Hawai‘i Greenhouse Gas Emissions Report for 2022

Final Report

April 2025

Prepared for:

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Acronyms and Abbreviations

AAPFCO	Association of American Plant Food Control Officials
AD	Anaerobic Digestion
ADI	Airline Data Inc.
AFOLU	Agriculture, Forestry, and Other Land Use
AG	Aboveground Residue
AR4	IPCC Fourth Assessment Report
AR5	IPCC Fifth Assessment Report
BAU	Business-as-Usual
Bbtu	Billion British Thermal Units
BE	Burning Efficiency
BEV	Battery Electric Vehicle
B_O	Maximum Potential Emissions
BOD	Biochemical Oxygen Demand
BTS	Bureau of Transportation Statistics
C	Carbon
CARB	California Air Resources Board
CbE	Combustion Efficiency
CCAP	Coastal Change Analysis Program
CE	Collection Efficiency
CF	Carbon Fraction
CFCs	Chlorofluorocarbons
CFac	Correction Factor
CH_4	Methane
CKD	Cement Kiln Dust
CO_2	Carbon Dioxide
CO_2 Eq.	Carbon Dioxide Equivalent
CS	Carbon Stored
DBEDT	Department of Business, Economic Development, and Tourism
DE	Destruction Efficiency
DLNR	Department of Land and Natural Resources
dm	Dry Matter
DMF	Dry Matter Fraction
DOC	Department of Commerce
DOE	Department of Energy
DOH	Department of Health
DOT	Department of Transportation

ECHO	Enforcement and Compliance History Online
EF	Emission Factor
EV	Electric Vehicle
EIA	Energy Information Administration
EIIRP	Energy Industry Information Reporting Program
EPA	U.S. Environmental Protection Agency
FCF	Fossil Carbon Fraction
FHWA	Federal Highway Administration
FOD	First Order Decay
FOFEM	First-Order Wildland Fire Effect Model
g	Gram
gal	Gallon
GHG	Greenhouse Gas
GHGRP	Greenhouse Gas Reporting Program
GSP	Gross State Product
GWP	Global Warming Potential
ha	Hectare
HAR	Hawaiʻi Administrative Rule
HB	House Bill
HCFCs	Hydrochlorofluorocarbons
HECO	Hawaiian Electric Company
HELCO	Hawaiʻi Electric Light Company
HFCs	Hydrofluorocarbons
HHV	High Heat Value
H-POWER	Honolulu Program of Waste Energy Recovery
IBF	International Bunker Fuels
ICC	Initial Carbon Content
IEA	International Energy Agency
IMO	International Maritime Organization
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
IW	Incinerated Waste
Kg	Kilogram
Km	Kilometer
Kt	Kiloton
lb	Pound
KIUC	Kauaʻi Island Utility Cooperative
LEV	Low-Emission Vehicle
LFC	Landfill Carbon
LFYTFS	Landfill Yard Trimmings and Food Scraps

LMOP	Landfill Methane Outreach Program
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, Land Use Change, and Forestry
m	Meter
MC	Moisture Content
MCF	Methane Conversion Factor
MECO	Maui Electric Company
mi	Mile
MG	Methane Generated
MMBtu	Million Metric British Thermal Units
MMT	Million Metric Tons
MPGGe	Miles per Gallon of Gasoline Equivalent
mscf	Thousand standard cubic feet
MSW	Municipal Solid Waste
MT	Metric Tons
MWh	Megawatt Hour
N	Nitrogen
NA	Not Applicable
NASF	National Association of State Foresters
NASS	National Agriculture Statistics Service
NE	Not Estimated
NEI	National Emission Inventory
NEU	Non-Energy Uses
Nex	Nitrogen Excretion Rate
N_2O	Nitrous Oxide
NO	Not Occurring
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
ODS	Ozone Depleting Substances
OECD	Organisation for Economic Co-operation and Development
OEMs	Original Equipment Manufacturers
OF; OX	Oxidation Factor
PDF	Probability Density Function
PFCs	Perfluorocarbons
PHEV	Plug-in Hybrid Electric Vehicle
PHMSA	Pipeline and Hazardous Materials Safety Administration
RDF	Refuse-Derived Fuel
RECS	Residential Energy Consumption Survey
RNG	Renewable Natural Gas
SEDS	State Energy Data System

SF_6	Sulfur Hexafluoride
SIT	State Inventory Tool
SNG	Synthetic Natural Gas
TAM	Typical Animal Mass
TJ	Terajoule
TVA	Tennessee Valley Authority
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
Urea	$CO(NH_2)_2$
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
VMT	Vehicle Miles Traveled
VS	Volatile Solids
WF	Waste Fraction
WMS	Waste Management System
WWTP	Wastewater Treatment Plant

Acknowledgments

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Executive Summary

The State of Hawaiʻi is committed to reducing its contribution to global climate change and has taken efforts to measure and reduce statewide greenhouse gas (GHG) emissions. In 2007, the State of Hawaiʻi passed Act 234, Session Laws of Hawaiʻi 2007 (Act 234 of 2007), to establish the state's policy framework and requirements to address GHG emissions. The law sought to achieve emission levels at or below Hawaiʻi's 1990 GHG emissions by January 1, 2020 (excluding emissions from airplanes). In 2008, the State of Hawaiʻi developed statewide GHG emission inventories for 1990 and 2007. To help Hawaiʻi meet the emissions target, Hawaiʻi Administrative Rules (HAR), Chapter 11-60.1 was amended in 2014 to establish a facility-level GHG emissions cap for large existing stationary sources with potential GHG emissions at or above 100,000 tons of CO_2 Eq. per year. In recent years, further GHG emissions goals have been set. Act 238, Session Laws of Hawaiʻi 2022 (Act 238 of 2022), established a goal for the level of statewide GHG emissions to be at least 50 percent below 2005 levels by the year 2030, and that the measurement of GHG emissions for the year 2005 include emissions from airplanes. Act 15, Session Laws of Hawaiʻi 2018 (Act 15 of 2018), established a statewide carbon net-negative goal by 2045. In an effort to track progress toward achieving the state's 2020, 2030, and 2045 GHG reduction goals, this report presents updated 1990, 2005, 2007, 2010, 2015, 2016, 2017, 2018, 2019, 2020, and 2021 emissions estimates;[1] emissions estimates developed for 2022; and emission projections for 2025, 2030, 2035, 2040, and 2045.

Based on the analysis presented in this report, net GHG emissions (excluding aviation) in 2020 are estimated to have been lower than net GHG emissions (excluding aviation) in 1990 pursuant to Act 234[2]. Net GHG emissions (including aviation) in 2030 are projected to be greater than the target emissions level of 50 percent below 2005 levels (including aviation) pursuant to Act 238, and in 2045 are projected to be greater than the target of net-negative levels pursuant to Act 15. While the development of future inventory reports as well as ongoing quantitative assessment of uncertainties will further inform whether Hawaiʻi will meet the 2030 and 2045 statewide targets, this report finds that Hawaiʻi met the 2020 target, but—given existing policies, anticipated adoption of technologies, and economic expectations—is not expected to meet the 2030 and 2045 targets.

Background

Greenhouse gases trap heat in the atmosphere by absorbing infrared radiation and thereby warm the planet. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O),

[1] It is best practice to review GHG emission estimates for prior years and revise these estimates as necessary to account for updated activity data and improved methodologies or for emission factors that reflect advances in the field of GHG accounting.
[2] Net emissions account for both GHG emissions and carbon sinks.

hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). The amount of warming caused by each GHG depends on how effectively the gas traps heat (radiative efficiency) and how long it stays in the atmosphere (lifetime). The Intergovernmental Panel on Climate Change (IPCC) developed the Global Warming Potential (GWP) concept to compare the ability of each GHG to trap heat in the atmosphere relative to the reference gas, CO_2 (IPCC 2014). Specifically, GWPs measure how much energy the emissions of 1 ton of gas will absorb relative to 1 ton of CO_2 over a specified time period. Therefore, throughout this report, the relative contribution of each gas is shown in million metric tons of carbon dioxide equivalent (MMT CO_2 Eq). The GWP values used in this report are from the IPCC *Fifth Assessment Report* (AR5) (IPCC 2013), assuming a 100-year time horizon.[3]

Inventory Scope and Methodology

The GHG emission estimates presented in this report include anthropogenic[4] GHG emissions and sinks for the state of Hawaiʻi for 1990, 2005, 2007, 2010, 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2022 from the following four sectors: Energy; Industrial Processes and Product Use (IPPU); Agriculture, Forestry, and Other Land Use (AFOLU); and Waste, and primarily serve the federal mandatory GHG reporting requirements in accordance with 40 Code of Federal Regulations (CFR) 98 (EPA 2021a). This report includes on-island[5] GHG emissions only. Lifecycle emission estimates are not included – only emissions occurring within the physical boundaries of the islands that constitute the State of Hawaiʻi. For example, all emissions estimated for the agriculture sector, such as farming activities, represent on-island emissions only, such as direct emissions from the fuel, energy, and farming operations, but exclude upstream emissions from the production of fuel used by the farming equipment, or the emissions related to the manufacturing of fertilizers and pesticides.

As it is best practice to review GHG emission estimates for prior years, this report includes revised estimates for 1990, 2005, 2007, 2010, 2015, 2016, 2017, 2018, 2019, 2020, and 2021 and newly developed estimates for 2022. ICF relied on the best available activity data, emission factors, and methodologies to develop emission estimates presented in this report. Activity data varies for each source or sink category; examples of activity data used include fuel consumption, vehicle-miles traveled, raw material processed, animal populations, crop production, land area, and waste landfilled. Emission factors relate quantities of emissions to an activity (EPA 2024b). Key guidance and resources included the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, *the 2019 Refinements to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, the U.S. Environmental Protection Agency's

[3] Recent decisions under the Paris Agreement and the UNFCCC require Parties to use 100-year GWP values from the IPCC Fifth Assessment Report (AR5) for calculating CO_2-equivalents in their national reporting (IPCC 2013) by the end of 2024. This reflects updated science and ensures that greenhouse gas inventories are comparable. This report uses AR5 100-year GWPs for comparability with the national inventory and alignment with UNFCCC best practices.

[4] Anthropogenic greenhouse gas emissions are those that originate from human activity.

[5] Domestic interstate activities originating in Hawaiʻi (e.g., flights from Honolulu to Los Angeles) are also included in Hawaiʻi inventory totals.

(EPA) Greenhouse Gas Reporting Program (GHGRP), the EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022*, and EPA's State Inventory Tool (SIT).

Quality Assurance and Quality Control (QA/QC)

ICF implemented a number of quality assurance and quality control measures during the process of developing this inventory to ensure inventory accuracy as well as to improve the quality of the inventory over time. This includes the evaluation of the quality and relevance of data inputs; proper management, incorporation, and aggregation of data in a series of Excel workbooks; review of the numbers and estimates; and clear documentation of the results and methods. As part of these activities, representatives from the Department of Health (DOH) as well as a group of other government entities reviewed the results.[6] ICF incorporated the comments and feedback provided by the review team into this report.

Uncertainty of Emission Estimates

Uncertainty is a component of each calculated result; thus, some degree of uncertainty in GHG estimates is associated with all emission inventories. This uncertainty (e.g., systematic error) can be attributed to several factors such as incomplete data, uncertainty in the activity data collected, the use of average or default emission factors, the use of national data where state-specific data were unavailable, and uncertainty in scientific understanding of emission pathways. For some sources (e.g., CO_2 emissions from fuel combustion), emissions are relatively well understood, and uncertainty is typically low and largely dependent on the accuracy of activity data. For other sources (e.g., CH_4 and N_2O emissions from wastewater and CO_2 emissions from agricultural soil carbon), emission estimates typically have greater uncertainty.

The intent of an uncertainty analysis is not to dispute the validity of the inventory estimates—which are developed using the best available activity data, emission factors, and methodologies available—but rather to guide prioritization of improvements to the accuracy of future inventories (EPA 2024b). For this report, quantitative uncertainty estimates for statewide emissions were developed using the IPCC Approach 2 uncertainty estimation methodology, which is considered the more robust approach of the two approaches provided by IPCC. Uncertainties in the emission calculations for sources in the AFOLU sector are driving the overall uncertainty for total emissions. Uncertainties in the emission calculations for sources and sinks in the AFOLU sector are driving the overall uncertainty for net emissions.

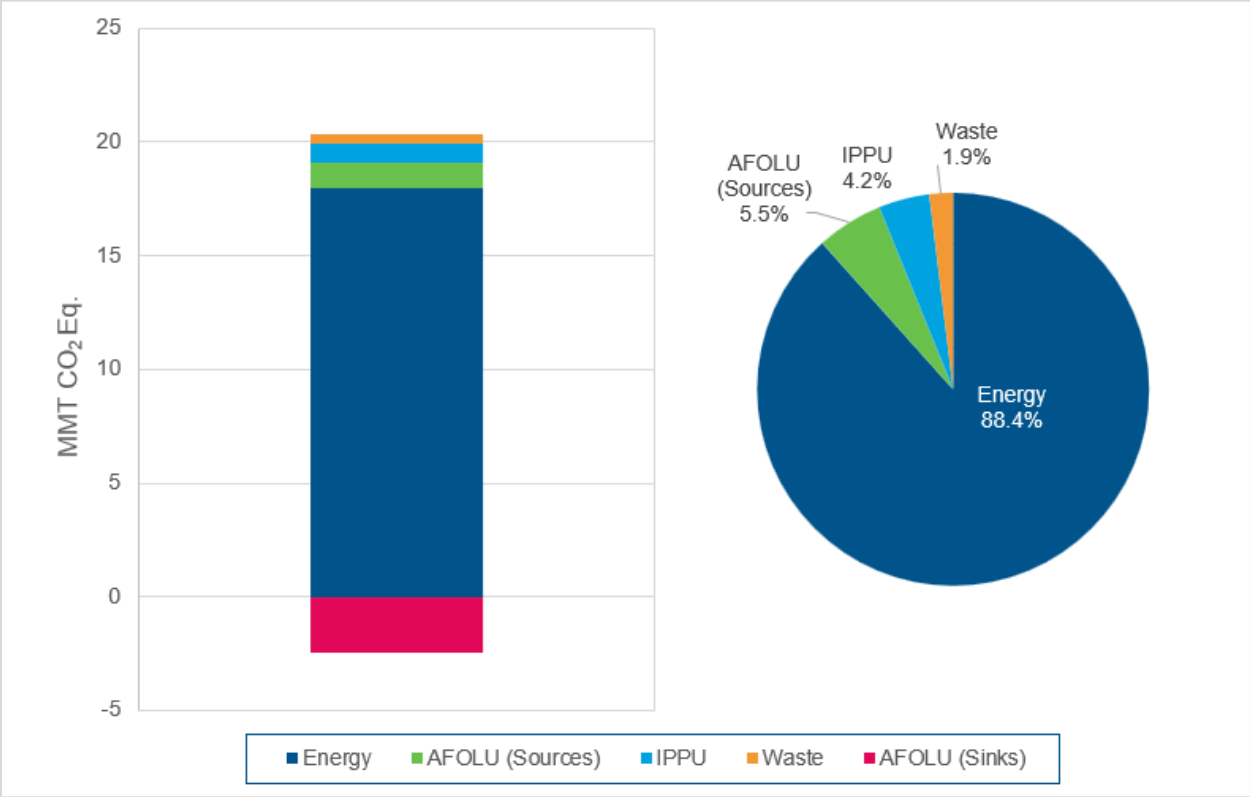
Emission Results

In 2022, total GHG emissions in Hawai'i were 20.32 MMT CO_2 Eq. Net emissions, which take into account carbon sinks, were 17.83 MMT CO_2 Eq. Emissions from the Energy sector accounted for the largest

[6] The review team included representatives from the Hawai'i Department of Business, Economic Development & Tourism (DBEDT), Division of Consumer Advocacy (DCA), and Public Utilities Commission (PUC).

portion of total emissions in Hawai‘i, followed by the AFOLU sector (when excluding sinks), the IPPU sector, and the Waste sector. Figure ES-1 below illustrates the emissions results for the new inventory year by sector.

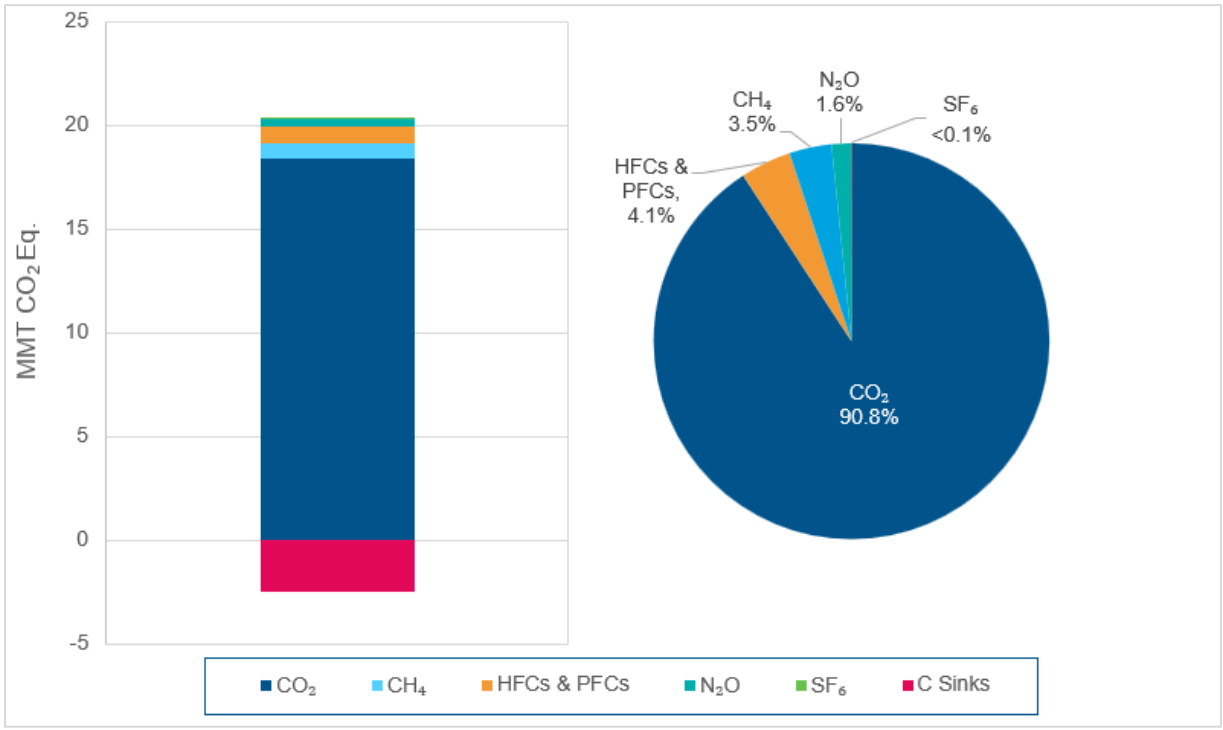
Figure ES-1: Hawai‘i 2022 GHG Emissions by Sector (Including Aviation) and Relative Contribution of Sector



Note: Emissions estimates include aviation emissions.

