainties

The electricity EF and transportation loss that are found in the eGRID surveys show a close match with default data. Therefore, SIT default data is taken for the years where direct data is not available. Other years' values were determined using linear interpolation which adds uncertainty. For some years where Florida-specific grid loss percent is not available, Eastern Zone Grid Loss factor was used. Now, RCIT segments in SIT have default data for "percentage of indirect use of electricity". These were kept at the default value because Florida-specific survey data on the appliances were not found. This may also contribute to some uncertainties on a small scale.

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Appendices for Net-Zero Action Planning

Appendix L

Concrete Production & Techniques

Current Concrete Production

a. *Traditional Method of Producing Cement*

The primary ingredient of the cement, limestone, is mined from a limestone quarry. Limestone is usually found below the surface, so obtaining the mineral begins with quarry workers scraping away the surface of the earth. Once the workers reach the limestone, they blast the rock with dynamite and use front-end loaders and dump trucks to collect and move the stone to the cement plant. The stones travel through the primary rock crusher at the plant and are broken into finer, more consistent pieces. This process uses heavy machinery and water. Afterward, the smaller pieces of limestone pushed through a second rock crusher, sans water. The smaller rocks are then ground into a fine powder by a roller. If necessary, the limestone powder is combined with additives. At this point, the mixture (known as raw meal) is put into a preheater for a short amount of time to remove carbon dioxide and allow for better binding. Afterward, the material is sent to a rotary kiln for additional heating. However, this process is much longer and hotter than the process before it. The material spins and collides together in a barrel for over 160 feet and reaches over 2800 degrees Fahrenheit. Both heating processes use gas flame for heat. The resulting material from the rotary kiln is known as clinker. Clinker is cooled with fans after the rotary kiln. In the final stages of cement production, the clinker is combined with gypsum and milled into a powder.

Most of this CO_2 comes from the cement-making process while preheating and releasing carbon dioxide from the raw meal (a mixture of various raw materials primarily limestone rock, before cement calcination). The general process also uses carbon dioxide (and other greenhouse gases) due to the frequent use of heavy trucks. In many cases, the components to make concrete are extracted locally. However, large trucks move the heavy materials around, contributing to the gases.

At a global level, the World Business Council for Sustainable Development (WBCSD) partnered with the Global Cement and Concrete Association (GCCA) to create the Cement Sustainability Initiative (CSI, n.d.). In 1999, the Battelle Memorial Institute was commissioned by the WBCSD, along with ten leading cement companies, to independently research the pathways to a more sustainable cement industry. The final report (Battelle Memorial Institute, 2002) summarized the following eight major challenges to address:

1) Resource productivity: Improving eco-efficiency through improved practices in quarrying, energy use, and waste recovery and reuse;
2) Climate protection: Understanding and managing CO_2 emissions;
3) Emission reduction: Reducing dust from quarrying, NOx, SOx, and other airborne pollutants from cement manufacture;
4) Ecological stewardship: Improving land-use and landscape management practices;

5) Employee well-being: Managing and improving employee health, safety, and satisfaction;
6) Community well-being: Working more effectively with local communities;
7) Regional development: Participating in regional affairs; and
8) Shareholder value: Creating more value for shareholder research.

Since this initial study, subsequent progress reports have been issued. The most recent report was in 2012, which identified several principal areas of sustainability. These areas are Water; Working with others; Safety; Air emissions; Supply chain management; Climate protection; Sustainability with concrete; Fuels and raw materials and Local impact on land, and communities (CSI, 2012).

The following section describes the alternative methods and techniques to reduce the embodied carbon from concrete production and construction by replacing key components of concrete. Embodied carbon is the carbon dioxide emissions related to the manufacturing and transportation of construction materials.

Cement Reducing Measures

The development of clinker is the process that produces the most CO_2 in concrete production. One alternative is to replace traditional limestone-based materials with pozzolan materials or materials containing alumina and silica. Pozzolan materials use fewer fuels to produce at reduced manufacturing temperatures when compared to limestone-based materials (Bondar et al., 2013). One company, Cemex, is using an alternative to “limestone-based clinker and replacing it with alkali-activated alumina-silicate polymer matrix” (Bettenhausen, 2020) to create a cement that emits 70% less CO_2 than the traditional portland cement (Bettenhausen, 2020; Cemex, n.d.). Another cement alternative is a pozzolan created from recycled post-consumer glass (Margolies, 2020; Urban Mining Industries (UMI), 2020). United Mining Industries has created a version of pozzolan called Pozzotive. The company claims Pozzotive can “replace up to 50% of cement in concrete, reducing the embodied CO_2 emissions on a nearly ton-for-ton basis” (UMI, 2020).

Another potentially promising cement alternative is chemically bonded phosphate ceramics (CBPCs), an acid-base cement (ABC) process which creates an insoluble orthophosphate from chemical reactions at ambient or near-ambient temperatures (Wagh, 2016). CBPCs leverage the power of phosphate bonds which are common in nature (e.g., fundamental building blocks of D.N.A. and bones) and are an emerging class of material that resides between more conventional ceramics and cement (Wagh, 2016, Chapter 1). The production of CBPCs consumes only 45% of the energy needed for conventional portland cement and releases only 26% of this material’s GHG emissions (Wagh, 2016, Chapter 20). Furthermore, the phosphate necessary for the production of CBPCs can come from wastewater effluent treatment byproducts and related industrial and community waste streams. Using more of these emerging alternative cement would help reduce net carbon emissions in concrete production.

Reducing Aggregate in Concrete

The process of producing virgin aggregate requires much less energy than cement; however, the environmental destruction is similar. In some instances, the method of making crushed stone begins with surface scraping and creating a surface mine, which involves removing vegetation and surface material until the miners reach sandstone. Quarry miners then drill and blast the rock and use heavy machinery to move the stone to the aggregate plant. It is then sorted, crushed to the desired aggregate size, and cleaned with water before loading onto a dump truck and sending it to the concrete plant. The process is also environmentally destructive for sand and gravel, as workers use heavy machinery to dig or dredge the material from rivers, lakes, and sea beds (Portland Cement Association (PCA), 2019).

a. Alternative Aggregate Measures

Coarse and fine aggregate constitute the majority of concrete at approximately 60 – 75% of the mix, so aggregate alternatives can significantly reduce the embodied carbon of concrete. Some companies have developed options to traditionally mine aggregate. One company, Blue Planet Systems (BPS), uses demolished or unused concrete and extracts the calcium from the material. The calcium is exposed to CO_2, which becomes chemically bonded to the aggregate. The company estimates that 440 kg of CO_2 is mineralized for each tonne of aggregate. It also claims that if one cubic yard of concrete (containing 3,000 lbs of aggregate) was completely composed of BPS synthetic limestone, this would offset a plant's sequestered CO_2 by 44%, or 1,320 lbs of CO_2 (MDU, 2020).

Efficient Concrete Usage

Investment in firms that implement efficient concrete usage strategies help not only reduce the carbon footprint of the building material in Florida but could also reduce the overall cost of construction. However, efficient concrete usage requires more preplanning and technological work than traditional concrete production methods.

a. 3D Concrete Printing

Digital applications have recreated designs that reduce the amount of concrete use by 70% compared to traditional concrete applications, according to researchers at ETH Zurich (Hahn, 2022; Hobson, 2021). The design potential can be complex, although they require placement precision, timing, and exact slurry consistency. 3D concrete printers (3DCP) can provide these conditions. 3DCPs can be used at a fixed site like a warehouse or dynamically at the job site (Hahn, 2022; De Schutter et al., 2018; Adaloudis & Bonnin Roca, 2021). In the printed precast, the reduction in materials translates to a decrease in shipping and handling measures to construction sites (Hahn, 2022).