Carbon dioxide was the largest single contributor to statewide GHG emissions in 2022. HFCs and PFCs were the second largest contributor, followed closely by methane, nitrous oxide, and sulfur hexafluoride. Figure ES-2 shows emissions for the new inventory year, by gas.

Figure ES-2: Hawai‘i 2022 GHG Emissions by Gas

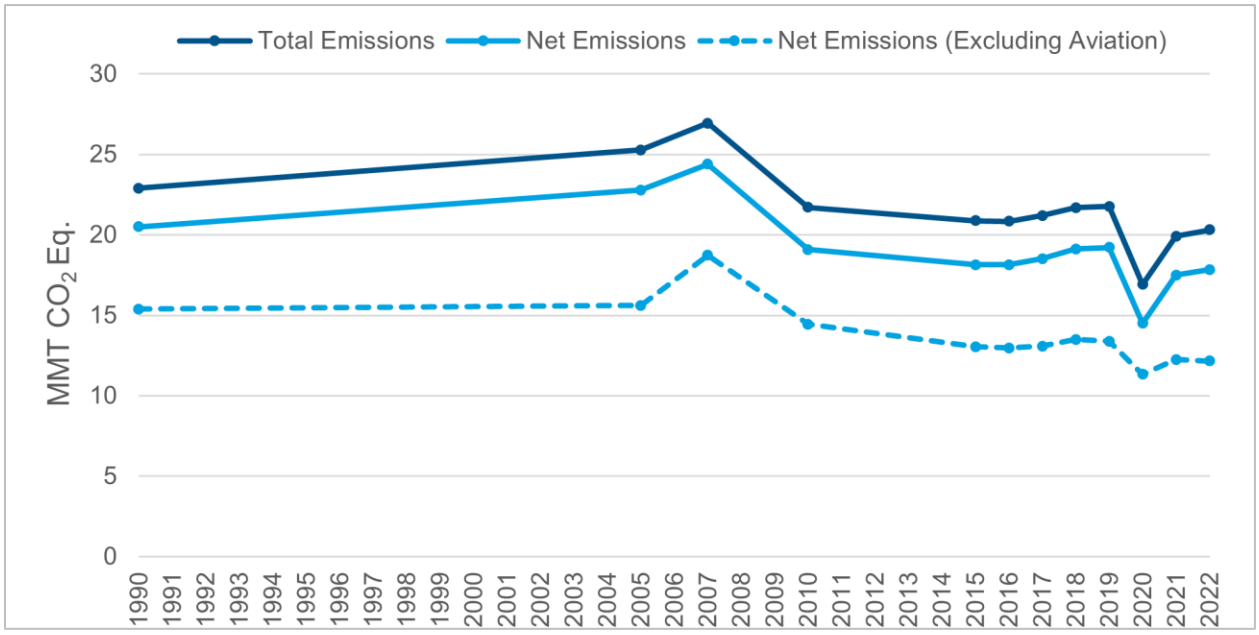


Notes: Totals may not sum due to independent rounding. Percentages represent the percent of total emissions excluding sinks and including aviation.

Emissions Trends

Total GHG emissions in Hawai‘i steadily increased from 1990 to 2007 before experiencing an overall decrease from 2007 to 2022. Net emissions followed a similar trend. Figure ES-3 below shows emissions for each inventory year. Statewide emissions and sinks by sector and source category for all inventory years are available in Table L-1.

Figure ES-3: Hawai'i Emissions Trends (MMT CO_2 Eq.)



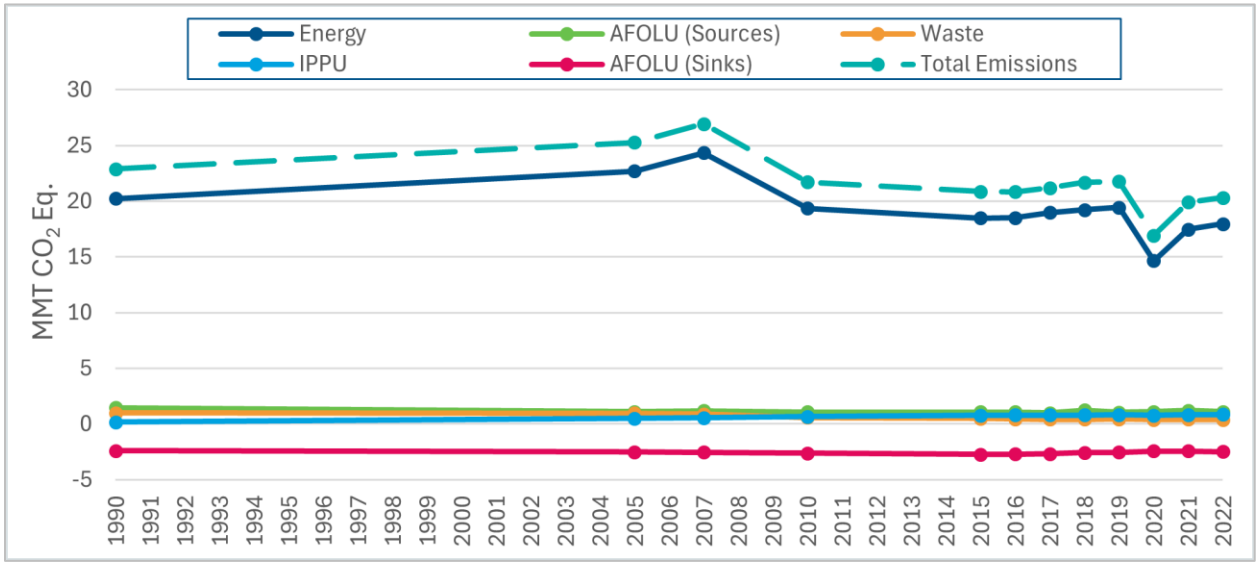
Notes: Emission estimates include sinks and domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Figure ES-4: Hawai'i GHG Emissions by Sector (Including Sinks and Aviation) shows GHG emissions by sector (including sinks and aviation) for each inventory year in Hawai'i. In all inventory years, emissions from the Energy sector accounted for the largest portion (more than 85 percent) of total emissions in Hawai'i. As the largest source of emissions in Hawai'i, the Energy sector is a major driver of the overall emissions trends, accounting for 81.4 percent of the emissions increase from 1990 to 2007 and 87.5 percent of reductions between 2007 and 2022. Transportation emissions—which increased between 1990 and 2007, and then decreased through 2022—accounted for the largest share of Energy sector emissions in all inventory years. Stationary combustion emissions—which similarly increased between 1990 and 2007, before decreasing through 2022—are the second largest share of Energy sector emissions. This trend is driven by emissions from energy industries (electric power plants and petroleum refineries) as well as industrial and commercial emissions. The decrease in energy emissions is largely due to reduced fuel consumption across all subsectors, which is driven by increased energy efficiency and the growth of renewable energy.

The year 1990 marked peak emissions from AFOLU sources during the time period evaluated; emissions from AFOLU sources decreased by about 24.0 percent between 1990 and 2022. Similarly for the Waste sector, the year 1990 marked peak emissions during the time period evaluated and emissions decreased by about 60.7 percent between 1990 and 2022. Emissions from the IPPU sector have steadily increased since 1990 and were more than four times higher in 2022 compared to 1990 levels. The increase in IPPU emissions is attributable to the growth in HFC and PFC emissions from substitution of ODS; there is no longer cement production in Hawai'i, and emissions from electrical transmission and distribution has

decreased over the time period 1990 to 2022. Lastly, carbon removals from AFOLU sinks have also increased since 1990, growing by roughly 3.6 percent between 1990 and 2022.

Figure ES-4: Hawai'i GHG Emissions by Sector (Including Sinks and Aviation)



Notes: Emission estimates include sinks and domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Additionally, county level emissions were estimated for 2022. In 2022, Honolulu County accounted for the largest share of net GHG emissions (71.3 percent), followed by Maui County[7] (15.3 percent), Hawai'i County (8.6 percent), and Kaua'i County (4.8 percent). More information on emissions by county can be found in Section 2.3.

Emission Projections

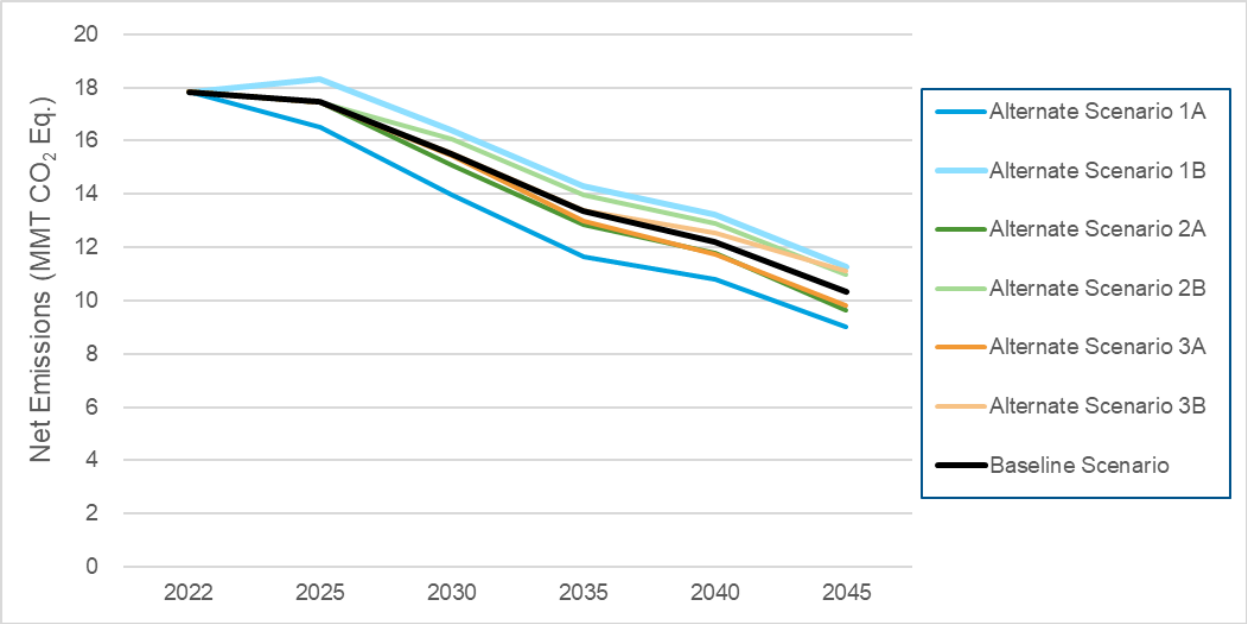
The projections analysis uses a combination of top-down and bottom-up approaches to develop baseline projections of statewide and county-level GHG emissions for the years 2025, 2030, 2035, 2040, and 2045. The projections for several sources (residential, commercial, and industrial energy use, domestic and international aviation, non-energy uses, composting and wastewater treatment) are based on either a long-range forecast for gross state/county product or future population (including visitor arrivals), using the 2022 statewide GHG inventory as a starting point. Source-specific approaches were taken for several small categories. For example, electricity sales forecasts were used to project GHG emissions for electrical transmission and distribution. Emissions for agriculture, forestry, and other land use (AFOLU) categories and landfill waste are projected by forecasting activity data using historical trends and published information available on expected future trends. Bottom-up approaches are used

[7] Maui County includes emissions from Kalawao County.

for GHG emitting sources with substantial federal and state policy intervention (energy industries, substitution of ozone depleting substances, and transportation). Due to policies that affect these sources, projected economic activities are only one component of future GHG emissions. Therefore, a more comprehensive sectoral approach was used to develop baseline projections for these emission sources.

Figure ES-5 shows net GHG emissions for the current inventory year and projected inventory years under different scenarios. In addition to the baseline scenario, three major points of uncertainty, namely world oil prices, renewable energy deployment, and ground transportation technology adoption, were assessed by modeling six alternate scenarios for statewide GHG emissions in 2025, 2030, 2035, 2040, and 2045. Alternate Scenario 1A and 1B are based on world oil prices. This alternate scenario looks at both high (Alternate Scenario 1A) and low (Alternate Scenario 1B) future oil price pathways. Alternate Scenario 2A and 2B are based on renewable energy deployment. Alternate Scenario 2A assumes a more aggressive path for renewable energy deployment than the Baseline Scenario. Alternate Scenario 2B projects renewable energy deployment based on the rate of deployment since 2016. Alternate Scenario 3A and 3B are based on ground transportation technology adoption. This alternate scenario creates a high EV adoption scenario (Alternate Scenario 3A) and a low EV adoption scenario (Alternate Scenario 3B). Hawai‘i GHG emissions for 1990, 2005, 2020, and 2022 and projections of statewide emissions and sinks by sector for 2025, 2030, 2035, 2040, and 2045 are summarized in Table ES-1.

Figure ES-5: Hawai‘i Net GHG Emissions Projections (MMT CO2 Eq.) (Including Sinks and Aviation)



Note: Emission estimates include sinks and domestic aviation emissions.

Table ES-1: Hawai'i GHG Emissions for 1990, 2005, 2020, and 2022 and Projections by Sector under the Baseline Scenario for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.) (Including Sinks, Excluding Aviation)

	Historical Emissions				Projections				
Sector	**1990**	**2005**	**2020**	**2022[a]**	**2025**	**2030**	**2035**	**2040**	**2045**
Energy[b]	20.25	22.72	14.66	17.95	17.69	15.92	14.08	13.25	11.52
IPPU	0.18	0.50	0.76	0.85	0.80	0.66	0.44	0.28	0.26
AFOLU (Sources)	1.47	1.10	1.10	1.11	1.03	0.98	0.93	0.89	0.85
AFOLU (Sinks)	(2.40)	(2.50)	(2.43)	(2.48)	(2.44)	(2.41)	(2.44)	(2.52)	(2.60)
Waste	1.01	0.98	0.41	0.40	0.36	0.35	0.34	0.33	0.32
Total Emissions (Excluding Sinks)	**22.90**	**25.29**	**16.93**	**20.32**	**19.89**	**17.91**	**15.79**	**14.74**	**12.95**
Net Emissions (Including Sinks)	**20.51**	**22.78**	**14.50**	**17.83**	**17.45**	**15.51**	**13.34**	**12.23**	**10.35**
Aviation[c]	5.11	7.16	3.17	5.67	6.10	6.24	6.32	6.38	6.40
Net Emissions (Including Sinks, Excluding Aviation)[c]	**15.40**	**15.62**	**11.33**	**12.16**	**11.35**	**9.26**	**7.02**	**5.85**	**3.94**

[a] Inventory year 2022 is included as it is used as the starting point of emissions projections.
[b] Emissions from international bunker fuels are not included in the totals, as per IPCC (2006) guidelines.
[c] Domestic aviation and military emissions, which are reported under the Energy sector, are excluded from Hawai'i's GHG emission reduction goal established in Act 234 of 2007.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

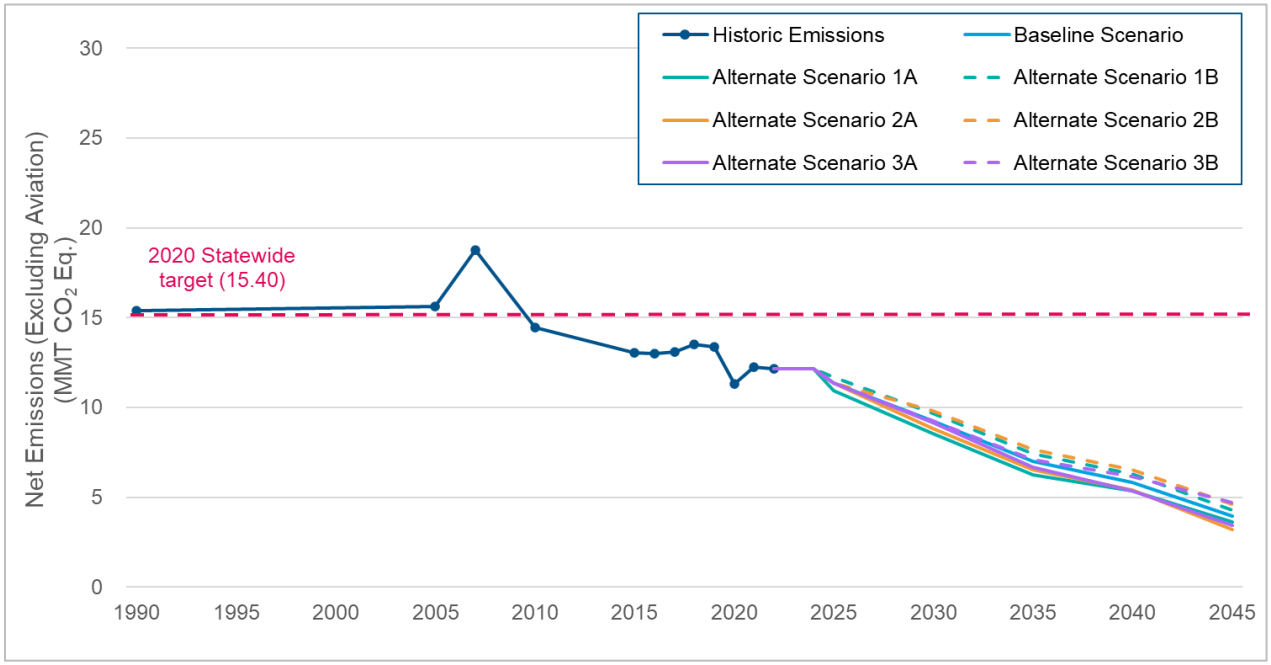
Relative to 2022, total emissions under the baseline scenario are projected to gradually decrease through 2025, with more significant reductions expected through 2045. Over the same period, net emissions, which take into account carbon sinks and are relevant for tracking progress toward the 2030 GHG target pursuant to Act 238 of 2022, are also expected to follow a similar downward trend, with a slight decrease from 2022 to 2025, followed by more substantial decreases through 2045. When excluding aviation, net emissions are projected to decrease at a faster rate, with reductions lower in 2030, 2045, and 2050.

Hawai'i GHG Goals Progress

Progress Towards 2020 GHG Goal: Excluding aviation, 1990 statewide GHG emissions were estimated to be 15.40 MMT CO_2 Eq., which represents the 2020 emission target (statewide GHG emissions must be at or below this level for all years 2020 and beyond). As net GHG emissions (excluding aviation) were 11.33 MMT CO_2 Eq. in 2020, 12.25 in 2021, and 12.16 in 2022, **this report finds that Hawai'i continues to meet the 2020 statewide GHG emissions target** set by Act 234 of 2007.

Figure ES-6 shows net GHG emissions (including sinks, excluding aviation) in Hawai'i for the inventory years presented in this report as well as GHG emission projections for 2025, 2030, 2035, 2040, and 2045 and the 2020 statewide target.

Figure ES-6: Hawai‘i Net GHG Emissions Estimates and Projections (MMT CO_2 Eq.) (Including Sinks, Excluding Aviation)

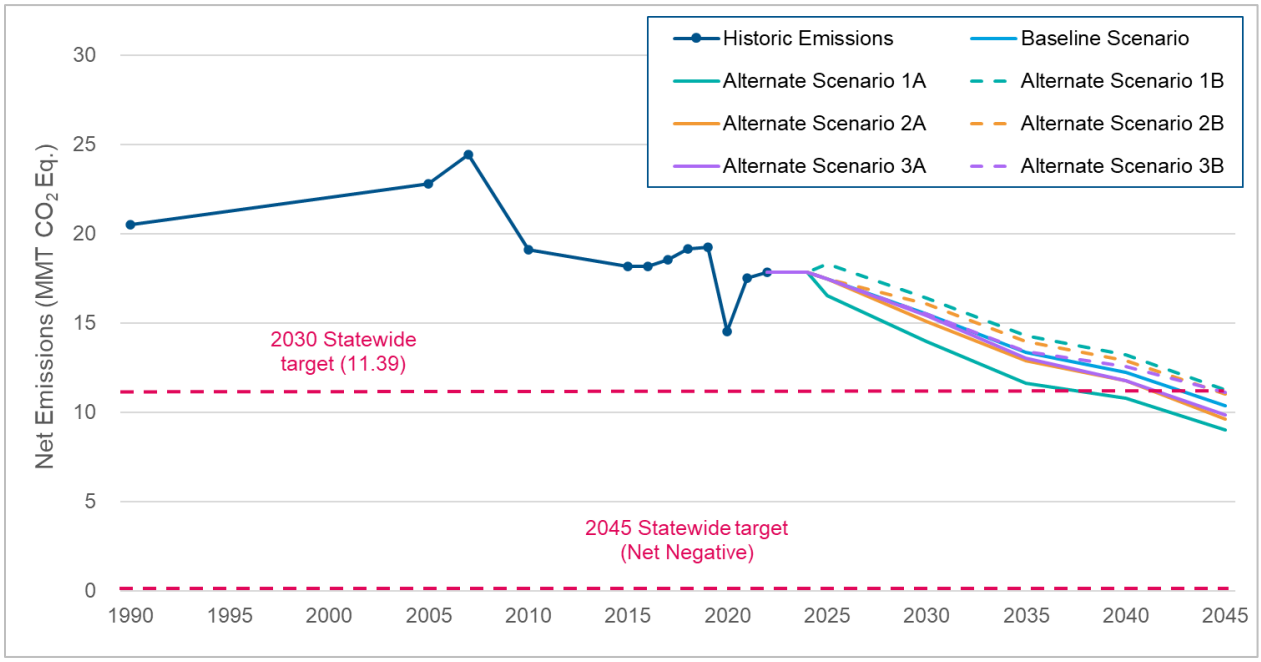


Note: Emission estimates include sinks but exclude domestic aviation emissions.

Progress Towards 2030 and 2045 GHG Goals: Act 15 of 2018 established a net-negative GHG emissions target to be achieved by 2045. In 2022, Act 238 established the interim target of achieving a 50 percent reduction from 2005 net emissions by 2030. Currently, that target is 11.39 MMT CO_2 Eq., but may continue to change with future updates to the 2005 emissions estimate. Net emissions (including sinks) for year 2030 are projected to be between 14.23 – 16.39 MMT CO_2 Eq. in 2030, and 6.00 – 11.29 MMT CO_2 Eq. in 2045. As such, **this report finds that Hawai‘i is currently not on track to meet the 2030 or 2045 statewide emissions targets,** set by Act 238 of 2022 and Act 15 of 2018 respectively.

Figure ES-7 shows net GHG emissions (including aviation) in Hawai‘i for the inventory years presented in this report; GHG emission projections by scenario; and the 2030 and 2045 statewide targets.

Figure ES-7: Hawai'i Net GHG Emissions Estimates and Projections (MMT CO_2 Eq.) (Including Sinks and Aviation)



Note: Emission estimates include sinks and domestic aviation emissions.

1. Introduction

The State of Hawai‘i is committed to reducing our contribution to global climate change and has taken efforts to measure and reduce statewide greenhouse gas (GHG) emissions. In 2007, the State of Hawai‘i passed Act 234 (Act 234 of 2007) to establish the state’s policy framework and requirements to address GHG emissions. The law sought to achieve emission levels at or below Hawai‘i’s 1990 GHG emissions by January 1, 2020 (excluding emissions from airplanes). In 2008, the State of Hawai‘i developed statewide GHG emission inventories for 1990 and 2007. To help Hawai‘i meet the emissions target, Hawai‘i Administrative Rules (HAR), Chapter 11-60.1 was amended in 2014 to establish a facility-level GHG emissions cap for large existing stationary sources with potential GHG emissions at or above 100,000 tons of CO_2 Eq. per year. In recent years, further GHG emissions goals have been set. Act 238, Session Laws of Hawai‘i 2022 (Act 238 of 2022), established a goal for the level of statewide GHG emissions to be at least 50 percent below 2005 levels by the year 2030, and that the measurement of GHG emissions for the year 2005 include emissions from airplanes. Act 15, Session Laws of Hawai‘i 2018 (Act 15 of 2018), established a statewide carbon net-negative goal by 2045. In an effort to track progress toward achieving the state’s 2020, 2030, and 2045 GHG reduction goals, this report presents updated 1990, 2005, 2007, 2010, 2015, 2016, 2017, 2018, and 2019, 2020 and 2021;[8] emissions estimates for 2022; and emission projections for 2025, 2030, 2035, 2040 and 2045.

Excluding aviation, 1990 statewide GHG emissions were estimated to be 15.40 MMT CO_2 Eq.,[9] which represents the 2020 emission target set by Act 234 of 2007 (statewide GHG emissions must be at or below this level for all years 2020 and beyond). Net GHG emissions (excluding aviation) were 11.33 MMT CO_2 Eq. in 2020, 12.25 in 2021, and 12.16 in 2022. Thus, this report finds that Hawai‘i continues to meet the statewide GHG emissions target set by Act 234 of 2007.

Act 15 of 2018 aims to achieve carbon net-negative emission levels by 2045. Act 238 of 2022 sets an interim target at 50 percent of 2005 net emissions or 11.39 MMT CO_2 Eq. (including sinks and aviation) by 2030. Net GHG emissions (including sinks and aviation) are projected to be between 13.93 – 16.86 MMT CO_2 Eq. in 2030, and 6.08 – 11.37 MMT CO_2 Eq. in 2045. The baseline goal (set in Act 238 of 2022), could change with future updates to the 2005 emission estimates, but it is not likely to change significantly. As such, this report finds that Hawai‘i is currently not on track to meet the 2030 or 2045 statewide emissions targets.

[8] It is best practice to review GHG emission estimates for prior years and revise these estimates as necessary to take into account updated activity data and improved methodologies or emission factors that reflect advances in the field of GHG accounting.

[9] Net emissions account for both GHG emissions and carbon sinks.

1.1 Background

Greenhouse gases trap heat in the atmosphere by absorbing infrared radiation and thereby warm the planet. These gases include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). While some of these gases occur naturally in the environment, human activities have significantly changed their atmospheric concentrations. Scientists agree that it is extremely likely that most of the observed temperature increase since 1950 is due to anthropogenic or human-caused increases in GHGs in the atmosphere (IPCC 2013).

The amount of warming caused by each GHG depends on how effectively the gas traps heat and how long it stays in the atmosphere. The Intergovernmental Panel on Climate Change (IPCC) developed the Global Warming Potential (GWP) concept to compare the ability of each GHG to trap heat in the atmosphere relative to the reference gas, CO_2 (IPCC 2013). Throughout this report the relative contribution of each gas is shown in million metric tons of carbon dioxide equivalent (MMT CO_2 Eq.). Recent decisions on common metrics adopted at the 27th United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP27) require Parties to use 100-year GWP values from the IPCC *Fifth Assessment Report* (AR5) (IPCC 2013). The GWP values used in this report, assuming a 100-year time horizon, are summarized in Table 1-1.

Table 1-1: AR5 Global Warming Potentials (GWPs) used in this Report

Gas	GWP
CO_2	1
CH_4	28
N_2O	265
HFC-23	12,400
HFC-32	677
HFC-125	3,170
HFC-134a	1,300
HFC-143a	4,800
HFC-152a	138
HFC-227ea	3,350
HFC-236fa	8.060
HFC-4310mee	1,650
CF_4	6,630
C_2F_6	11,100
C_4F_{10}	9,200
C_6F_{14}	7,910
SF_6	23,500
NF_3	16,100

Note: This inventory uses GWPs with a 100-year time horizon in accordance with Mandatory GHG Reporting (EPA 2021a).
Source: *IPCC Fifth Assessment Report* (AR5) (2013).

The persistence of excess GHGs in the atmosphere has had, and continues to have, significant impacts across the globe. Global climate is being altered, with a net warming effect of the atmosphere and ocean that is causing glaciers and sea ice levels to decrease, global mean sea levels to rise, and an increase in extreme weather events (IPCC 2013). In an effort to better understand the sources and drivers of GHG emissions and to mitigate their global impact, communities and organizations at all levels—including federal governments, state and local jurisdictions, multinational firms, and local enterprises—develop GHG inventories. A GHG inventory quantifies emissions and sinks for a given jurisdictional or organizational boundary. The results of these inventories, which are continually

improved over time to reflect advances in the field of GHG accounting, are then used to inform strategies and policies for emission reductions, and to track the progress of actions over time.

1.2 Inventory Scope

The Climate Impact of Black Carbon

Beyond GHGs, other emissions are known to contribute to climate change. For example, black carbon is an aerosol that forms during incomplete combustion of certain fossil fuels (primarily coal and diesel) and biomass (primarily fuel wood and crop waste). Current research suggests that black carbon has a positive radiative forcing by heating the Earth's atmosphere and causing surface warming when deposited on ice and snow (EPA 2024b, IPCC 2013). Black carbon also influences cloud development, but the direction and magnitude of this forcing is an area of active research (EPA 2024b). There is no single accepted method for summarizing the range of effects of black carbon emissions on the climate or representing these effects and impacts in terms of carbon dioxide equivalent; significant scientific uncertainties remain regarding black carbon's total climate effect (IPCC 2013). Although literature increasingly recognizes black carbon as a major heat source for the planet (Ramanathan and Carmichael 2008, Bond et al. 2013), it is not within the scope of a GHG inventory to quantify black carbon climate impacts.

The GHG emission estimates presented in this Technical Support Document include anthropogenic[10] GHG emissions and natural and anthropogenic sinks[11] within the state of Hawai'i for 1990, 2005, 2007, 2010, 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2022 from the following four sectors:

- **Energy**, including emissions from stationary combustion, transportation, incineration of waste for energy purposes, and oil and natural gas systems.
- **Industrial Processes and Product Use (IPPU)**, including emissions from cement production, electrical transmission and distribution, and substitution of ozone depleting substances.
- **Agriculture, Forestry, and Other Land Use (AFOLU)**, including emissions from agricultural activities, land use, changes in land use, and land management practices. Specifically, this includes emissions from enteric fermentation, manure management, agricultural soil management, field burning of agricultural residues, urea application, agricultural soil carbon, and forest fires, as well as emissions sequestration from landfilled yard trimmings and food scraps, urban trees, and forest carbon.
- **Waste**, including emissions from waste management and treatment activities such as landfills, composting, and wastewater treatment.

[10] The term "anthropogenic," in this context, refers to greenhouse gas emissions and removals that are a direct result of human activities or are the result of natural processes that have been affected by human activities (IPCC 2006).
[11] The sink capacity encompasses both "natural" and "anthropogenic" system states.

This report includes state-originated GHG emissions only. Lifecycle emission estimates are not included – only emissions originating within the physical boundaries of the islands that constitute the State of Hawaiʻi. For example, all emissions estimated for the agriculture sector, such as farming activities, represent on-island emissions only, such as direct emissions from the fuel, energy, and farming operations, but exclude upstream emissions occurring outside Hawaiʻi from the production of fuel used by the farming equipment, or the emissions related to the manufacturing of fertilizers and pesticides.

This inventory was developed in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*[12] and the *2019 Refinements to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*[13], to ensure completeness and allow for comparability of results with other inventories. The inventory accounts for GHG emissions and removals that take place within the physical boundary of the state. While Hawaiʻi imports a range of goods and products that contribute to the generation of GHG emissions outside of the state, these emissions are outside the scope of this inventory and therefore are not reflected in this report. For emissions that are within the scope of this report, results are presented by source and sink category and gas. Appendix A provides a summary of all IPCC source and sink categories as well as the reason for any exclusions from this analysis.

As it is best practice to review GHG emission estimates for prior years, this report includes revised estimates for previous inventory years and newly developed estimates for 2022. The previous inventory year estimates were updated to account for updated activity data and methods, and to ensure time-series consistency across all inventory years. Changes in emission estimates from the 2021 inventory report estimates are largely due to the following:

1. Updates to Hawaiʻi specific data for wastewater treatment plants (WWTP) (e.g., flow rates and BOD_5 National Pollutant Discharge Elimination System [NPDES]). See Section 6.3.
2. Updates to Hawaiʻi specific data for annual area burned in wildfires, soil emissions, urban tree cover, and the distribution of crop and grasslands by county. See Sections 5.6, 5.7, and 5.9.
3. Updates to Hawaiʻi specific data (e.g., historical population numbers). See Sections 5.1 and 5.2.
4. Incorporation of emissions from the consumption of renewable natural gas (RNG) produced by the Honouliuli Wastewater Treatment Plant. See Sections 3.1 and 3.7.
5. A new State Energy Data System (SEDS) category for other petroleum products consumed by the transportation sector was added with biodiesel consumed by the transportation sector, as the new category was determined to only represent biodiesel consumption and is not duplicative of other biodiesel consumption already incorporated in the inventory. See Sections 3.2 and 3.6.
6. The CH_4 emission factor for jet fuel was updated to match updates to the U.S. Greenhouse Gas Inventory. Across the timeseries, the Emission Factor is now zero. See Section 3.2.

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[12] The 2006 IPCC Guidelines are inventory guidelines from the IPCC. These guidelines are still widely in use, as they largely reflect the most up-to-date scientific information for estimating emissions.
[13] The *2019 Refinements to the 2006 IPCC Guidelines* are the most recent inventory guidelines from the IPCC. They reflect the most up-to-date scientific information for estimating emissions, but do not include updates or refinements for each sector. These refinements have been incorporated into emissions calculation methodologies.

Updates to the U.S. Environmental Protection Agency's (EPA) *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022* (hereafter referred to as the U.S. Inventory) also resulted in some minor updates compared to the 2021 report for the sectors that utilize data from the U.S. Inventory, such as agricultural soil carbon, substitution of ozone depleting substances (ODS), and electric transmission and distribution. These and other updates that impacted emission estimates are discussed on a source-by-source basis in the subsequent sections of this report. Appendix B summarizes the changes made to emission estimates since the 2021 inventory report. Appendix C additionally summarizes the effort undertaken to investigate and implement areas for improvement that were identified since the 2017 inventory report.

1.3 Methodologies and Data Sources

ICF relied on the best available activity data, emission factors, and methodologies to develop emission estimates presented in this report. Activity data varies for each source or sink category; examples of activity data used include fuel consumption, vehicle-miles traveled, raw material processed, animal populations, crop production, land area, and waste landfilled. Emission factors relate quantities of emissions to an activity (EPA 2024b).

Key guidance and resources included the *2006 IPCC Guidelines for National Greenhouse Gas Inventories, 2019 Refinements to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories,* EPA's Greenhouse Gas Reporting Program (GHGRP), EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022*, and EPA's State Inventory Tool (SIT).

The *2006 IPCC Guidelines* highlight the standard methodological approaches adopted by the United States and all other Annex 1 (developed) countries that are signatories to the United Nations Framework Convention on Climate Change (UNFCCC). As appropriate and feasible, emissions and removals from source and sink categories included in this report were estimated using methodologies that are consistent with the *2006 IPCC Guidelines*. The methodologies used to estimate emissions align with the IPCC "Tier" approach, which is a useful framework for addressing the combined challenges of data availability and resources, while maintaining transparency and consistency. For most source and sink categories, the *2006 IPCC Guidelines* suggest three tiers: Tier 1 is the most basic; Tier 2 provides an intermediate approach; and Tier 3 is the most resource-intensive (requiring highly specific activity data inputs). Specific data sources and methodologies used to develop estimates are discussed for each source and sink category in the subsequent sections of this report. Where applicable, refinements to the methodologies and emission factors from the IPCC Guidelines were updated to reflect the *2019 Refinements to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.*

1.4 Quality Assurance and Quality Control (QA/QC)

ICF implemented a number of quality assurance and quality control measures during the process of developing this inventory to ensure inventory accuracy as well as to improve the quality of the inventory over time. This includes the evaluation of the quality and relevance of data inputs; proper management, incorporation, and aggregation of data in a series of Excel workbooks; review of the numbers and estimates; and clear documentation of the results and methods.

Evaluation of Data Inputs. As described in the section above, the best available data and methodologies were used to develop the emission estimates presented in this report. This was ensured by referencing data sources used in recent analyses and reports of similar detail and complexity (e.g., the U.S. Inventory), reassessing the relevancy and accuracy of data inputs used to develop previous inventory reports, and conducting targeted data comparisons across multiple data sources.

Data Management. ICF used a series of Excel workbooks to compile and analyze the inventory results. These spreadsheets are clearly labeled and linked, as appropriate, to make them easy to navigate. The calculations are transparent to support error-checking and updating. The spreadsheets incorporate automated error checks to facilitate QA/QC. Prior to the finalization of this report, ICF conducted a multi-level review process was to ensure the accuracy of all results that were transcribed from the workbooks into this report. This review involved (1) updating all links within the workbooks to ensure they link to the latest version of each spreadsheet, (2) reviewing each workbook for #REF errors, (3) cross walking all numbers and figures in the workbooks against the information presented in this report, (4) confirming the descriptions provided in the text of this report are consistent with the data presented in the tables and figures within the report, and (5) and confirming statistics that are cited in multiple sections of this report are consistent throughout the document.

Review of Estimates. ICF reviewed the results of this work against other available data sets and emission estimates. ICF also used EPA's State Inventory and Projection Tool to estimate GHG emissions and sinks for Hawaiʻi using default values and compared the output against the 2022 inventory and the inventory projections for 2025, 2030, and 2045.[14] The results of this comparison are presented and discussed in Appendix K. In addition, the results were reviewed by representatives from the Department of Health (DOH) as well as a group of other government entities.[15] ICF then incorporated the comments and feedback provided by the review team into this report.

Documentation of Results. As documented in this report, all assumptions, methodologies, and data sources used to develop the emission estimates are clearly described. This transparency allows for replication and assessment of these results.

1.5 Uncertainty of Emission Estimates

Uncertainty is a component of each calculated result; thus, some degree of uncertainty in GHG estimates is associated with all emission inventories. This uncertainty (e.g., systematic error) can be attributed to several factors such as incomplete data, uncertainty in the activity data collected, the use of average or default emission factors, the use of national data where state-specific data were unavailable, and uncertainty in scientific understanding of emission pathways. For some sources (e.g., CO_2 emissions from fuel combustion), emissions are relatively well understood, and uncertainty is expected to be low and largely dependent on the accuracy of activity data. For other sources (e.g., CH_4

[14] 2021 is the most recent inventory year available in the SIT as of December 2024.