Use of Gas Emissions in Concrete Construction

Another strategy for carbon sequestration in concrete is capturing carbon and injecting it directly into the concrete. One company, CarbonCure, uses a method of carbon injection that increases the compressive strength of the concrete while reducing the need for cement in the mixture (CarbonCure Technologies Inc., 2022). CarbonCure works with ready-mix companies, such as Ozinga Bros, Inc., to inject their CarbonCure Technology into their customer's existing concrete mixes. CarbonCure estimates show that Ozinga Bros, Inc. produced more than 453,000 cubic yards of concrete with CarbonCure technology, resulting in 7,200 tons of CO_2 sequestration (CarbonCure Technologies Inc., n.d.). Ozinga Bros, Inc. is the first producer of ready-mix that supplies Florida with CarbonCure concrete (CarbonCure Technologies Inc., n.d.).

Another cement and concrete technology company, Solidia, estimates that their cement manufacturing processes reduce GHG emissions by 30-40% (Solidia, n.d.). Their concrete curing processes convert the injected CO_2 into calcium carbonate (CaCO3) within the concrete, potentially eliminating 1.5 gigatonnes of CO_2 and saving 3 trillion liters of freshwater (Solidia, n.d.). Solidia estimates their concrete curing process reduces cement plant energy consumption by 260 million barrels of oil annually while curing the concrete in 24 hours instead of the more conventional industry standard of 28 days for traditional concrete (Solidia, n.d.).

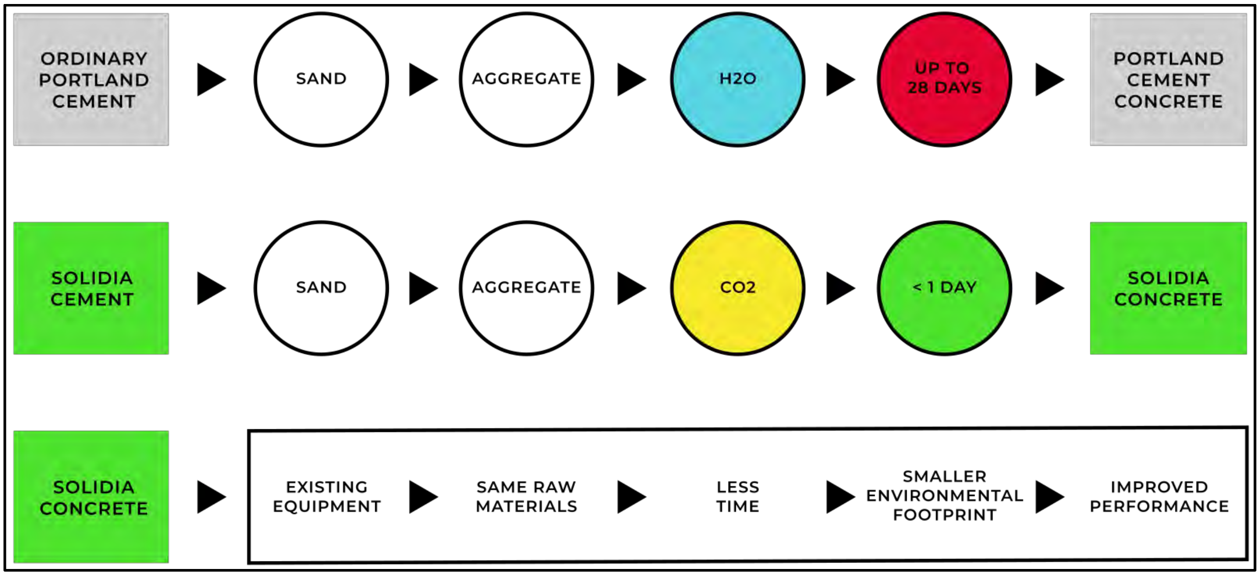


Figure L-1: Solidia's broad adoption would help cement manufacturers meet or exceed the industry's carbon reduction goals, as stated in the Cement Sustainability Initiative of the World Business Council for Sustainable Development and the Global Cement and Concrete Association (GCCA) (Solidia, n.d.).

An Act to Reduce Embodied Carbon in Large-Scale Public Projects

Using the various alternatives to traditional concrete production and construction would reduce CO_2 emissions. One way to effectively implement the strategy is to directly require its use in public projects. The proposal is a state requirement to use low embodied carbon technologies to reduce global warming potential for large-scale public projects. The potential to reduce GHG emissions depends on the limits set by the legislation. In 2021, eight states passed legislation to reduce embodied carbon (Washington, Oregon, California, Colorado, Minnesota, Connecticut, New York, and New Jersey) (Lewis, 2021).

Tradable Low Carbon Cement Standard

Another method to facilitate the development of carbon-reducing strategies and solutions is to create a market with tradable carbon credits for cement producers and importers. The proposition is to connect carbon credits to emissions, where producers and importers with low-carbon cement would have credits they could sell to those with high-carbon cement, incentivizing decarbonization. While the concrete and cement industry is developing more low carbon embodied solutions, a credit-trading marketplace would help incentivize companies to implement solutions more rapidly.

Implementation Processes

Appendix M

Implementing Solar Projects

The National Renewable Energy Laboratory outlines five steps recommended to formally launch a solar project:

I. Identify Potential Locations

While identifying potential locations for PV installation, it is important to keep in mind issues of potential shading and to weigh the benefits of ground versus rooftop solar panels. Typically, solar installations are 5 to 10 watts per square foot of usage (Cory et al., 2009). This is an important metric when determining the financial feasibility of a purchase power agreement (PPA) and approximating the size of the PV system(s) (Cory et al., 2009). However, it may be the responsibility of the owner to make investments in their property in order to support the installation of the system (an example would be rooftop repairs or trimming trees that shade the PV system) (SEIA, n.d.).

II. Issue a Request for Proposal to Competitively Select a Developer

If the aggregated sites are at least 500 kilowatts (kW) in electricity demand, then the request for a proposal process will likely be the best way to proceed usage (Cory et al., 2009). However, if the aggregate demand is less, then the request may not receive adequate response rates from developers' usage (Cory et al., 2009). Thus, if government entities are handling a smaller site, then they should either seek to aggregate multiple sites into one request or contact developers directly to receive bids without a formal request process usage (Cory et al., 2009).

III. Contract Development[17]

After a winning bid is selected, the contracts go through a time-sensitive process of negotiations (Cory et al., 2009). During this step, the range of a PPA is specified. PPAs typically range from 10 to 25 years (SEIA, n.d.). The PPA's specified time range, coupled with predetermined electricity rates, helps avoid unpredictable price fluctuations from utility rates (Cory et al., 2009). At the conclusion of a PPA contract term, a customer may be able to extend the PPA, have the developer remove the system, or choose to buy the solar energy system from the developer (SEIA, n.d.).

[17] A sample of Terms of Executed Power Purchase Agreements can be found at: https://www.nrel.gov/docs/fy10osti/46668.pdf

IV. Permitting and Rebate Processing

Typically, the seller will be responsible for filling permits and rebates in a timely manner; however, the government agency should note filing deadlines for state-level incentives because there may be limited windows or auction processes (Cody et al., 2009).