[15] The review team included representatives from the Hawaiʻi Department of Business, Economic Development & Tourism (DBEDT), Division of Consumer Advocacy (DCA), and Public Utilities Commission (PUC).

and N_2O emissions from wastewater and CO_2 emissions from agricultural soil carbon), emission estimates typically have greater uncertainty. Parameter uncertainty, as quantified in this report, arises from the potential bias or lack of accurate, complete, or representative input data such as emission factors, activity data, and inherent variability. Appendix I provides additional detail on the methodology used to develop the quantitative uncertainty results as well as a discussion on limitations of the analysis. The information presented in these sections should be evaluated as potential focus areas for improvement for future inventory reports.

The intent of an uncertainty analysis is not to dispute the validity of the inventory estimates—which were developed using the best available activity data, emission factors, and methodologies available—but rather to guide prioritization of improvements to the accuracy of future inventories (EPA 2024b). The uncertainty analysis determines the quantitative uncertainty associated with the emission source and sink estimates and evaluates the relative contribution of the input parameters to the uncertainty associated with each source or sink category estimate. This analysis helps to inform and prioritize improvements for the source and sink category estimation processes and highlights opportunities for changes to data measurement, data collection, and calculation methodologies to reduce uncertainties. Overall, it is important to recognize that some level of uncertainty exists with all GHG estimates and the data used to generate such estimates, and these uncertainties vary between sector, source, and gas.

For this report, uncertainty estimates for statewide emissions were developed using the IPCC Approach 2 uncertainty estimation methodology, which is considered the more robust approach of the two approaches provided by IPCC. This methodology is discussed in more detail in Appendix I. Overall and sector-level uncertainty estimates are summarized below in Table 1-2. Uncertainties in the emission calculations for sources in the AFOLU sector are driving the overall uncertainty for total emissions. Uncertainties in the emission calculations for sources and sinks in the AFOLU sector are driving the overall uncertainty for net emissions.

Source category-level uncertainty results and a discussion of specific factors affecting the uncertainty associated with the GHG emission estimates for each emission source and sink category are provided in the subsequent sections of this report.[16]

[16] Uncertainty was quantified for each emission source and sink category. Uncertainty end-use cases (such as stationary combustion and transportation) were not quantified but are discussed qualitatively in Chapter 3.

Table 1-2: Overall Estimated Quantitative Uncertainty (MMT CO_2 Eq. and Percent)

Sector	2022 Emission Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emission Estimate[a]				Mean[b]	Standard Deviation[b]
		(MMT CO_2 Eq.)		(percent)		(MMT CO_2 Eq.)	
		Lower Bound[c]	Upper Bound[c]	Lower Bound	Upper Bound		
Energy	17.5	17.1	18.0	-2.2%	2.8%	17.6	0.2
IPPU	0.8	0.8	0.9	-3.6%	7.7%	0.8	0.0
AFOLU (Sources)	1.4	(1.4)	4.1	-194.3%	180.0%	1.4	1.4
AFOLU (Sinks)	(2.4)	(2.8)	(2.0)	17.1%	-16.5%	(2.4)	0.2
Waste	0.4	0.4	0.43	-5.3%	5.4%	0.4	0.0
Total Emissions	**20.2**	**17.4**	**22.9**	**-13.8%**	**13.7%**	**20.2**	**1.4**
Net Emissions	**17.8**	**14.9**	**20.6**	**-16.0%**	**15.6%**	**17.8**	**1.4**

[a] The uncertainty estimates correspond to a 95 percent confidence interval, with the lower bound corresponding to 2.5th percentile and the upper bound corresponding to 97.5th percentile.
[b] Mean value indicates the arithmetic average of the simulated emission estimates; standard deviation indicates the extent of deviation of the simulated values from the mean.
[c] The lower and upper bound emission estimates for the sub-source categories do not sum to total emissions because the low and high estimates for total emissions were calculated separately through simulations.

1.6 Organization of Report

The remainder of this report is organized as follows:

- **Chapter 2: Emissions Results –** Summarizes 2022 inventory results for the state of Hawai‘i, trends in GHG emissions and sinks across the inventory years since 1990, and emissions by county.

Chapters 3 through 6 describe the detailed emission results by source category for each sector, including a description of the methodology and data sources used to prepare the inventory, and key uncertainties. Chapter specific information is detailed:

- **Chapter 3: Energy –** Presents GHG emissions that occur from stationary and mobile energy combustion activities.
- **Chapter 4: Industrial Processes and Product Use (IPPU) –** Presents GHG emissions that occur
- from industrial processes and product use.
- **Chapter 5: Agriculture, Forestry and Other Land Uses (AFOLU) –** Presents GHG emissions from agricultural activities, land use, changes in land use, and land management practices.
- **Chapter 6: Waste –** Presents GHG emissions from waste management and treatment activities. Describes the detailed emission results by source category, including a description of the methodology and data sources used to prepare the inventory, and key uncertainties.
- **Chapter 7: Emission Projections** – Presents projections for statewide GHG emissions and sinks for 2025, 2030, 2035, 2040, and 2045 under a baseline and six alternate scenarios. County-level

projected GHG emissions and sinks for 2025, 2030, 2035, 2040, and 2045 under the baseline scenario are also provided.

- **Chapter 8: GHG Reduction Goal Progress –** Provides an assessment of statewide progress relative to the statewide GHG emissions limit based on the emission estimates developed.
- **Chapter 9: References –** Lists the sources of data and other information used in the development of this report.

Appendices

- **Appendix A: IPCC Source and Sink Categories –** Provides a summary of all IPCC source and sink categories and the reason for any exclusions from this analysis as well as a summary of which source and sink categories are included in the inventory totals.
- **Appendix B: Updates to the Historical Emission Estimates Presented in the 2022 Inventory Report –** Summarizes changes in emission estimates relative to the 2021 inventory report.
- **Appendix C: Inventory Improvements –** Summarizes the effort undertaken to investigate and implement areas for improvement that were identified in the 2021 inventory report.
- **Appendix D: County Emissions Methodology –** Summarizes the methodology used to quantify Hawaiʻi's GHG emissions by county.
- **Appendix E: Hawaiʻi Administrative Rule (HAR) Facility Data –** Summarizes annual GHG emissions from HAR affected facilities for 2010 to 2022.
- **Appendix F: Activity Data –** Summarizes by sector the activity data used to develop the inventory presented in this report.
- **Appendix G: Emission Factors –** Summarizes by sector the emission factors used to develop the inventory presented in this report.
- **Appendix H: ODS Emissions –** Summarizes for informational purposes estimated emissions from ozone depleting substances (ODS) for the state of Hawaiʻi.
- **Appendix I: Uncertainty–** Provides a summary of the methodology used to develop the quantitative uncertainty results as well as a discussion on limitations of the uncertainty analysis.
- **Appendix J: Emission Projections Methodology –** Summarizes the methodology used to project emissions for 2025, 2030, 2035, 2040, and 2045 by source and sink category, and includes a discussion of key uncertainties and areas for improvement.
- **Appendix K: Comparison of Results with the State Inventory Tool and Projection Tool –** Compares emission estimates for Hawaiʻi generated by EPA's State Inventory and Projections Tool against the results of the 2021 inventory and the emission projections for 2025, 2030, and 2045.
- **Appendix L: Full Emissions Data Series –** Provides the full emissions data series by sector and by county for 1990, 2005, 2007, 2010, and 2015 – 2022.

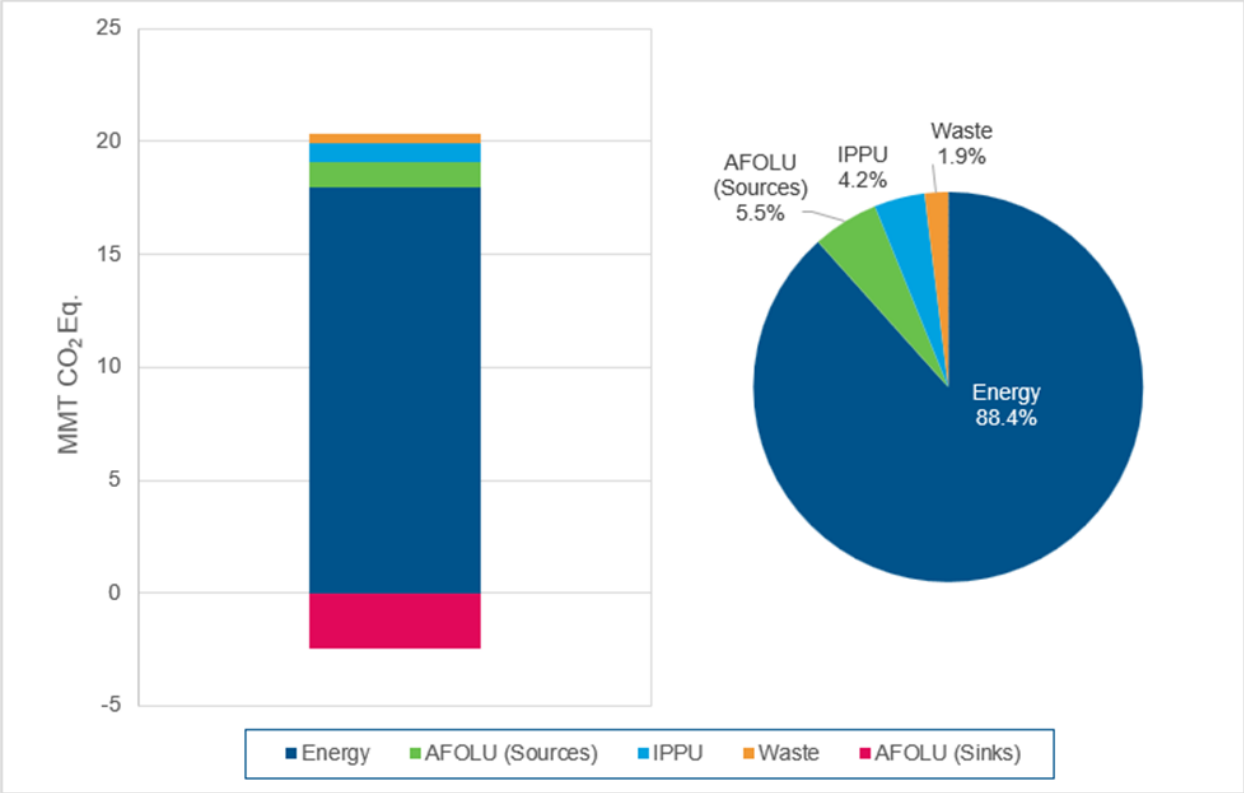
2. Emissions Results

This chapter summarizes 2022 inventory results for the state of Hawai‘i, trends in GHG emissions and sinks across the inventory years since 1990, and emissions by county. Inventory year 2022 is the most recent year for which a full inventory has been developed.

2.1 Overview of 2022 GHG Emissions

In 2022, total GHG emissions in Hawai‘i were 20.32 MMT CO_2 Eq. Net emissions, which take into account carbon sinks, were 17.83 MMT CO_2 Eq. Emissions from the Energy sector accounted for the largest portion of total emissions in Hawai‘i, followed by the AFOLU sector when excluding sinks, the IPPU sector, and the Waste sector. Figure 2-1 below illustrates the emissions results for the new inventory year by sector.

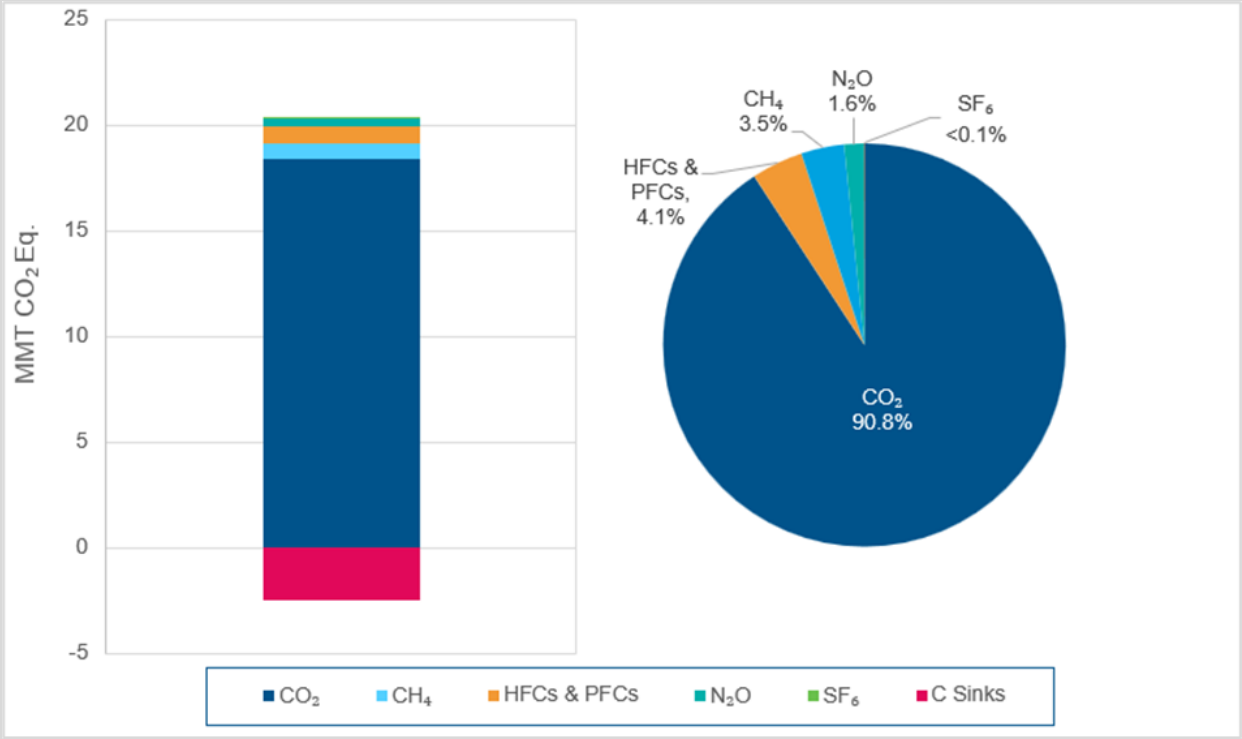
Figure 2-1: Hawai‘i 2022 GHG Emissions by Sector (Including Aviation)



Notes: Emissions estimates include aviation emissions. Percentages represent the percent of total emissions excluding sinks and including aviation.

Carbon dioxide was the largest single contributor to statewide GHG emissions in 2022. HFCs and PFCs were the second largest contributor, followed closely by methane, nitrous oxide, and sulfur hexafluoride. Figure 2-2 shows emissions for the new inventory year by gas.

Figure 2-2: Hawai‘i 2022 GHG Emissions by Gas

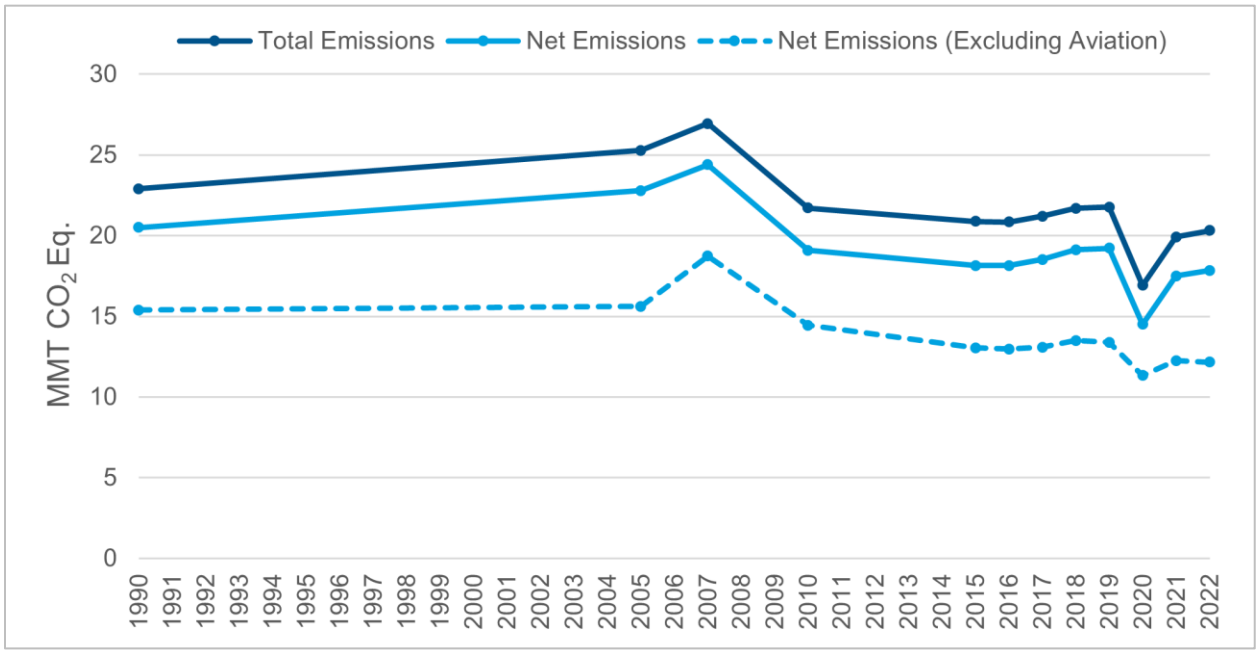


Notes: Totals may not sum due to independent rounding. Percentages represent the percent of total emissions excluding sinks and including aviation.

2.2 Emission Trends

Total GHG emissions in Hawai‘i steadily increased from 1990 to 2007 before experiencing an overall decrease from 2007 to 2022. Net emissions followed a similar trend. As the Energy sector is the largest source of emissions in Hawai‘i, changes within the Energy sector are a major driver of statewide overall emissions trends. The overall emission declines observed from 2007 onward can largely be attributed to factors such as emissions standards in vehicles and increased fuel prices. The increase in total emissions between 2020 and 2022 was driven largely by an increase in CO_2 emissions from fossil fuel combustion across most end-use sectors due in part to increased energy use from the continued rebound of economic activity after the height of the COVID-19 pandemic. Figure 2-3 below shows total and net GHG emissions for each inventory year compiled between 1990 and 2022.