V. Project Design, Procurement, Construction, and Commissioning

During the final step of the PV project launch process, the developer will complete a detailed design, then procure, install, and commission the solar PV equipment. The PPA should establish realistic developer responsibilities and a process for determining monetary damages for failure to perform (Cody et al., 2009).

Appendix N

Implementing Carbon Pricing Programs

To establish an effective carbon pricing program, decisions on policy structure and design need to be prepared. These decisions include the scope of the program, point of regulation, setting the price or cap, and reporting and verification mechanisms.

I. Scope

Scope refers to the portion of overall GHG emissions covered by the carbon pricing program. If Florida were to implement a program with a broader scope, then this would imply greater emission reductions. To determine a program's scope, policymakers need to: 1) decide whether the program covers only CO_2 or other greenhouse gases as well; 2) determine which economic sectors are covered by the program; and 3) choose whether all emitters or only those above a certain emission threshold, are regulated (Kennedy et al., 2015).

II. Point of Regulation

There are two common approaches used to enforce paying taxes or surrendering allowances: "upstream" and "downstream." An upstream approach applies the carbon price at the extraction site of materials that will result in emissions (Kennedy et al., 2015). Examples of this include activities taking place at a coal mine, at an oil or gas drilling site, or at the entry point of fuel imports.

The downstream approach, on the other hand, applies the carbon price at the point where the emissions are generated (Kennedy et al., 2015). The downstream approach would cover large point sources like power plants and steel manufacturing plants (Kennedy et al., 2015). This approach may be useful for a program that is limited to the electricity-generating sector, like the RGGI (Kennedy et al., 2015).

However, it is also common practice to mix the two approaches. For instance, California's cap-and-trade program initially covered large industrial sources directly. Yet it has since expanded to include the use of natural gas by homes and small businesses through the utility distribution companies; thus, moving from a downstream to a midstream approach (Kennedy et al., 2015).

III. Setting the Price or Cap

Whether Florida decides to implement a carbon tax or an emission trading system (ETS), setting the level of the tax or cap will require balancing a variety of political, economic, and environmental considerations. Areas with a carbon pricing program commonly increase the stringency of the program over time. This is done to allow businesses and consumers to adjust and to maintain flexibility to modify the price or cap if conditions change (Kennedy et al., 2015).

Estimates of the environmental cost of carbon emissions are sensitive to scientific and economic assumptions (Tax Policy Institute, 2020). A global study by Ricke, et al. (2018) determined the social cost of carbon[18] across countries from around the world. In this study, the authors found that the social cost of carbon is about \$50 per tCO_2. Considering that this study, coupled with EPA's calculations, reports the socioeconomic cost of GHGs to be \$50/tCO_2, (based on a 3% discount rate), then that cost should be adopted by Florida. However, if Florida uses other policies, like a renewable portfolio standard (RPS) or command-and-control, then this can offset emissions and the tax can be below \$50/tCO_2.

IV. Reporting and Verification

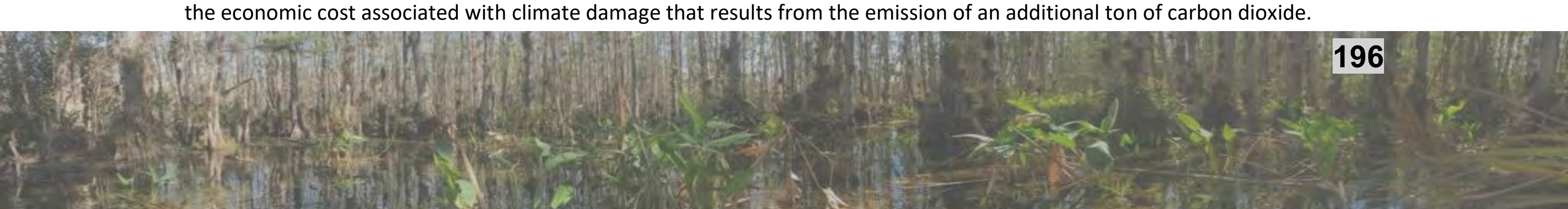
Every successful carbon pricing policy has accurate emissions monitoring, significant violation penalties, and high compliance (Schmalensee, 2017). An upstream approach involves reporting the production and imports of fossil fuels and translating the fuel report data into equivalent emissions (Kennedy et al., 2015). While downstream or midstream approaches mean that reporting must accurately tie the emissions to the responsible entity (Kennedy et al., 2015).

Appendix O

Implementing Renewable Portfolio Standards (RPS)

RPS policies are unique to every state considering each has different political motivations, targets, and technology approaches (Heeter et al., 2019). These policies vary internationally and differ among states within the U.S. Yet, they have common elements designed to achieve the desired underlying policy objectives at the least cost (Heeter et al., 2019). According to Heeter et al., (2019), common elements typically include the following:

[18] A common metric of the expected economic damages from carbon dioxide emissions. The social cost of carbon represents the economic cost associated with climate damage that results from the emission of an additional ton of carbon dioxide.



Production Target	Typically listed in megawatt-hours: *MWh*. Using megawatt-hours as the unit to measure the production target aids to incentivize project developers to use equipment and installation that maximize renewable energy generation.
Target Year	Typically established on an annual basis with an end-year target. For example: RPS target may be 30% of annual electricity sales in 2030, starting at 20% in 2020 and increasing 1% annually to reach the 30% end-year target.
List of eligible Renewable Technologies	Providing a list of eligible technologies to stakeholders is essential for tracking compliance since definitions of "renewable" can vary.
Consideration of Renewable Imports	Whether renewable generation imports are eligible. Renewable energy resources may be available to be developed at lower costs in other regions.
Compliance & Enforcement Structure	Penalties for noncompliance. Assuring investors that a market for renewable technologies will exist over the life of their investment.

To establish a thorough RPS with these common elements, states should consider the following practices: (1) component analysis to inform RPS design, (2) gathering stakeholder input before creating targets, (3) identifying eligible renewable resource types and ages, (4) clearly defining RPS, (5) enforcing compliance, and (6) providing a cost-containment provision (Heeter et al., 2019).

I. <u>Component analysis to inform RPS design</u>

Numerous components and their potential should be considered when defining RPSs. These include resource characteristics (e.g., physical constraints), technical characteristics (e.g., land use constraints), as well as economic and market components such as projected fuel costs and regulatory limits. Renewable energy potential can be examined in multiple ways. Figure O-1 shows the hierarchy of the different potential components and key assumptions within resource, technical, economic, and market potentials:

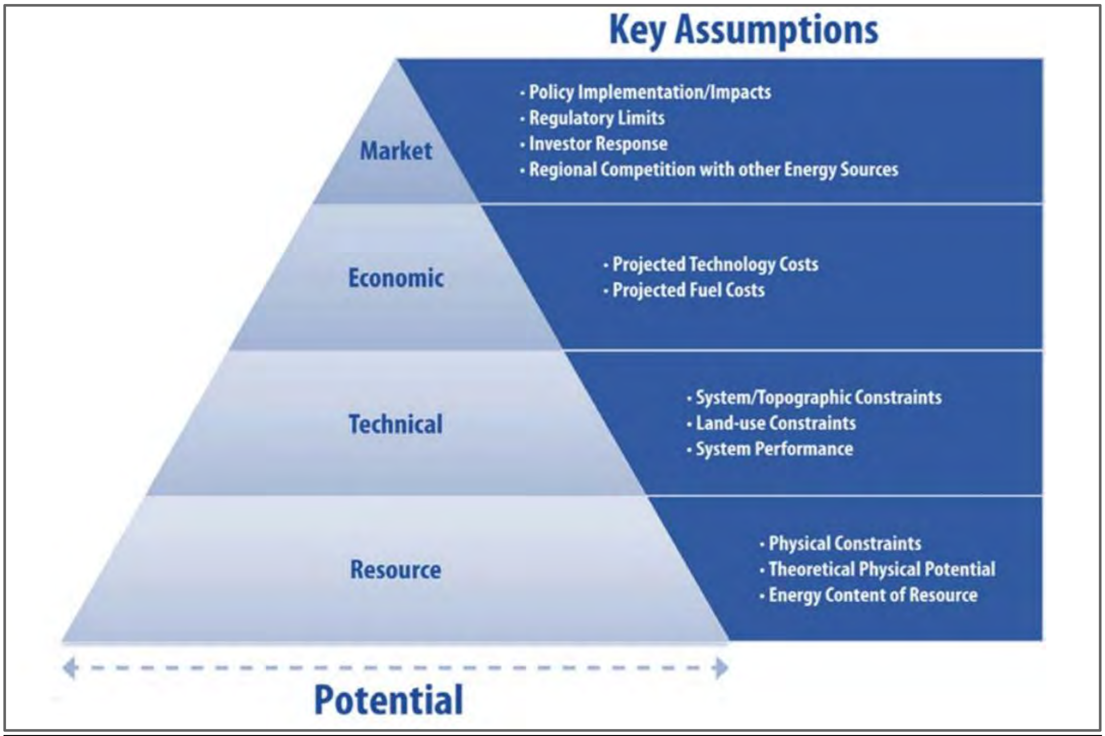


Figure O-1: Types of renewable energy potential. Source: Lopez et al. (2012).

II. <u>Gathering stakeholder input before creating targets</u>

Following a thorough analysis, key elements need to be specified in RPS design. Stakeholder input and buy-in during the target development process can lead to smoother policy implementations and sustained support even after implementation (Heeter et al., 2019).

III. <u>Identifying eligible renewable resource types</u>

Major eligible renewable resources include solar, wind, geothermal, hydropower, and biomass (Heeter et al., 2019). However, to avoid choosing a singular least costly renewable option, many states mandated a “carve-out” of their RPS policy (most commonly in solar generation) (Heeter et al., 2019). Technology carve-outs can ensure the desired diversity of generating technologies and limit over-reliance on a single resource option (Heeter et al., 2019).

Eligible resources vary state by state. Therefore, determining which resources are optimal can be based on the state’s existing energy generation mix and its potential for renewable energy development. Florida could focus on biomass and solar energy since these sources currently provide most of the state’s renewable-sourced electricity generation. In 2020, renewable resources contributed to ~5% of Florida’s electricity net generation, with two-thirds of the state’s renewable generation coming from solar energy (EIAa, 2021).

Despite Florida’s current ranking as third in the nation for increased solar installations, solar energy accounts for only about 4% of its total energy consumption (SEIA, 2021). Figure O-2 illustrates the annual solar irradiance in the U.S., highlighting the solar energy potential that is not harvested by the state. States such as Massachusetts, Nevada, Vermont, North Carolina, New Jersey, Maryland, Rhode Island, Idaho, Delaware, and Minnesota all have less solar energy potential than Florida, yet they rank higher in terms of percentage of electricity derived from solar.

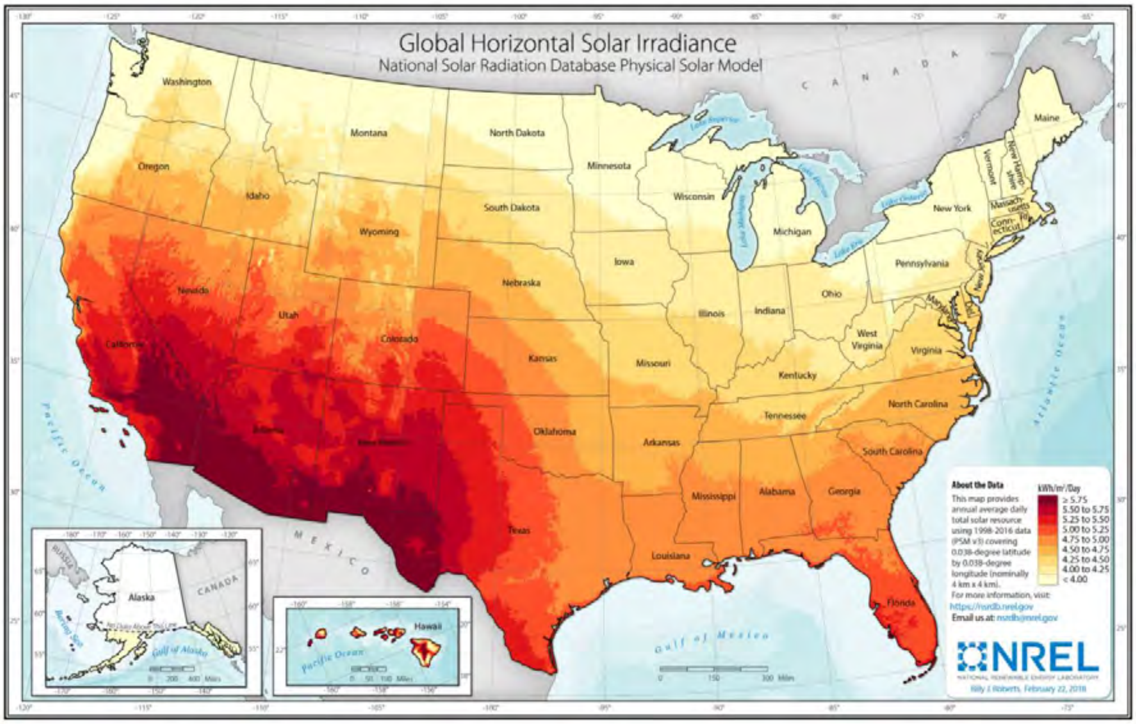


Figure O-2: U.S. Annual Solar Global Horizontal Solar Irradiance. Source: NREL (2018).

Moreover, Florida accounts for about 7% of the nation's biomass-fueled[19] electricity generation (EIA, 2021). Florida Energy Systems Consortium estimates that as much as 10 billion gallons of ethanol per year from biomass resources could be produced in the state. However, a large portion would be from material that is currently going to landfills, such as yard waste. Identifying efficient and well-sourced feedstocks, to increase biomass production, would be a significant step towards expanding on this resource type.

In addition to solar and biomass, Florida could also expand nuclear energy production. Compared to other forms of renewable energy, nuclear energy produces more electricity on less land than any other clean-energy source (Office of Nuclear Energy, 2021). According to the Office of Nuclear Energy (2021), a typical 1,000-MW nuclear facility in the U.S. needs slightly more than one square mile to operate. In contrast, to produce the same amount of energy, wind farms require 360 times more land and solar photovoltaic plants require 75 times more land (Office of Nuclear Energy, 2021). Building more nuclear power plants in Florida would help the state reach its energy reduction goals.

Moving forward, as energy-efficient technologies become more advanced, wind power could become a viable renewable energy resource in Florida. Currently, the state does not have a wind farm. Advances in wind turbine technology and taller towers could allow for improved wind harvesting potential. This can be applied across different areas along the Gulf Coast. Figure O-3 illustrates wind speeds at 100 meters above surface and displays potential land for wind-generated energy. Turbines and tall towers (110 meters) can effectively increase wind energy

[19] Biomass energy uses the energy found in plants, and relies on feedstocks including corn, soy, or wood.

potential. An estimated 11,000 MW of land-based wind potential exists in Florida, which is equivalent to powering nearly three million homes a year (SACE, 2015).