Figure 2-3: Hawai‘i GHG Emissions Inventory Estimates (1990 – 2022)



Notes: “Total Emissions” exclude sinks and include aviation, “Net Emissions” include sinks and aviation, and “Net Emissions (Excluding Aviation)” include sinks and exclude aviation. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Trends by Sector

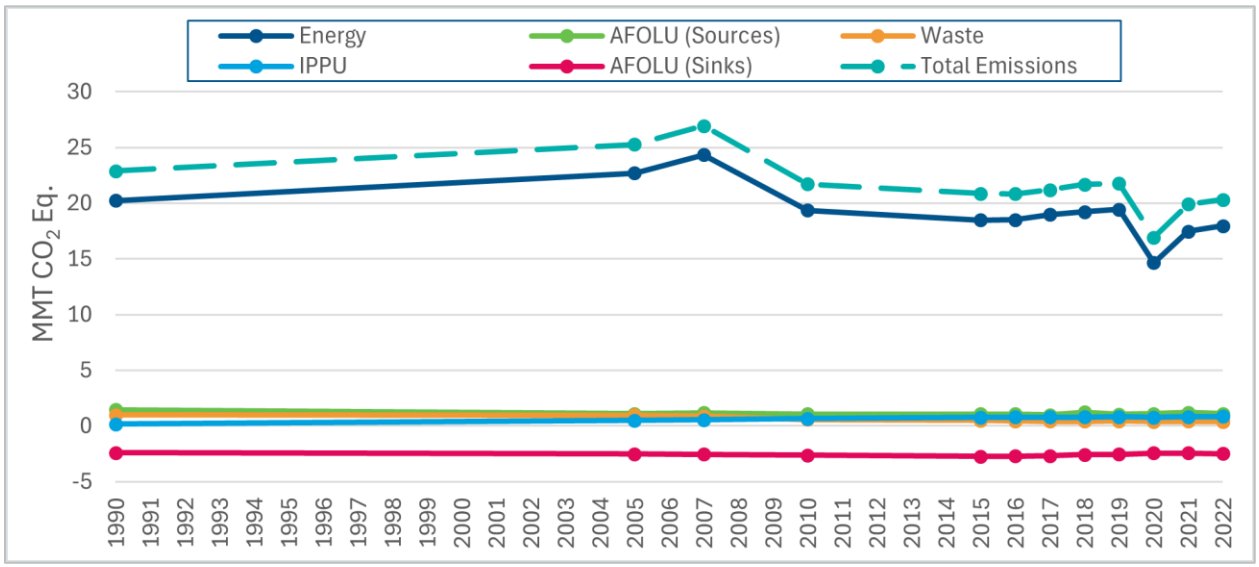
In all inventory years, emissions from the Energy sector accounted for the largest portion (more than 85 percent) of total emissions in Hawai‘i, and therefore is a major driver of the overall emissions trends. Transportation emissions—which have decreased since 2007—accounted for the largest share of Energy sector emissions in all inventory years. Transportation emissions are primarily driven by domestic aviation and ground transportation emissions. Stationary combustion emissions are the second largest share of Energy sector emissions. Stationary combustion emissions are driven by emissions from energy industries (electric power plants and petroleum refineries) as well as industrial and commercial emissions. The decrease in energy emissions is largely due to reduced fuel consumption across all subsectors due to increased energy efficiency and the growth of renewable energy. Renewable energy sources—solar, wind, geothermal, biomass, and hydropower—have contributed an increasing share of the state’s annual electricity generation in the past decade.

The year 1990 marked peak emissions from AFOLU sources during the time period evaluated; since then, emissions from AFOLU sources have significantly decreased between 1990 and 2022. Similarly for the Waste sector, the year 1990 marked peak emissions during the time period evaluated, followed by substantial decline between 1990 and 2022. In contrast, emissions from the IPPU sector have steadily increased since 1990 and were more than four times higher in 2022 compared to 1990 levels. The increase in IPPU emissions is attributable to the growth in HFC and PFC emissions from substitution of

ODS; there is no longer Cement Production in Hawai‘i, and emissions from Electrical Transmission and Distribution has decreased over the time period 1990 to 2022. Lastly, carbon removals from AFOLU sinks have also seen a slight increase since 1990.

Figure 2-4 below shows emissions for each inventory year by sector. Emissions by source and year for all inventory years are summarized in Appendix L. Further discussion regarding trends specific to each sector and for source categories are included in the Energy (Chapter 3), IPPU (Chapter 4), AFOLU (Chapter 5), and Waste (Chapter 6) chapters.

Figure 2-4: Hawai‘i GHG Emissions by Sector (Including Sinks and Aviation)

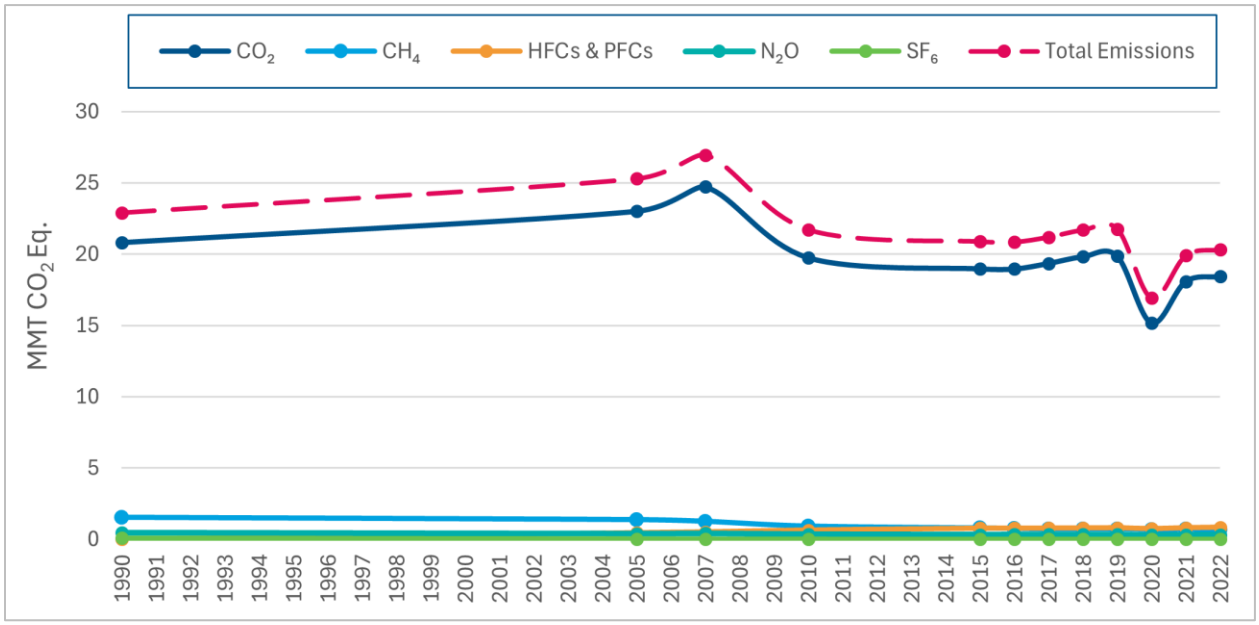


Notes: Emission estimates include sinks and domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Trends by Gas

In all inventory years, CO_2 made up the vast majority of emissions. As CO_2 is the primary gas emitted from fossil fuel consumption, trends in CO_2 emissions are consistent with Energy sector emission trends, increasing between 1990 and 2007 and decreasing between 2007 and 2022. Other gases, including methane, HFCs & PFCs, SF_6, and N_2O are also critical due to their high global warming potential. Methane emissions followed a decreasing trajectory between 1990 and 2022. Emissions of HFCs and PFCs grew substantially from 1990 to 2022, while SF_6 emissions decreased over the same period. Emissions of N_2O similarly decreased between 1990 and 2007 and continue to decrease slightly between 2007 and 2022, largely due to forest fires. Figure 2-5 shows emissions for each inventory year by gas.

Figure 2-5: Hawai‘i GHG Emissions by Gas (Excluding Sinks and Including Aviation)



Notes: Emissions estimates include domestic aviation emissions but exclude sinks. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

2.3 Emissions by County

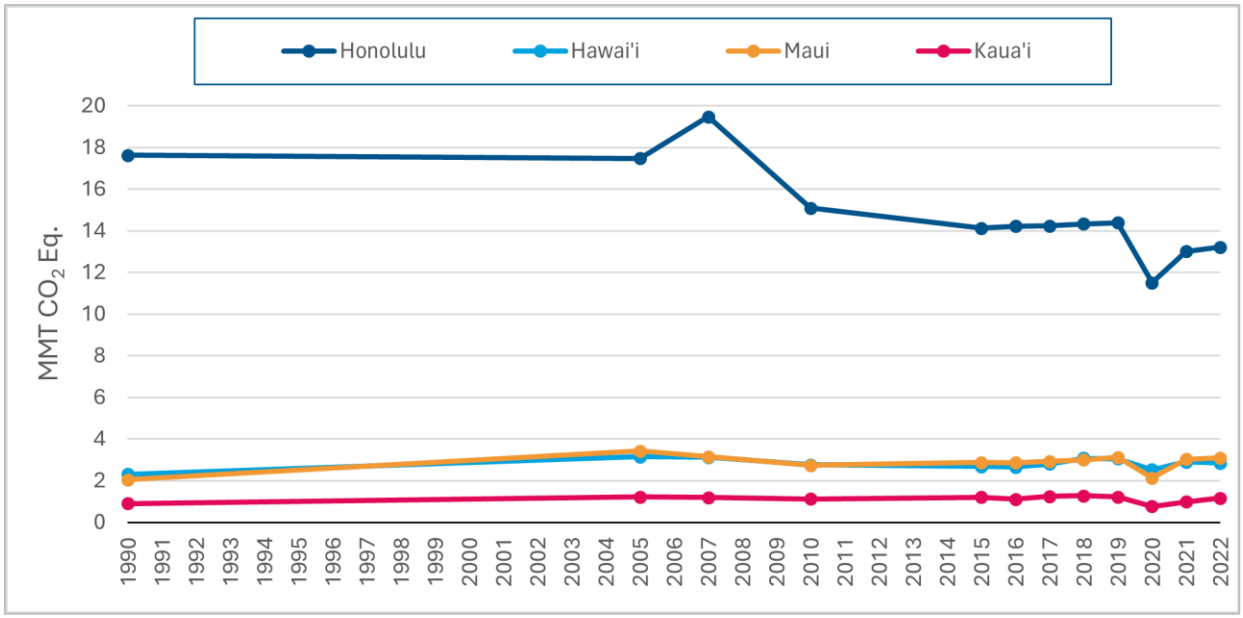
In 2022, Honolulu County accounted for the largest share of net GHG emissions (71.3 percent), followed by Maui County[17] (15.3 percent), Hawai‘i County (8.6 percent), and Kaua‘i County (4.8 percent). The majority of emissions in all four counties were generated within the energy sector. Figure 2-6 shows the breakout of net emissions by county in 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions by county for all inventory years are available in Appendix L. This appendix also displays county level data for the subsectors within each sector for all inventory years.

Emissions from the Energy sector accounted for the largest portion of the total emissions from each county in all inventory years. Emissions from AFOLU sources accounted for the second largest portion of emissions from all counties. Figure 2-7 shows net emissions by county and sector in 2022.

The methodology used to develop estimates of emissions and sequestration varies by the source or sink. For some sources, county-level activity data were available to build bottom-up county level emissions estimates. For other sources, only state-level activity data were available, requiring emissions to be apportioned to each county using data such as population or vehicle miles traveled (VMT). Appendix D summarizes the methodology used to quantify Hawai‘i’s GHG emissions by county.

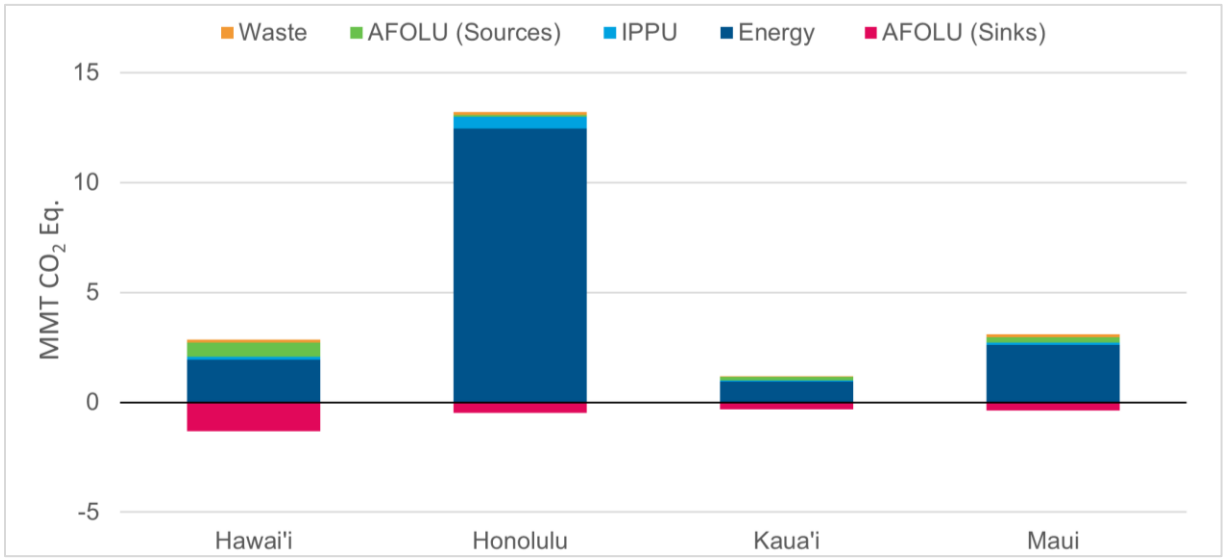
[17] Maui County includes emissions from Kalawao County.

Figure 2-6: Net GHG Emissions by County (Excluding Sinks and Including Aviation)



Notes: Emissions estimates represent total emissions excluding sinks and including domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Figure 2-7: Net GHG Emissions by County and Sector in 2022 (Including Sinks and Aviation)



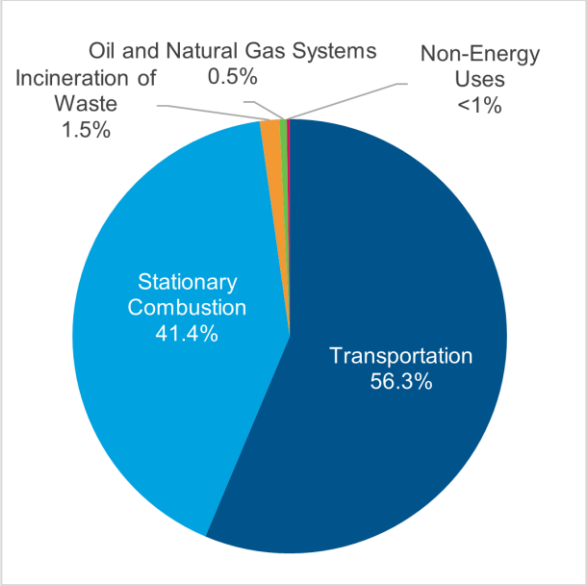
Note: Emissions estimates include sinks and aviation emissions.

3. Energy

This chapter presents GHG emissions that result from energy-related activities, primarily fuel combustion for transportation and generation of electricity. For the state of Hawai'i, energy sector emissions are estimated from the following sources: stationary combustion (IPCC Source Categories 1A1, 1A2, 1A4, 1A5), transportation (IPCC Source Category 1A3), incineration of waste for energy purposes (IPCC Source Category 1A1a), oil and natural gas systems[18] (IPCC Source Category 1B2), and non-energy uses[19] (NEUs) (IPCC Source Category 2D).[20] Emissions from international bunker fuels (IPCC Source Category 1: Memo Items) and CO_2 emissions from wood biomass and biofuel consumption (IPCC Source Categories 1A) are also estimated as part of this analysis; however, these emissions are not included in the totals, consistent with IPCC (2006) guidelines.

In 2022, emissions from the Energy sector were 17.95 MMT CO_2 Eq., accounting for 88.4 percent of Hawaii's total emissions. Emissions from transportation accounted for the largest share of Energy sector emissions across the timeseries. Figure 3-1 and Figure 3-2 show emissions (% and MMT CO_2 Eq.) from the Energy sector by source for 2022.

Figure 3-1: 2022 Energy Emissions (%) by Source (Including Aviation)



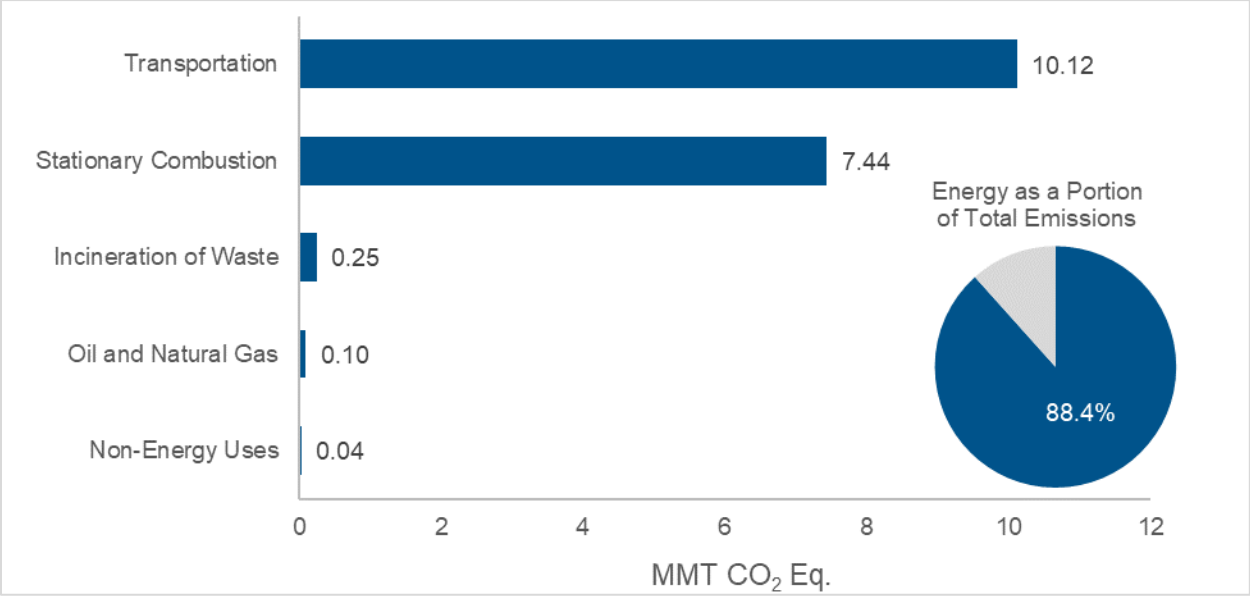
Notes: Totals may not sum due to independent rounding. Percentages represent the percent of energy emissions including aviation.

[18] The state of Hawai'i does not have any natural gas exploration, production, or processing. Sources of emissions in the natural gas systems category include fugitive emissions from propane and synthetic natural gas transmission and distribution.

[19] Non-energy uses of fuels include use of fossil fuel feedstocks for industrial and transportation applications that do not involve combustion, including production of lubricants, asphalt, and road oil.

[20] IPCC Source Categories for which emissions were not estimated for the state of Hawai'i include: fugitive emissions from solid fuels (1B1) and CO_2 transport, injection and geological storage (1C). Appendix A provides information on why emissions were not estimated for these IPCC Source Categories.