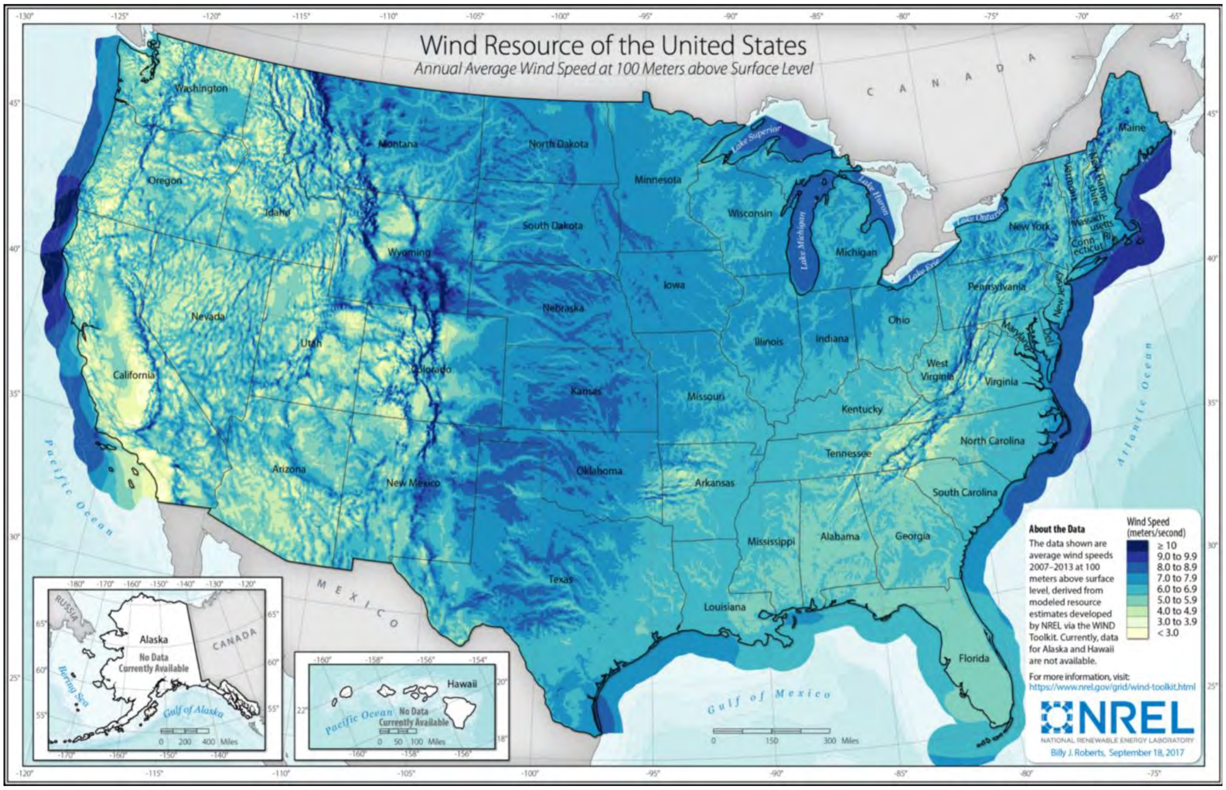


Figure O-3: Annual Average Wind Speed at 100 meters above Surface Level in the U.S. Source: NREL (2017).

IV. <u>Clearly defining the RPS</u>

A clearly defined RPS is essential for avoiding misinterpretation by energy stakeholders and the general public (Heeter et al., 2019). According to Heeter et al., (2019), a clear definition should include the following: :

- Allowable resource types;
- Timing of the interim and final targets;
- Specific entities to be held accountable for meeting targets and the method of compliance, reporting, and enforcement;
- Whether targets apply to all renewable energy generation or only new generation;
- Exclusions or waivers, with attention to unintentional loopholes.

V. <u>Ensuring Compliance via Enforcement</u>

Typically, an RPS is enforced by a regulatory entity that oversees energy and electricity. For instance, California's RPS was implemented and is continually regulated, jointly by the California Energy Commission (CEC), the California Public Utilities Commission (CPUC), and the California Air Resources Board (CARB) (CPUC, 2021).

Regulatory entities can identify and measure noncompliance using scheduled reports of public utility companies, or assessing performance/progress towards set targets. Noncompliance could include missing performance/progress report deadlines, or not meeting expectations set by the RPS. To ensure that future annual targets will be met, noncompliant actions could result in a payment penalty or other means of enforcement. A common penalty is the alternative compliance payment (ACP) (Heeter et al., 2019). For example, if the RPS requires a certain number of megawatt-hours (MWh) of renewable electricity, an ACP might specify a penalty of $100 for each MWh out of compliance from the entity (Heeter et al., 2019). In the U.S., ACPs have been structured so that they differ for solar carve-outs, considering that solar costs have historically been higher than costs of main tier resources (wind power) (Heeter et al., 2019).

Although ACP is the most common penalty, there are others that could be used for noncompliance. Instead of an ACP, California's regulators are allowed to assess fees on the utility for noncompliance (Heeter et al., 2019). These fees cannot be passed on to ratepayers but instead must be absorbed by the utility's stakeholders (Heeter et al., 2019).

VI. <u>Providing a Cost-Containment Provision</u>

A cost-containment provision, included in most RPSs, ensures customers of utility companies or other entities are protected from excessive cost increases that may result from future renewable generation costs (Heeter et al., 2019). If the compliance entity is unable to absorb the cost increases without increasing charges to their customers, then the entity will be exempted from complying with the RPS during the reporting period. An ACP mechanism can be used to limit costs by placing a ceiling on the cost of compliance. In addition, retail rate caps from the end-use consumer side can also be used to ensure that electricity rates do not rise above a certain percentage or dollar amount (Heeter et al., 2019).

Specific Case Studies Beyond Florida

Appendix P

Successful Implementation of Solar Energy in the United States

In the United States, 28 states and Washington D.C. authorize, or allow purchase power agreements (PPAs) for solar photovoltaic (PV); however, Florida is one of the few states with legal barriers that make it extremely difficult for PPAs to materialize (Stevens et al., 2020). Florida's State Statute 366.02[20] classifies that every entity selling power in Florida is a public entity and must adhere to the same rules as large energy companies (Stevens et al., 2020). This leads to high administrative costs and regulatory hurdles, which are extremely difficult for small solar service providers (Stevens et al., 2020).