Figure 3-2: 2022 Energy Emissions by Source (MMT CO_2 Eq.) (Including Aviation)

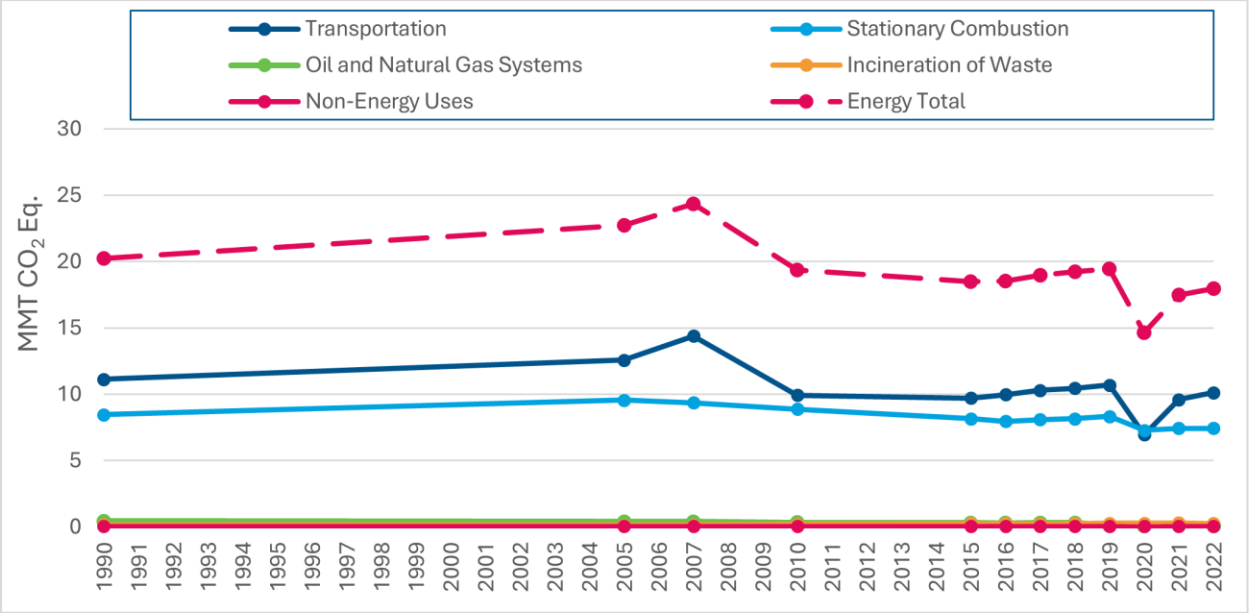


Notes: Biogenic CO_2 emissions from wood biomass and biofuel consumption are not included in emission totals, as per IPCC (2006) guidelines. Aviation emissions are included in emission totals. Totals may not sum due to independent rounding.

Figure 3-3 shows energy sector emissions by source and year (including aviation) for all inventory years in Hawai‘i. Relative to 1990, emissions from the Energy sector in 2022 were lower by roughly 11.3 percent. In general, sector emission trends follow trends in transportation emissions, as transportation accounts for the majority of energy sector emissions. Transportation emissions are largely driven by domestic aviation and ground transportation emissions, which together account for roughly 82.8 percent of transportation emissions and 41.2 percent of overall statewide emissions. The next largest contributor, stationary combustion, is primarily driven by emissions from energy industries (electric power plants and petroleum refineries) as well as industrial and commercial emissions.

The general decline in emissions from 2019 to 2020 is largely due to the impacts that the coronavirus (COVID-19) pandemic had on travel and economic activities; the increase in emissions in from 2020 to 2022 is due to continued rebound of economic activity after the height of the pandemic. Emissions by source and year are summarized in Table L-3.

Figure 3-3: Energy Sector Emissions by Source and Year (MMT CO_2 Eq.) (Including Aviation)



Notes: Emission estimates include domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

The remainder of this chapter describes the detailed emission results by source category, including a description of the methodology and data sources used to prepare the inventory. Facility-level data for Hawai‘i Administrative Rule (HAR) affected facilities are provided in Appendix E.[21] Activity data and emission factors used in the analysis are summarized in Appendix F and Appendix G, respectively.

[21] HAR affected facilities refers to large existing stationary sources with potential GHG emissions at or above 100,000 tons of CO_2 Eq. per year. Hawai‘i Administrative Rules, Chapter 11-60.1, excludes municipal waste combustion operations and conditionally exempts municipal solid waste landfills.

3.1 Stationary Combustion (IPCC Source Categories 1A1, 1A2, 1A4, 1A5)

Fossil fuels are burned to generate energy for a variety of stationary sources, including electric power plants, industrial facilities, commercial businesses, and homes. When fossil fuels are combusted, they release CO_2, CH_4, and N_2O emissions. In 2022, emissions from stationary combustion in Hawai'i were 7.44 MMT CO_2 Eq., accounting for 41.4 percent of Energy sector emissions and 36.6 percent of statewide total emissions (excluding sinks), as shown in Figure 3-4.

Stationary combustion emissions can be broken out by economic sector (i.e., energy industries[22], residential, commercial, and industrial). The contribution of each economic sector to the energy sector emissions and overall statewide emissions are presented in Table 3-1.

Figure 3-4: Stationary Combustion Sector Contributions to Statewide Total Gross Emissions

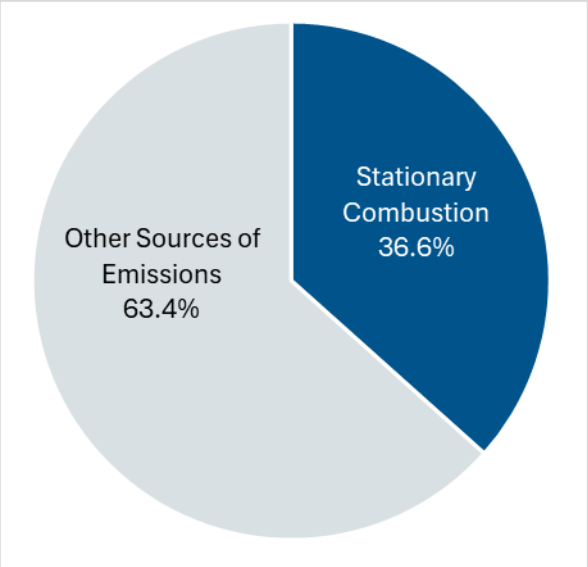


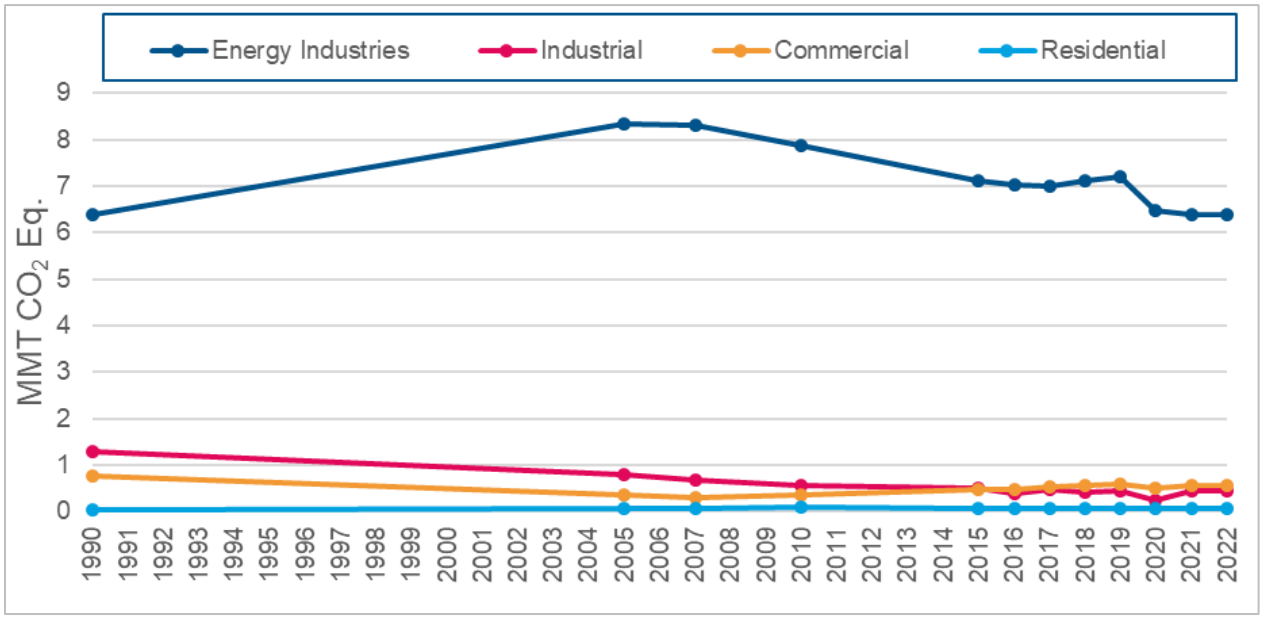
Table 3-1: Share of Stationary Combustion Emissions in 2022 (%) by Economic Subsector

Economic Sector	Share of Stationary Combustion Emissions	Share of Statewide Total Emissions
Energy Industries	85.7%	31.4%
Residential	7.4%	2.7%
Commercial	6.0%	2.2%
Industrial	0.9%	0.03%

Relative to 1990, emissions from stationary combustion in 2022 were lower by roughly 12.2 percent. This trend is largely driven by emissions from residual fuel consumption associated with energy industries, which decreased from 1990 to 2022. Emissions from energy industries followed an inconsistent trend, fluctuating between 6.37 and 8.33 MMT CO_2 Eq. over the time period. Similarly, emissions from the residential sector followed an inconsistent trend, fluctuating between 0.05 and 0.09 MMT CO_2 Eq. over the time period.[23] Emissions from the commercial sector fluctuated over the timeseries, and 2022 emissions were 27 percent below 1990 emissions levels. Figure 3-5 presents emissions from stationary combustion in Hawai'i by economic sector for 1990, 2005, 2007, and 2015 to 2022. The full timeseries of emissions by economic sector and gas are found in Table L-4.

[22] Energy industries includes both electric power plants (i.e., facilities that generate electricity for the residential, commercial, and industrial economic sectors) and petroleum refineries.
[23] All inventory years are available in Appendix L.

Figure 3-5: GHG Emissions from Stationary Combustion by Economic Sector and Year (MMT CO_2 Eq.)



Notes: Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Methodology

With the exception of emission estimates obtained directly from EPA's GHGRP, CO_2 emissions from stationary combustion were calculated using an IPCC (2006) Tier 2 methodology. Emissions were calculated using the following equation[24]:

$$CO_2\ Emissions\ =\ Fuel\ Consumption \times C_{fuel} \times \frac{44}{12}$$

where,

Fuel Consumption	= total amount of fuel combusted (Billion British Thermal Units or Bbtu)
C_{fuel}	= fuel specific Carbon Content Coefficient (lbs C/Bbtu)
44/12	= conversion of carbon to CO_2

Methane and N_2O emissions were calculated using an IPCC (2006) Tier 1 methodology. Emissions were calculated using the following equation[25]:

[24] All CO_2 emissions have been converted to MMT CO_2 Eq. based on the conversion factor for pounds to MMT, which is 0.00045359 lb/MMT.
[25] All CH_4 and N_2O emissions have been converted to MMT CO_2 Eq. based on the GWPs provided in Table 1-1.

$$CH_4 \text{ and } N_2O \text{ Emissions} = \text{Fuel Consumption} \times EF_{fuel}$$

where,

Fuel Consumption	= total amount of fuel combusted (Billion British Thermal Units or Bbtu)
EF_{fuel}	= emission factor of CH_4 and N_2O by fuel type (MT gas/Bbtu)

Carbon content coefficients for estimating CO_2 emissions, which are specific to each fuel type, were taken from the U.S. Inventory (EPA 2024b). Methane and N_2O emission factors were obtained from the *2006 IPCC Guidelines* (IPCC 2006) for fossil fuels, wood biomass, ethanol, and biodiesel.

Fuel consumption data by end-use sector were obtained from Energy Information Administration's State Energy Data System (SEDS) (EIA 2024b) for all years.[26] For some fuel types, consumption data were not available in SEDS and were obtained from additional data sources. Specifically, fuel gas and naphtha consumption were collected by the Hawaiʻi Department of Business, Economic Development, and Tourism (DBEDT 2008a) for 2007.[27] Fuel gas and naphtha consumption estimates for 2005 were set equal to 2007 estimates. For 2010, and 2015 to 2022, CO_2, CH_4, and N_2O emissions from fuel gas and naphtha consumption were obtained directly from EPA's GHGRP (EPA 2024c). EPA's GHGRP fuel-level emissions data had already been converted by EPA into CO_2-equivalent units, using AR4 GWP values. The ratio of AR5 GWP values to AR4 GWP values was applied to these values to convert them into CO_2-equivalent units in AR5 GWP values. Methane and N_2O emissions from biodiesel consumption at the Hawaiian Electric Company (HECO), Hawaiʻi Electric Light Company (HELCO), and the Maui Electric Company (MECO) were estimated based on biodiesel consumption data obtained from DBEDT's Data Warehouse (DBEDT 2024a) and Hawaiʻi Department of Health (Hawaiʻi DOH 2020).[28]

Emissions from petroleum refineries are included in the inventory through both the Industrial and Oil and Gas sectors. Stationary combustion at refineries is captured in the Industrial sector using SEDS data, which reflects product supplied and includes fuel used by refineries. Fugitive emissions from refining processes (e.g., flares, leaks, and tanks) are included under the Oil and Gas sector using GHGRP subpart Y data.

Changes in Estimates since the Previous Inventory Report

Changes that were implemented relative to the 2021 inventory report include the following:

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[26] Motor gasoline consumption obtained from EIA (2024a) includes blended ethanol. Pure ethanol consumption obtained from EIA (2024a) was subtracted from motor gasoline prior to estimating emissions. Natural gas consumption obtained from EIA (2024a) includes RNG. RNG consumption obtained from City & County of Honolulu (2022 and 2024) was subtracted from natural gas prior to estimating emissions.

[27] As DBEDT is the conduit of this data but not the source of this data, DBEDT cannot ascertain the data's accuracy. Use of this data was at the discretion of the authors of this report.

[28] Carbon dioxide emissions from wood biomass and biofuels consumption are reported in Section 3.7.

- Emissions from the consumption of RNG were incorporated into the inventory. As of 2018, this RNG is produced by the Honouliuli WWTP and captured by Hawaiʻi Gas natural gas for injection into their synthetic natural gas (SNG) distribution system (Hawaiʻi Free Press 2018). Starting in 2019, RNG consumption in Hawaiʻi is included in the natural gas consumption totals reported in EIA's SEDS. Therefore, RNG consumption is subtracted from natural gas consumption in the residential and commercial sectors to avoid double counting. It is assumed that RNG is consumed half by the residential sector and half by the commercial sector based on conversations with City & County of Honolulu (2024). This methodological change impacts 2018 through 2021 historical estimates.
- The percentage of non-energy use consumption by fuel type was updated to reflect changes made in the U.S. Greenhouse Gas Inventory. Non-energy use consumption is subtracted from consumption for energy use, which impacts historical estimates.
- In the 2021 inventory report, the CH_4 emission factor associated with natural gas was inadvertently applied to industrial propane for the years 2005 and 2016 through 2021. The correct emission factor associated with petroleum was applied for these years in the 2022 inventory.
- The CO_2, CH_4, and N_2O emission factors were updated to reflect the same significant figures as the values publicly available in the U.S. Inventory (EPA 2024b). This resulted in very slight changes across the timeseries.

The resulting changes in historical emission estimates are presented in Table 3-2.

Table 3-2: Change in Emissions from Stationary Combustion Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	8.47		9.56		9.37		8.09	8.16	8.33	7.29	7.44
This Inventory Report	8.47		9.56		9.37		8.09	8.16	8.32	7.29	7.44
Percent Change	+%		+%		+%		+%	+%	(+%)	(+%)	(+%)

+ Does not exceed 0.05 percent. (+) Does not exceed -0.05 percent.

Uncertainties

Uncertainties associated with stationary consumption estimates include the following:

- Emissions from fuel gas and naphtha consumption were only available from EPA's GHGRP starting in 2010. Data on fuel gas and naphtha consumption in 2007 were collected by DBEDT. DBEDT data on fuel gas and naphtha consumption was not available for 2005, so 2007 DBEDT data is used to estimate emissions in 2005. As DBEDT is the conduit of this data but not the source, there is uncertainty associated with data collected by DBEDT.
- Emissions from fuel gas and naphtha consumption in the energy industries sector for 2010 and 2015 through 2021 that were obtained from EPA's GHGRP (EPA 2024c) do not include emissions

from facilities that are below the reporting threshold of 25,000 metric tons of carbon dioxide equivalent (MT CO_2 Eq.) per year.

To estimate uncertainty associated with emissions from stationary combustion, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on IPCC (2006) and expert judgment. Uncertainty ranges for activity data were developed using the *2006 IPCC Guidelines* due to lack of available information from EIA. The *2006 IPCC Guidelines* provide default uncertainty bounds for activity data based on the type of energy data system from which the activity data were obtained. Because SEDS is a robust national dataset based on data from thousands of industry-specific surveys, these data were assumed to fall under the "Well developed statistical systems: Surveys" category. The highest range of uncertainties were used for this analysis. This value may change as additional analysis is conducted in the future.

The following parameters contributed the most to the quantified uncertainty estimates: (1) CO_2 emission factor for coal consumption in the energy industries sector, (2) CO_2 emission factor for residual fuel consumption in the energy industries sector, and (3) residual fuel consumption in the energy industries sector. The results of the quantitative uncertainty analysis are summarized in Table 3-3. Emissions from stationary combustion were estimated to be between 7.40 and 7.55 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately one percent below and one percent above the emission estimate of 7.44 MMT CO_2 Eq.

Table 3-3: Quantitative Uncertainty Estimates for Emissions from Stationary Combustion

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
7.44	7.40	7.55	-1%	1%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

3.2 Transportation (IPCC Source Category 1A3)

Emissions from transportation result from the combustion of fuel for ground, domestic marine, domestic aviation, military aviation, and military (non-aviation) transportation. Ground transportation includes passenger cars, light trucks, motorcycles, and heavy-duty vehicles (i.e., trucks and buses). In 2022, emissions from transportation activities in Hawai'i were 10.12 MMT CO_2 Eq, accounting for 56.3 percent of Energy sector emissions and 49.8 percent of statewide total emissions (excluding sinks), as shown in Figure 3-6. The contributions of each end-use sector to energy sector and statewide emissions are presented in Table 3-4.