[20] The Florida Senate. (2012). Chapter 366 Section 02 – 2019 Florida Statutes. Retrieved from http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&Search_String=&URL=0300-0399/0366/Sections/0366.02.html

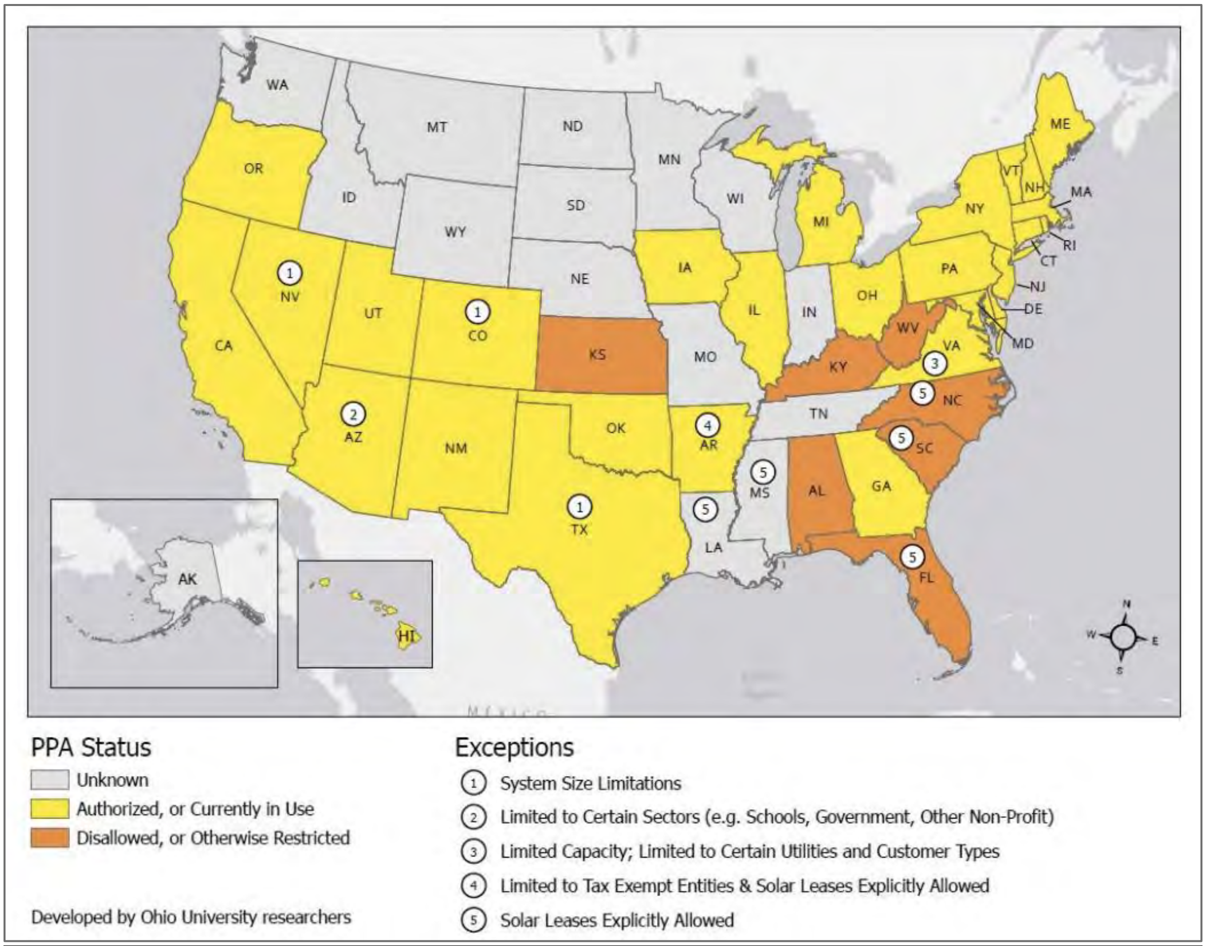


Figure P-1: States that Authorize or Restrict Solar PPAs. Source: Ohio University (2019).

Oregon

Oregon offers residents interested in a solar electric system the option to either buy, lease, or sign a solar PPA. If a resident decides to buy and own a solar electric system, then they are able to claim all the incentives and tax credits. Additionally, owning a system is encouraged if it is a long-term investment since it makes more financial sense than going solar through a solar lease or PPA, though all options will save the customer money in the long run (Solar Oregon, n.d.). If a customer decides to sign a solar lease, then they pay monthly installments based on the cost of the system. Those payments are offset by lower electricity payments (Solar Oregon, n.d.). Lastly, if a customer wants to go solar through a PPA, then they do not purchase the system, but rather purchase the electricity produced by the system - this is typically at a lower rate than offered by the utility (Solar Oregon, n.d.).

Georgia

According to the U.S. Energy Information Administration (EIA) data, Georgia currently has 3.5 times more small-scale solar generation than Florida. Passing through the Georgia legislature in 2015, the Solar Power Free-Market Financing Act allows “solar energy procurement agreements” to finance small-scale solar projects less than 10 KW in size (Georgia General

Assembly, 2015). With the help of this act, Georgia's electricity generation from solar PV is nearly four times greater in 2020 than in 2016 (EIA, 2021). Additionally, in 2020, small-scale (less than 1 megawatt), customer-sited solar PV installations, such as rooftop panels, accounted for about one-tenth of the state's solar generation (EIA, 2021).

Appendix Q

Successful Implementation of Carbon Pricing

Domestic carbon pricing initiatives have been implemented and strengthened as jurisdictions around the world adopt more ambitious climate targets (World Bank Group, 2020). In 2020 and 2021, many countries scaled up their emission reduction pledges under the Paris Agreement (World Bank Group, 2020). As countries have proposed more aggressive emission reduction targets and pledges, carbon pricing initiatives have expanded. Today, there are 61 carbon pricing initiatives in place or scheduled for implementation (World Bank Group, 2020). Among the 61, there are 31 ETSs and 30 carbon taxes, accounting for 12 gigatons of carbon dioxide equivalent ($GtCO_2e$), or about 22% of global GHG emissions (World Bank Group, 2020).

In the U.S., there is no ETS or carbon tax policy implemented at the federal level. However, various states have developed their own carbon pricing initiatives[21]. These states' market-based pricing policies have proved effective at reducing emissions and can serve as models for other states and for guiding national policy.

Northeast United States

Through the Regional Greenhouse Gas Initiative (RGGI), eleven Northeast states jointly capped emissions associated with their energy sector. Launched in 2009, RGGI was the first U.S. cap-and-trade program to reduce carbon dioxide emissions from the energy sector (C2ESb, n.d.). The RGGI participants include Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, Vermont, and Virginia.

The RGGI requires fossil fuel power plants with a capacity greater than 25 MW to obtain an allowance for each ton of CO_2 emitted annually. These allowances can be purchased from quarterly auctions, other generators within RGGI, or through projects that offset CO_2 emissions. Programs funded with RGGI investments have benefitted local businesses, low-income communities, industrial facilities, and households throughout the regions (RGGI, 2021). According to The Investment of RGGI Proceeds in 2019 report, lifetime benefits of RGGI investments include $1.8 billion in energy bill savings, 2.5 million short tons of CO_2 avoided, 21.8 MMBTU of fossil fuel use avoided, and 5.6 million MWh of electricity use avoided (see Table Q-1 below). Additionally, in 2019, the RGGI states derived 50% of total generation from clean or renewable sources.

[21] All carbon pricing initiatives in the U.S. are ETS'.

Category	Annual Benefits of 2019 Investments	Lifetime Benefits of 2019 Investments
Short Tons CO_2 Avoided	48,816	857,471
MWh Avoided*	194,173	3,467,464
MMBtu Avoided	19,388	406,147
Energy Bill Savings	$31,317,999	$596,188,665

*RGGI investments in clean and renewable energy decrease the electricity generated from marginal generating units, which are typically more expensive and carbon-intensive.

Table Q-1: Benefits of 2019 RGGI Investments in Clean Energy. Source: The Investment of RGGI Proceeds (2019).

Apart from the financial benefits gained, a recent analysis of the states participating in the RGGI found that net economic benefits and job creation were highest in states with the greatest levels of energy reinvestments (Hibbard et al., 2015). Although these impacts are quite small on a global scale, the RGGI could prove to be extremely beneficial if the remaining states in the U.S. adopted this policy.