Figure 3-6: Transportation Sector Contribution to Statewide Total Gross Emissions

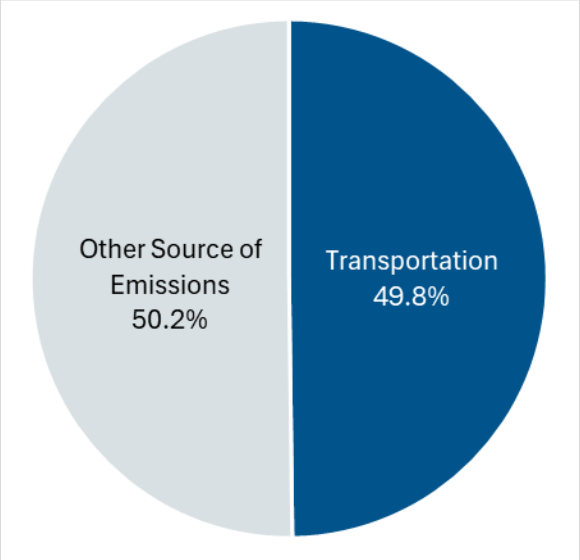
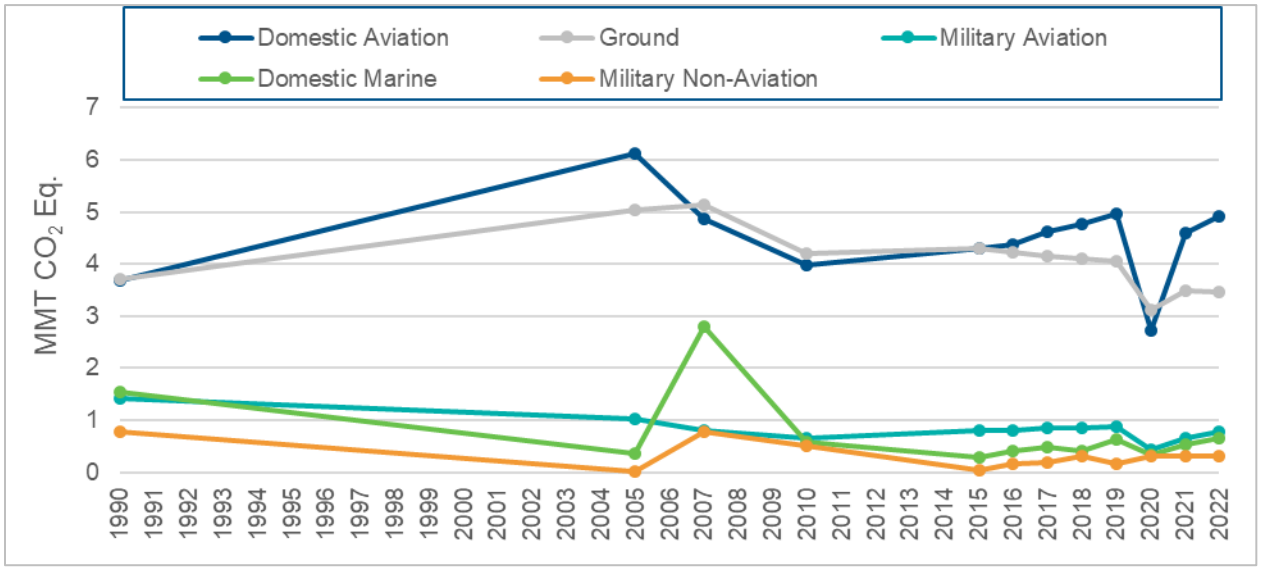


Table 3-4: Share of Transportation Emissions (%) by End-Use Sector

End-Use Sector	Share of Transportation Emissions	Share of Statewide Total Emissions
Domestic Aviation	85.7%	24.1%
Ground Transportation	7.4%	17.1%
Military Aviation	6.0%	3.8%
Domestic Marine	0.9%	3.2%
Military Non-Aviation	1.8%	1.6%

Relative to 1990, emissions from transportation in 2022 were lower by 9.1 percent. Emissions from ground transportation increased from 1990 to 2007, generally decreased from 2007 to 2020, and then generally increased from 2020 to 2022. Domestic aviation transportation increased from 1990 to 2005, decreased from 2005 to 2010, and increased from 2010 to 2019, before decreasing in 2020 and increasing again from 2020 to 2022. The emissions trends from ground and domestic aviation transportation are largely due to a similar trend in consumption of motor gasoline, diesel fuel, and jet fuel kerosene. Emissions from domestic marine and military transportation fluctuated across the timeseries and followed a similar trend in consumption of residual fuel, diesel fuel, and jet fuel kerosene. Figure 3-7 presents emissions from transportation in Hawai'i by end-use sector for 1990, 2005, 2007, and 2018 to 2022. The full timeseries of emissions can be found in Table L-5 and Table L-6 extracts emissions from electric vehicles over the timeseries for informational purposes only.

Figure 3-7: Transportation Emissions by End-Use Sector and Year (MMT CO_2 Eq.) (Including Aviation)



Notes: Emission estimates include domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Domestic vs. International Aviation and Marine

Consistent with IPCC (2006), the following approach is used to determine emissions from the transportation sector:

- **Included in Hawai'i Inventory Totals:** All transportation activities that occur within Hawai'i (e.g., flights from O'ahu to Maui) and domestic interstate activities originating in Hawai'i (e.g., flights from Honolulu to Los Angeles).
- **Estimated but Excluded from Hawai'i Inventory Totals:** Any fuel combustion used for international flights and marine voyages that originate in Hawai'i (e.g., flights from Honolulu to Hong Kong).
- **Not Estimated:** All transportation activities that originate outside Hawai'i (e.g., travel from Los Angeles to Honolulu, travel from Tokyo to Honolulu).

Methodology

Calculating CO_2 emissions from all transportation sources (except EVs)

Carbon dioxide emissions were estimated using the following equation, consistent with IPCC (2006):

$$CO_2\ Emissions\ =\ [Fuel\ Consumption\ -\ IBF\ Consumption\ ] \times C_{fuel}\ \times \frac{44}{12}$$

where,

Fuel Consumption	= total energy consumption by fuel type (Bbtu)
IBF Consumption	= total consumption of international bunker fuels by fuel type (Bbtu)
C_{fuel}	= total mass of carbon per unit of energy in each fuel (lbs C/Bbtu)
44/12	= conversion of carbon to CO_2

Carbon content coefficients for estimating CO_2 emissions, which are specific to each fuel type, were taken from the U.S. Inventory (EPA 2024b). Fuel consumption data for transportation were obtained from EIA's SEDS (EIA 2024b) for all years.[29] These data were available at an aggregate level by fuel type. EIA's SEDS dataset is used because it covers the entire timeseries, is reliable and well documented, and represents the data inputs needed to follow IPCC's approach for estimating fuel consumption emissions. Disaggregated transportation data collected by DBEDT (2008a, 2024b) were used to allocate transportation fuel consumption from EIA (2024a) for diesel fuel, lubricants, motor gasoline, propane, residual fuel, and natural gas, and ethanol into marine and ground transportation for each fuel type. Aviation gasoline is assumed to all be used for aviation.

Aviation gasoline and naphtha-type jet fuel for military were obtained from EIA (2019) for all years prior to 2017.[30] Diesel fuel and residual fuel consumption were obtained from EIA's Petroleum and Other Liquids dataset through 2020 (EIA 2024c). Data for the years 2021 and 2022 were set equal to 2020 while awaiting data replacement from the EIA. Aviation gasoline and naphtha-type jet fuel were assumed to be consumed for aviation purposes, while diesel and residual fuel were assumed to be consumed for non-aviation purposes. These values were subtracted from the aggregate transportation aviation gasoline, diesel fuel, and residual fuel consumption data from EIA (2024a) prior to estimating emissions for the other subcategories.[31]

EIA's SEDS follows an updated methodology for the 2020 data publication to estimate state-level jet fuel consumption for 2010 onwards. While conversations with EIA indicated that this update produces more accurate fuel estimates, EIA did not make this adjustment for years prior to 2010, and therefore updated fuel consumption for 2010 onwards in EIA SEDS is not compatible with the estimates for years prior to 2010 (EIA 2024b). EIA revised these estimates using data from the U.S. Bureau of Transportation Statistics which is not available prior to 2010. This revision impacts fuel consumption for domestic and military aviation, as well as aviation international bunker fuels for the years 1990, 2005, and 2007. To maintain timeseries consistency, jet fuel consumption was back-casted for the years 1990 to 2009 using the overlap splicing technique as prescribed by IPCC 2006. There is a high correlation between post-2010 estimates developed using the 2020 data publication and the 2018 data publication methodology

[29] Diesel fuel consumption data obtained from EIA (2024a) includes blended biodiesel within the transportation sector. Biodiesel consumed by the transportation sector was subtracted from diesel fuel consumption from EIA to estimate pure diesel consumption.

[30] Unpublished military fuel consumption data from SEDS for 2017 through 2022 were not available, therefore consumption for these fuel types were set equal to 2016 data.

[31] EIA SEDS (2024a) does not include any naphtha consumption for Hawai'i, so naphtha-type jet fuel consumption in 1990 obtained from EIA (2024c) was assumed to be excluded from SEDS.

which allows for this technique to be used. The estimates were developed using IPCC's overlap method (IPCC 2006) as described by equation 5.1:

$$y_0 = x_0 \left(\frac{1}{n - m + 1} \times \sum_{i=m}^{n} \frac{y_i}{x_i} \right)$$

where,

y_0	= recalculated jet fuel kerosene consumption (Bbtu)
x_0	= the original SEDS jet fuel kerosene consumption estimate (Bbtu)
y_i, x_i	= estimates of jet fuel kerosene consumption prepared using the new and previous used SEDS methodology for years 2010 – 2018 (Bbtu)
m, n	= years in which the overlap of SEDS data were occurring (2010 – 2018)

For 1990 and 2007, kerosene-type jet fuel consumption data for military were collected by DBEDT (2008a). These values were used with the unadjusted SEDS jet fuel consumption data to develop an estimate of the fraction of emissions from military aviation.[32] This fraction was used to subtract military aviation consumption from total transportation jet fuel consumption data from EIA (2024a); emission estimates for military are reported separately. For 2010 and 2015 to 2022, total transportation jet fuel consumption data from EIA (2024a) were allocated to military transportation and non-military transportation using the 2007 proportional breakout, as estimates for military jet fuel consumption were not available for these years.

For all years, aviation and marine fuel consumption were categorized as either domestic or international consumption for the purposes of estimating emissions from international bunker fuels. The methodology used to apportion aviation and marine fuel consumption into domestic or international consumption is discussed in Section 3.6.

Calculating CH_4 and N_2O emissions from highway vehicles (except EVs)

Methane and N_2O emissions from highway vehicles are dependent on numerous factors, such as engine type and emissions control technology. Consistent with the IPCC (2006) Tier 2 methodology, the following equation was used to calculate CH_4 and N_2O emissions from highway vehicles:

$$CH_4 \text{ and } N_2O \text{ Emissions} = VMT \times EF_t$$

where,

VMT	= Vehicle Miles Traveled by vehicle type, fuel, model year and control technology (mi)
EF_t	= Emission Factor by vehicle type and control technology (kg CH_4 or N_2O/mi)

[32] Prior research has shown that the DBEDT and SEDS data developed using the method employed prior to the 2019 update were closely aligned and thus could be compared, Appendix C of Hawai'i DOH (2021).

For 2005, 2010, and 2015 to 2022, vehicle miles traveled (VMT) estimates by functional class (e.g., interstate, local, other freeways and expressways, other principal arterial, minor arterial, etc.) for the state of Hawai'i were obtained from the Federal Highway Administration's (FHWA) Annual Highway Statistics (FHWA 2005; 2010; 2015 to 2022). The distribution of annual VMT by vehicle type for each functional class for the state of Hawai'i, which was also obtained from FHWA (2005; 2010; 2015 to 2022), was then used to calculate VMT by vehicle type. For 1990 and 2007, VMT estimates by vehicle type were provided by the Hawai'i Department of Transportation (DOT) (Hawai'i DOT 2008). A small amount of VMT by electric vehicles (EVs) was subtracted from the FHWA vehicle types of passenger cars and light trucks. This is because EVs rely on electric motors instead of internal combustion engines and therefore, do not produce CH_4 and N_2O tailpipe emissions. VMT by EVs is calculated according to the methodology detailed in the Calculating VMT by electric vehicles section below. Vehicle age distribution by model year, as well as control technologies and emission factors by vehicle type for all years, were obtained from the U.S. Inventory (EPA 2024b).[33]

Calculating VMT by electric vehicles

VMT by EVs were estimated using the following equation:

$$VMT = \frac{Electricity\ Consumption}{kWh\ per\ mile}$$

where,

Electricity Consumption	= Total electricity consumption per vehicle type (kWh)
kWh per mile	= Average kWh consumed per mile

Electricity consumption data for Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) were obtained from EIA's SEDS to ensure consistency with the main data source used throughout Energy sector calculations (EIA 2024b). Further adjustments were made to EIA's SEDS data on electricity consumption as outlined in the Calculating CO2, CH4, and N2O emissions from electric vehicles section below. Electricity consumption data for BEVs and PHEVs were further disaggregated among passenger cars and light trucks based on the ratio of passenger cars to light trucks for BEVs and PHEVs, calculated using mileage data for the most popular types of BEVs and PHEVs in the United States from iSeeCars (iSeeCars 2023). This mileage data was used to disaggregate electricity consumption based on the assumption that a consistent amount of electricity is consumed per mile driven.

Miles per gallon of gasoline equivalent (MPGGe) for all four vehicle types (passenger car BEV, passenger car PHEV, light truck BEV, and light truck PHEV) were calculated by taking the average of all makes and models per vehicle type and year, available from DOE (DOE 2024). By multiplying the inverse of MPGGe

[33] Emission factors by vehicle type and control technology can be found in Annex 3.2 table "Emission Factors for CH_4 and N_2O for On-Road Vehicles".

per vehicle type (gallons of gasoline equivalent per mile) by the standard conversion value of 33.7 kWh/gallon, published by the EPA, the fuel efficiency values are converted into units of kWhs/mile (EPA 2024e). Then, the electricity consumption per vehicle type was divided by the corresponding fuel efficiency in units of kWhs/mile to obtain the VMT per vehicle type. Finally, passenger car BEV and passenger car PHEV VMT were added to obtain total VMT by electric passenger cars, and light truck BEV and light truck PHEV VMT were added to obtain total VMT by electric light trucks.

Calculating CH_4 and N_2O emissions from non-highway vehicles

Methane and N_2O emissions from non-highway vehicles[34] were estimated using the following equation, consistent with the IPCC (2006) Tier 1 methodology:

$$CH_4 \text{ and } N_2O \text{ Emissions } = [\, C_{Non\ Highway} - C_{IBF}] \times EF$$

where,

$C_{Non\ Highway}$	= total amount of fuel combusted by non-highway vehicles by fuel type (Bbtu)
C_{IBF}	= total amount of international bunker fuels combusted by fuel type (Bbtu)
EF	= emission factor for non-highway vehicles (kg CH_4 or N_2O/Bbtu)

Default emission factors for estimating emissions from non-highway vehicles were obtained from the U.S. Inventory (EPA 2024b). This source was used because the *2006 IPCC Guidelines* do not include updated emission factors for non-highway vehicles.

Calculating CH_4 and N_2O emissions from alternative fuel vehicles (except EVs)

Methane and N_2O emissions from alternative fuel (i.e., biodiesel and ethanol) vehicles were estimated using the following equation, consistent with the IPCC (2006) Tier 1 methodology:[35]

$$CH_4 \text{ and } N_2O \text{ Emissions } = \text{Fuel Consumption} \times EF_{fuel}$$

where,

Fuel Consumption	= total amount of biodiesel or ethanol combusted (Bbtu)
EF_{fuel}	= emission factor of CH_4 and N_2O by fuel type (kg CH_4 or N_2O/Bbtu)

Methane and N_2O emission factors were taken from IPCC (2006) for ethanol and biodiesel. Biodiesel consumed by the transportation sector and ethanol consumed by the commercial and industrial sectors was estimated based on consumption data obtained from EIA (2024a). Biodiesel consumed by energy industries, as obtained from DBEDT's Economic Data Warehouse (DBEDT 2024a) and Hawai'i DOH (2020), was subtracted from the SEDS biodiesel consumption total to estimate the amount of biodiesel

[34] Non-highway vehicles are defined as any vehicle or equipment not used on the traditional road system, excluding aircraft, rail, and watercraft. This category includes snowmobiles, golf carts, riding lawn mowers, agricultural equipment, and trucks used for off-road purposes, among others.

[35] Carbon dioxide emissions from wood biomass and biofuels consumption are reported in Section 3.7.

consumed by the transportation sector. Ethanol consumed by the transportation sector was estimated based on consumption data obtained from EIA (2024a), allocated into marine and ground transportation using disaggregated transportation data collected by DBEDT (2008a, 2024b).

Calculating CO_2, CH_4, and N_2O emissions from electric vehicles – INFORMATIONAL ONLY

CO_2, CH_4, and N_2O emissions from EVs were estimated using the following equation, consistent with the IPCC (2006) Tier 1 methodology:

$$CO_2, CH_4, and\ N_2O\ Emissions\ =\ [Electricity\ Consumption] \times EF$$

where,

Electricity Consumption = Total electricity consumption per vehicle type (kWh)

EF = Emission factor (kg CO_2, CH_4, or N_2O/kWh)

Electricity consumption data and the number of registered vehicles for BEVs and PHEVs were obtained from the EIA's SEDS to ensure consistency with the main data source used throughout Energy sector calculations (EIA 2024b). This electricity consumption data were converted from million kilowatt hours to kWh by multiplying by 1,000,000. This registered vehicles data were converted from thousands of registered vehicles to total vehicles by multiplying by 1,000. Note that the EIA only publishes the number of registered vehicles for light-duty stock and estimates kWh based on the number of registered vehicles. The EIA's methodology is outlined in Appendix D Electric Vehicle Consumption (EIA 2024a).

EIA's SEDS does not contain annual counts of registered EVs prior to 2016. However, according to the Hawai'i DOT Motor Safety data, EVs were driven in Hawai'i as early as 2013 (Hawai'i DOT 2024). Although the Hawai'i DOT data does not cover pre-2013, the number of EVs in 2013 was very small, at only 338 EVs, compared to 4,030 in 2015, supporting the current assumption that no EVs were driven in Hawai'i in 2010. Data from before 2010 requires additional research to refine and confirm the assumption. Therefore, annual counts of registered BEVs and PHEVs in 2015 from EIA's SEDS were estimated by apportioning 2016 EIA's SEDS data using the ratio of 2015 to 2016 EVs from the Hawai'i DOT data. Additionally, EIA's SEDS did not contain annual BEV and PHEV electricity consumption prior to 2018. Annual BEV and PHEV electricity consumption for the years 2015 through 2017 were estimated by apportioning those years' BEV and PHEV vehicle counts by the 2018 ratio of BEV and PHEV vehicle counts to electricity consumption.

Finally, emissions were estimated by multiplying kWh consumption by annually variable Hawai'i-specific CO_2, CH_4, and N_2O total output emission rates (kg gas/kWh), from EPA eGRID (EPA 2024f). These emissions are estimated only for informational purposes and are not added to overall transportation or energy sector emissions. The GHG emissions from electricity consumption is covered already in the stationary combustion energy industries subsector. Because the Hawai'i inventory is a generation-based GHG inventory that estimates emissions created by the power sector, emissions from electricity consumption (e.g., by electric vehicles) would be double counted. GHG emissions from electricity used in electric vehicles provide a comparison of the general GHG emission magnitudes across vehicle types.