Washington

In 2021, the governor of Washington signed the state's Climate Commitment Act. The Act creates and implements a cap-and-invest program by 1) limiting emissions from covered economic entities, 2) distributing allowances, and 3) establishing a climate investment account for revenues from allowances (C2ESb, n.d.). This program will cover entities emitting at least 25,000 tCO_2e per year and use the revenue from those entities to deploy clean energy, reduce GHGs on overburdened communities, grant transition assistance for fossil fuel workers, and aid programs to increase resilience to wildfires (C2ESb, n.d.). This cap-and-invest initiative, coupled with other carbon-reducing efforts, will be implemented with the goal that Washington will reach their net-zero emissions target by 2050.

California

In 2013, California adopted the first multi-sector cap-and-trade program in North America (C2ESa, n.d.). Unlike the RGGI, which covers only the power sector, California's cap-and-trade policy is more ambitious, covering nearly the entire state economy (C2ESb, n.d.). In implementing this more progressive action, California hopes to achieve 100% carbon-free electricity by 2045 (C2ESa, n.d.).

From the start of the program in 2013 to 2017, statewide GHG emissions have decreased 5.3%, with $12.5 billion generated in revenue. These funds are deposited into the state's Greenhouse Gas Reduction Fund and then appropriated to state agencies which are required to direct 35% of the funds to environmentally-disadvantaged and low-income communities (C2ESa, n.d.).

Around the Globe

Carbon pricing policies are a popular climate mitigation mechanism in numerous countries across the globe. A few of these countries include Argentina, Canada, Chile, China, Columbia, Denmark, Japan, Mexico, the UK, the European Union's 27 countries, and many others. A recent 2021 world map below (Figure Q-1) shows areas that have an ETS or carbon tax implemented, and/or areas that are genuinely considering implementing an ETS or a carbon tax.

Although many of these policies differ in their carbon price or tax, combined they account for a substantial source of revenue. Globally, governments have raised $45 billion in 2019 from carbon pricing initiatives, with over half of this money going into environmental or developmental projects (World Bank Group, 2020).

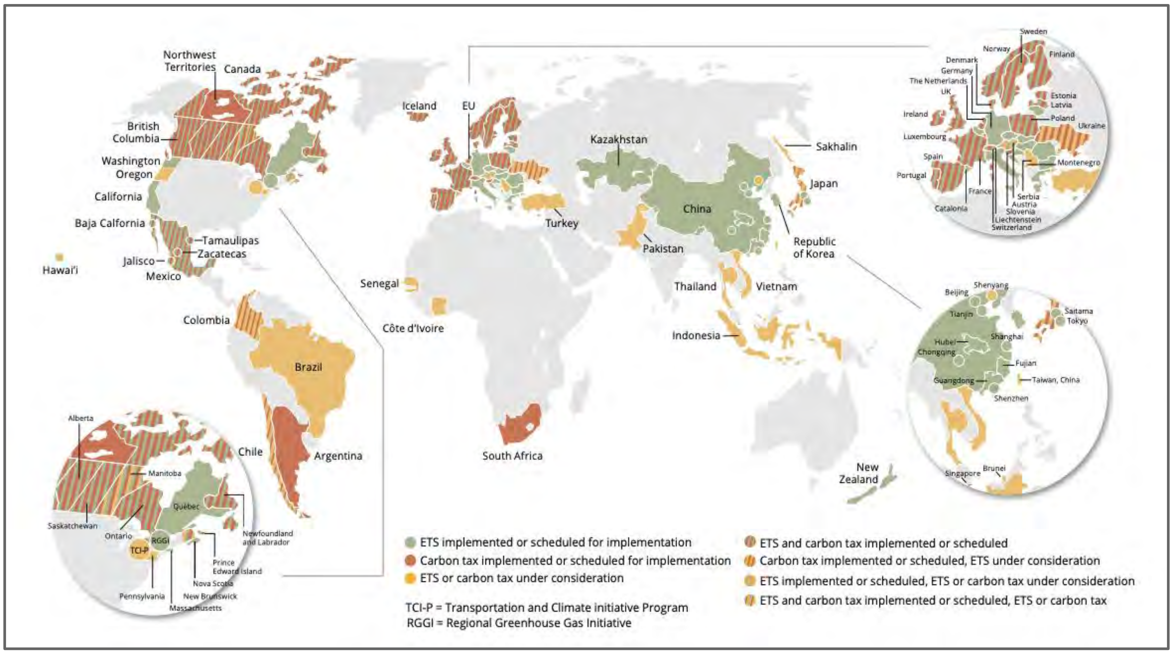


Figure Q-1: Carbon Pricing Map (2021). Source: States and Trends of Carbon Pricing 2021; World Bank Group (2021).

Appendix R

Successful Implementation of an RPS in the United States

Since the 1980s, beginning with Iowa in 1983, RPS policies have been implemented at the state level within the United States (Heeter et al., 2019). Thereon, many more states have adopted these standards, and even expanded or renewed their initial targets. As of 2021, renewable portfolio standard (RPS) policies have been enacted in 30 states and the District of Columbia, and they apply to 58% of total U.S. retail electricity sales (Barbose, 2021).

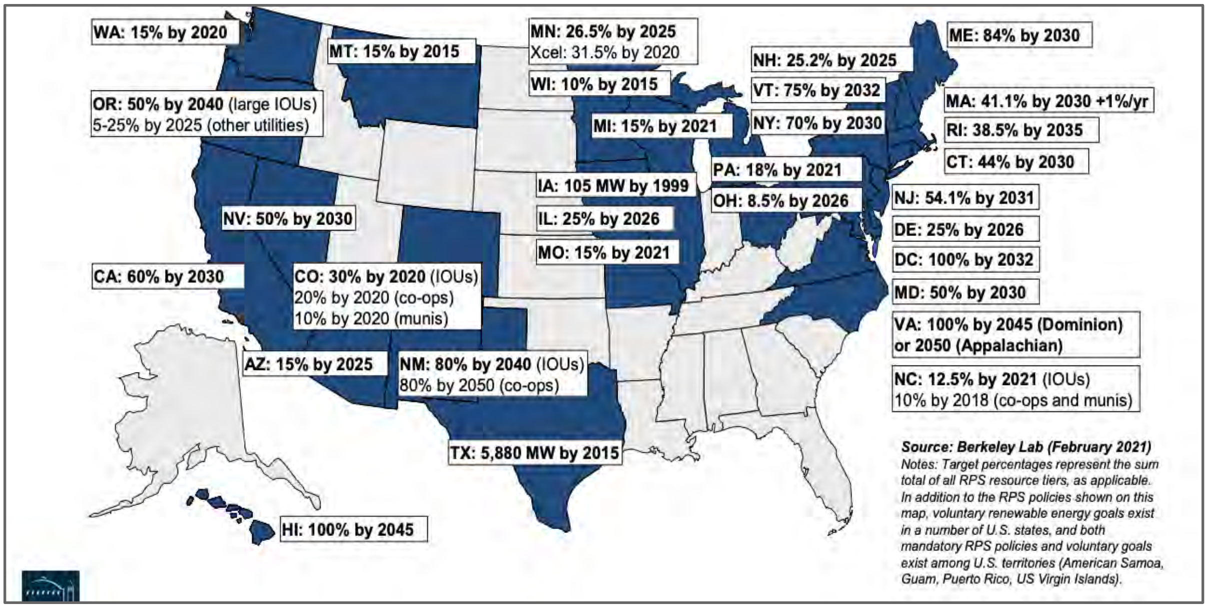


Figure R-1: RPS Policies within 30 States and Washington DC. Adapted from Barbose (2021).

RPS policies are highly adopted in the U.S. because of their positive impacts on the economy, society, and climate. These policies have been a key driver for renewable energy generation growth and have contributed to a 45% increase in total U.S. renewable energy generation since 2000 (Figure R-1; Barbose, 2021). This increase in renewable energy has helped stimulate cost reductions for renewable energy sources and increased industry development (Barbose, 2021).

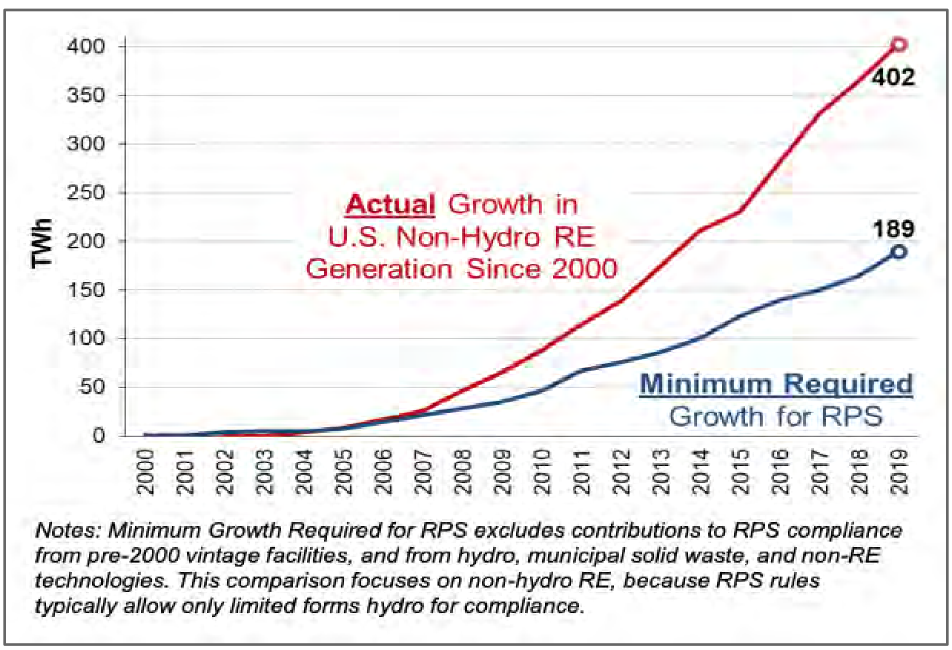


Figure R-2: Growth in Non-Hydro Renewable Generation: 2000 – 2019. Source: Barbose (2021).

Although these policies are common, an RPS is never designed the same in any two states. Therefore, states are able to adapt these policies to their individual goals and renewable energy circumstances. Many policies differ in targets and timeframes, obligated and exempted entities, eligibility rules related to technology, use of carve-outs, existence and design of cost caps, and compliance enforcement methods (Barbose, 2021).

Texas

Established in 1999, Texas's RPS mandated utilities to acquire 1280 megawatts (MW) of generating capacity from renewable technologies by 2003, 1730 MW by 2005, and 2880 MW by 2009 (equal to 3% of total capacity) (ILSR, 2022). Utilities met and exceeded these goals; so, in 2005, the Texas Legislature doubled the standards. The new goals call for 5,880 MW of new renewables to be installed by 2015 and 10,000 MW to be installed by 2025 (equal to 10% of the state's electricity) (ILSR, 2022). According to the annual compliance report[22], Texas surpassed its 2025 goal in 2009 and had 26,045 MW of additional renewable energy capacity in 2017 relative to 1999 (Electric Reliability Council of Texas, n.d.). Texas was able to successfully accomplish its goal early due to its well-structured and detailed RPS. The RPS applies to investor-owned utilities and retailer suppliers, and includes eligible technologies such as solar, wind, geothermal, hydroelectric, wave or tidal energy, and biomass or biomass-based waste products including landfill gas (ILSR, 2022).

California

California's RPS was established in 2002 and applied to investor-owned utility and municipal utility sectors. It requires clean energy goals of 44% by 2024, 52% by 2027, 60% by 2030, and 100% by 2045 (NCSL, 2021). Although these goals are ambitious, California is already meeting and exceeding expectations. Based on reported electric generation from RPS-eligible sources divided by forecasted electricity sales for 2019, the California Energy Commission (CEC) estimates that 36% of retail electricity sales were served by RPS-eligible renewable resources, as shown in Figure R-3 below. This was attainable due to California's solar generation increase of over 350% since 2016 (California Energy Commission, 2020).

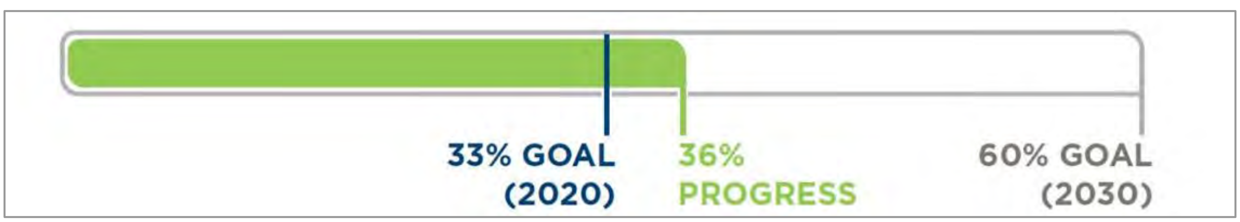


Figure R-3: Estimated Current Renewables Portfolio Standard Progress. Source: CEC staff analysis (2019).

Additionally, carbon-free energy, including large hydroelectric generation and nuclear as RPS-eligible renewables, accounted for 63% of the state's electricity retail sales in 2019 (see Figure R-4). Therefore, contributing to the drop of 50 million tons of CO_2e emissions in the

[22] Prepared by the Electric Reliability Council of Texas (ERCOT): https://sa.ercot.com/rec/home

electricity sector in California (University of California, 2019). This sets the example that even for large states with a high demand for electricity, an RPS is a feasible and effective option.

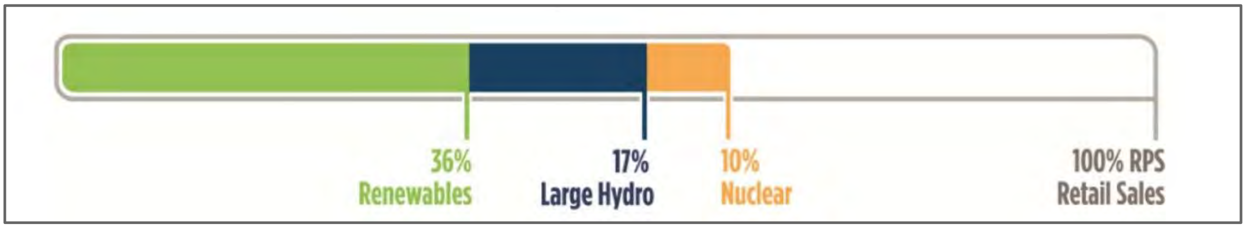


Figure R-4: Estimated 2019 RPS-Eligible Renewables, Large Hydroelectric, and Nuclear Percentages of Retail Sales. Source: CEC staff analysis (2020).

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