Changes in Estimates since the Previous Inventory Report

Changes that were implemented relative to the 2021 inventory report include the following:

- The CH_4 Emission Factor for jet fuel was updated to match updates made in the U.S. Greenhouse Gas Inventory. Across the timeseries, this Emission Factor is now zero. According to the U.S. Greenhouse Gas Inventory, "Recent research indicates that modern aircraft jet engines are typically net consumers of methane (Santoni et al., 2011). Methane is emitted at low power and idle operation, but at higher power modes aircraft engines consume methane. Over the range of engine operating modes, aircraft engines are net consumers of methane on average. Based on this data, CH_4 emissions factors for jet aircraft were changed to zero to reflect the latest emissions testing data."
- In the 2022 inventory, a new SEDS category for other petroleum products consumed by the transportation sector was added with biodiesel consumed by the transportation sector. This new SEDS category only represents biodiesel consumption for the state of Hawaiʻi and is not duplicative of other biodiesel consumption already being incorporated in the inventory. Biodiesel consumption is subtracted from diesel consumption, which impacts transportation sector emissions estimates slightly. Consumption data for this new SEDS category is available starting in 2021, which only impacts 2021 historical estimates.
- In the 2021 Inventory report, the disaggregated transportation data collected by DBEDT (2008a, 2024b) were applied incorrectly to allocate motor gasoline and lubricants consumption in 2010 through 2021 from EIA (2024a). A small portion of motor gasoline was inadvertently classified as water instead of ground transportation. A small portion of lubricants was inadvertently classified as air and water instead of ground transportation, and a small portion of lubricants consumption was inadvertently removed from the analysis. The disaggregation of motor gasoline and lubricants consumption has been corrected in the 2022 inventory.
- The CO_2, CH_4, and N_2O emission factors were updated to reflect the same significant figures as the values publicly available in the U.S. Inventory (EPA 2024b). This resulted in very slight changes across the timeseries.
- In the 2022 inventory, annual VMT by EVs was subtracted from the FHWA VMT data to improve the accuracy of emissions estimates for on-road vehicles with internal combustion engines. CO_2, CH_4, and N_2O emissions were also calculated for EVs as an informational item in the Hawaiʻi inventory.

The resulting changes in historical emission estimates are presented in Table 3-5.

Table 3-5: Change in Emissions from Transportation Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990	2005	2007	2017	2018	2019	2020	2021
Ground								
2021 Inventory Report	3.71	5.04	5.14	4.16	4.10	4.05	3.13	3.53
This Inventory Report	3.71	5.04	5.14	4.16	4.10	4.05	3.13	3.50
Percent Change	+%	(+%)	(+%)	(+%)	(+%)	(+%)	(+%)	(1.0%)

Emission Estimates	1990	2005	2007	2017	2018	2019	2020	2021
Domestic Marine								
2021 Inventory Report	1.53	0.37	2.81	0.49	0.40	0.63	0.34	0.52
This Inventory Report	1.53	0.37	2.81	0.49	0.40	0.63	0.34	0.52
Percent Change	(+%)	+%	(+%)	(+%)	0.2%	0.1%	(+%)	(+%)
Domestic Aviation								
2021 Inventory Report	3.70	6.14	4.87	4.61	4.78	4.96	2.73	4.59
This Inventory Report	3.69	6.13	4.86	4.61	4.78	4.96	2.73	4.58
Percent Change	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)
Military Aviation								
2021 Inventory Report (MMT CO_2 Eq.)	1.42	1.03	0.80	0.85	0.86	0.88	0.45	0.67
This Inventory Report	1.42	1.03	0.80	0.85	0.86	0.88	0.45	0.67
Percent Change	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)	(0.1%)
Military Non-Aviation								
2021 Inventory Report (MMT CO_2 Eq.)	0.77	0.02	0.79	0.20	0.32	0.16	0.32	0.32
This Inventory Report	0.77	0.02	0.79	0.20	0.32	0.16	0.32	0.32
Percent Change	(+%)	+%	(+%)	+%	(+%)	(+%)	+%	+%
Total								
2021 Inventory Report (MMT CO_2 Eq.)	11.14	12.59	14.40	10.31	10.46	10.69	6.96	9.63
This Inventory Report	11.13	12.58	14.40	10.31	10.46	10.69	6.96	9.59
Percent Change	(+%)	(+%)	(+%)	(+%)	(0.1%)	(0.1%)	(+%)	(0.4%)

+ Does not exceed 0.05 percent. (+) Does not exceed -0.05 percent.

Uncertainties

Uncertainties associated with transportation estimates include the following:

- There are uncertainties around the data collected by DBEDT and SEDS data; while significant effort has been made to validate each dataset and make a determination regarding which dataset has lower uncertainty, this remains an area of uncertainty.
- Data collected by DBEDT were used to disaggregate SEDS fuel consumption data from EIA into air, ground, and marine transportation. There is uncertainty associated with the disaggregation of the DBEDT-collected data by fuel type and end-use sector; however, since this uncertainty is only applicable to the apportioning of data, uncertainty surrounding the overall emission estimates for the transportation sector are unaffected. Also, since the data collected by DBEDT are not used to apportion aviation sector consumption, net emissions excluding aviation are not impacted by this uncertainty.

- Due to a SEDS methodology change for years prior to 2010, SEDS kerosene-type jet fuel for 1990, 2005, and 2007 was back casted to remain compatible with data for years after and including 2010.
- Kerosene-type jet fuel consumption for military was not available from EIA. For 1990 and 2007, the analysis used kerosene-type jet fuel consumption data for military as collected by DBEDT. As DBEDT is the conduit of this data but not the source, there is uncertainty associated with data collected by DBEDT. The 1990 data collected by DBEDT were used to disaggregate the jet fuel consumption from EIA into military or non-military for 1990. The 2007 data collected by DBEDT were used to disaggregate the jet fuel consumption from EIA into military or non-military for 2005, 2007, 2010, and 2015 through 2021. This resulted in some uncertainty.
- There are uncertainties around the data on electricity consumption by BEVs and PHEVs from EIA's SEDS. This data was estimated by EIA based on the annual number of registered vehicles, following the methodology outlined in Appendix D Electric Vehicle Consumption (EIA 2024a). There are also uncertainties around the data and methodology used to calculate VMT by EVs based on the annual electricity consumption, including back-calculating electricity consumption for the year 2015, disaggregating annual VMT by passenger cars and light trucks, and converting annual electricity consumption into annual VMT using MPGGe averages. On average, VMT by EVs made up around 0.5% of total VMT, so the associated uncertainties do not have a large impact on the overall transportation sector emission estimates.

To estimate uncertainty associated with emissions from transportation, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on IPCC (2006) and expert judgment. Uncertainty ranges for activity data were developed using the *2006 IPCC Guidelines* due to lack of available information from EIA. The *2006 IPCC Guidelines* provide default uncertainty bounds for activity data based on the type of energy data system from which the activity data were obtained. Because SEDS is a robust national dataset based on data from thousands of industry-specific surveys, these data were assumed to fall under the "Well developed statistical systems: Surveys" category. The highest range of uncertainties were used for this analysis. This value may change as additional analysis is conducted in the future.

The following parameters contributed the most to the quantified uncertainty estimates: (1) CO_2 emission factor for jet fuel kerosene, (2) motor gasoline consumption, (3) jet fuel kerosene consumption, (4) percent of total aviation consumption subtracted for international bunker fuels, and (5) CO_2 emission factor for motor gasoline. The results of the quantitative uncertainty analysis are summarized in Table 3-6. Emissions from transportation were estimated to be between 9.70 and 10.61 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately four percent below and five percent above the emission estimate of 10.12 MMT CO_2 Eq.

Table 3-6: Quantitative Uncertainty Estimates for Emissions from Transportation

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
10.12	9.70	10.61	-4%	5%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.
Note: Uncertainty estimates include aviation emissions.

3.3 Incineration of Waste for Energy Purposes (IPCC Source Category 1A1a)

Municipal solid waste (MSW) emits CO_2, CH_4, and N_2O emissions when combusted. In 2022, emissions from the incineration of waste for energy purposes in Hawai‘i were 0.26 MMT CO_2 Eq., accounting for 1.5 percent of Energy sector emissions and 1.3 percent of statewide total emissions (excluding sinks).[36] In 1990, MSW was combusted in Hawai‘i at two facilities: the Honolulu Program of Waste Energy Recovery (H-POWER) plant and the Waipahu Incinerator. The Waipahu Incinerator ceased operations in the early 1990s. As a result, emissions from the incineration of waste for energy purposes in Hawai‘i decreased between 1990 and 2007. Between 2007 and 2016 emissions increased due to expansions in H-POWER’s processing capacity; emissions then decreased from 2016 to 2017 before increasing again from 2017 to 2021, and slightly decreasing again in 2022. Table L-7 summarizes emissions from the incineration of waste for energy purposes in Hawai‘i by gas for the entire timeseries.

Methodology

2010 and 2015 – 2022

Emissions for the H-POWER plant for 2010 and 2015 to 2022 were obtained directly from EPA’s GHGRP (EPA 2024c). This includes non-biogenic CO_2, CH_4, and N_2O emissions and biogenic CH_4 and N_2O emissions.

1990, 2005, and 2007

Waipahu Incinerator: For the Waipahu Incinerator, CO_2, CH_4, and N_2O emissions were calculated using the IPCC (2006) Tier 1 methodology. For CO_2 emissions, this approach uses waste composition data (i.e., the percent of plastics and synthetic materials) and their respective carbon content to determine emissions from the combustion of these materials, as described in the following equation:

$$CO_2\ Emissions = MSW\ x \sum_i (WF_i\ x\ dm_i\ x\ CF_i\ x\ FCF_i\ x\ OF_i)$$

[36] Consistent with the U.S. Inventory (EPA 2024b), emissions from waste incineration are reported under the Energy sector because the waste is used to produce energy.

where,

CO_2 Emissions	= CO_2 emissions in the inventory year
MSW	= total amount of Municipal Solid Waste incinerated
WF_i	= fraction of waste type/material of component i in the MSW
dm_i	= dry matter content in the waste incinerated
CF_i	= fraction of carbon in the dry matter (total carbon content)
FCF_i	= fraction of fossil carbon in the total carbon
OF_i	= oxidation factor
i	= type of waste incinerated

For CH_4 emissions, this Tier 1 approach uses the waste input to the incinerator and a default emission factor, as described in the following equation:

$$CH_4\ Emissions = IW\ x\ EF$$

where,

CH_4 Emissions	= CH_4 emissions in the inventory year
IW	= amount of incinerated waste
EF	= CH_4 emission factor

For N_2O emissions, this Tier 1 approach uses the waste input to the incinerator and a default emission factor, as described in the following equation:

$$N_2O\ Emissions = IW\ x\ EF$$

where,

N_2O Emissions	= N_2O emissions in the inventory year
IW	= amount of incinerated waste
EF	= N_2O emission factor

Data on the quantity of waste combusted at the Waipahu Incinerator was provided by Steve Serikaku, Honolulu County Refuse Division (Serikaku 2008). Emission factors and the proportion of plastics, synthetic rubber, and synthetic fibers in the waste stream were taken from the U.S. EPA's State Inventory Tools – Solid Waste Module (EPA 2024d).

H-POWER plant: For the H-POWER plant, emissions were calculated using a Tier 3 methodology consistent with California Air Resources Board (CARB) guidance for Mandatory GHG Emissions Reporting (Hahn 2008) for the years 1990, 2005, and 2007. This methodology is believed to be more accurate than the IPCC methodology and attributes a specific ratio of carbon emissions to account for biogenic and anthropogenic sources based on carbon isotope measurements at the facility. This approach utilizes facility-specific steam output data from H-POWER to estimate CO_2, CH_4, and N_2O emissions from the combustion of refuse-derived fuel (RDF) which is processed from MSW, as described in the following equation:

$$Emissions = \sum_i Heat\ x\ EF_i$$

where,

Emissions	= GHG emissions in the inventory year
Heat	= heat output at a given facility
EF_i	= default emission factor for GHG i
i	= type of GHG emitted (CO_2, CH_4, and N_2O)

Facility-specific information for the H-POWER plant for 1990, 2005, and 2007 was obtained directly from Covanta Energy, which operates the H-POWER facility. This data included steam generation, refuse-derived fuel (RDF) composition, biogenic carbon ratios, fuel consumption data, and CO_2 and N_2O emissions (Hahn 2008).

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from the incineration of waste for energy purposes since the 2021 inventory report.

Uncertainties

To estimate uncertainty associated with emissions from waste incineration, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on the U.S. Inventory (EPA 2024b) and expert judgment. The quantified uncertainty estimated for non-biogenic CO_2 emissions for H-POWER facility contributed the vast majority to the quantified uncertainty estimates. The remaining input variables had a minor impact on the overall uncertainty of this source category.

The results of the quantitative uncertainty analysis are summarized in Table 3-7. Emissions from waste incineration were estimated to be between 0.24 and 0.30 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately eight percent below and 13 percent above the emission estimate of 0.26 MMT CO_2 Eq.

Table 3-7: Quantitative Uncertainty Estimates for Emissions from Waste Incineration

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.26	0.24	0.30	-8%	13%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

3.4 Oil and Gas Operations (IPCC Source Category 1B2)

Refinery activities release CO_2, CH_4, and N_2O to the atmosphere as fugitive emissions, vented emissions, and emissions from operational upsets.[37] Prior to 2020, two refineries, Par West and Par East,[38] operated in Hawaiʻi that contributed to these emissions (EIA 2024c). Par West began shutting down operations in 2020, with some equipment still running and generating emissions until they were fully shut down in 2022 (Widlansky 2024). In addition, CH_4 fugitive emissions occur from the distribution and transmission of propane and synthetic natural gas along pipelines. In 2022, emissions from oil and natural gas systems in Hawaiʻi were 0.10 MMT CO_2 Eq., accounting for 0.5 percent of Energy sector emissions and 0.5 percent of statewide total emissions (excluding sinks). Relative to 1990, emissions from oil and natural gas systems in 2022 were lower by roughly 77.4 percent. This decrease is attributed to a reduction in crude oil throughput over this time period. Table L-8 summarizes emissions from oil and natural gas systems in Hawaiʻi by gas across the timeseries.[39]

Methodology

Refinery emissions for 2010, 2015 – 2022

Emissions from oil and gas systems for 2010 and 2015 to 2022 were taken directly from EPA's GHGRP (EPA 2024c). This includes non-biogenic CO_2, CH_4, and N_2O fugitive emissions from petroleum refining and hydrogen production for Hawaiʻi's two refineries.

Refinery emissions for 1990, 2005, and 2007

Emissions from oil and gas systems for 1990 and 2007 were estimated by scaling 2010 emissions data from EPA's GHGRP (EPA 2024c) based on the ratio of crude oil refined (i.e., throughput) in 1990 and 2007 for the two refineries relative to 2010. This methodology assumes that emissions are proportional to the amount of crude oil processed. 2005 estimates are set equal to 2007 emissions without any further scaling adjustments. Data on the amount of crude oil refined was obtained from reports collected by DBEDT as well as direct correspondence with the refinery owners (DBEDT 2008b; Island Energy Services 2017; Par Petroleum 2017).

Fugitive emissions from natural gas distribution and transmission pipelines

[37] The state of Hawaiʻi does not have any natural gas exploration, production, or processing. Sources of emissions in the natural gas systems category include fugitive emissions from propane and synthetic natural gas transmission and distribution.

[38] The Par West Refinery was previously known as the Island Energy Services Refinery and, prior to that, as the Chevron Products Company Hawaiʻi Refinery; the Par East Refinery was previously known as Refinery Kapolei which was previously known as the Hawaiʻi Independent Energy Petroleum Refinery.

[39] Emissions from fuels combusted at refineries are included in under the stationary combustion source category.

Emissions from natural gas distribution and transmission pipelines for all inventory years were estimated using the following equation[40]:

$$CH_4\ Emissions = (M_{distribution} \times PLF_{material}) + (M_{transmission} \times PLF_{transmission})$$

where,

$M_{distribution}$ = pipeline miles used for natural gas distribution by material type

$M_{transmission}$ = pipeline miles used for natural gas transmission

$PLF_{material}$ = distribution pipeline leak factor for CH_4 by material type (mscf/mile-year)

$PLF_{transmission}$ = transmission pipeline leak factor for CH_4 (mscf/mile-year)

Distribution miles data by material for both main and service lines, as well as transmission miles data, were obtained from DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) database (DOT 2022b) and pipeline leak factors were obtained from the U.S. Inventory (EPA 2024b).

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from oil and gas systems since the 2021 inventory report.

Uncertainties

Fugitive emissions from petroleum refining for 1990, 2005, and 2007 were not available from EPA's GHGRP. These emissions were instead estimated based on annual throughput for each refinery. For well-controlled systems the primary source of emissions are fugitive equipment leaks, which are independent of system throughputs (IPCC 2000). As a result, there is uncertainty associated with using throughput as an estimate for emissions in 1990, 2005, and 2007. Additionally, annual throughput for the Par West Refinery was not available for 1990; for the purposes of this analysis, it was assumed that 1990 throughput was consistent with 2007 levels. Lastly, annual throughput for the Par West Refinery and Par East Refinery was not available for 2005; for the purposes of this analysis, it was assumed that 2005 throughput was consistent with 2007 levels. Fugitive emissions from natural gas distribution and transmission are disaggregated by pipeline material. Data from DOT's PHMSA does not provide details on the material types included in the "other materials" category for gas distribution services. An average pipeline leak rate was applied to the distribution services, other materials, and as a result, there is uncertainty associated with these emissions.

To estimate uncertainty associated with emissions from oil and gas operations, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on expert judgment. The quantified uncertainty estimated for CO_2 emissions for the Par East Refinery contributed the vast majority to the quantified uncertainty estimates. The remaining input

[40] All CH_4 emissions are converted to MMT CO_2 Eq. based on the GWPs provided in Table 1-1 and the conversion factor for thousand standard cubic feet to MMT, which is 0.00000001926 mscf/MMT.

variables had a minor impact on the overall uncertainty of this source category. The results of the quantitative uncertainty analysis are summarized in Table 3-8. Emissions from oil and natural gas systems were estimated to be between 0.10 and 0.10 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 0.1 percent below and 0.1 percent above the emission estimate of 0.10 MMT CO_2 Eq.

Table 3-8: Quantitative Uncertainty Estimates for Emissions from Oil and Natural Gas Systems

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.10	0.10	0.10	-0.1%	0.1%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

3.5 Non-Energy Uses of Fossil Fuels (IPCC Source Category 1A)

In addition to being combusted for energy, fossil fuels are also consumed for non-energy uses in Hawai‘i. Emissions may occur during the manufacture of a product or during the product’s lifetime. Fuels used in non-energy uses include coal, diesel fuel, propane, asphalt and road oil, lubricants, and waxes. In 2022, emissions from non-energy uses of fuels in Hawai‘i were 0.04 MMT CO_2 Eq., accounting for 0.2 percent of Energy sector emissions and 0.2 percent of statewide total emissions (excluding sinks). These emissions are included under the Energy sector, rather than the IPPU sector, consistent with the U.S. Inventory (EPA 2024b) and in compliance with IPCC Guidelines. The methods for calculating emissions from fossil fuel combustion and NEU emissions both rely on a carbon balance approach, which considers the total amount of fossil fuels used for energy and NEU.[41] Table L-9 summarizes emissions from non-energy uses of fuels in Hawai‘i by gas across the timeseries.

Methodology

Carbon dioxide emissions were estimated using the following equation, consistent with IPCC (2006):[42]

$$CO_2\ Emissions\ =\ [Fuel\ Consumption\ \times NEU\ Consumption\ \%\ ] \times C_{fuel}\ \times \frac{44}{12} \times [1 - C_{stored}]$$

[41] As depicted in Figure 3-3 of the U.S. Inventory, NEU and energy emissions are estimated through a mass balance of carbon flows (i.e., carbon inputs and outputs). Both emission sources use the same initial fuel consumption values from SEDS and are summarized in the same sector. Emissions are reported under the Energy chapter to provide a complete carbon balance and avoid double counting with IPPU for related activities. To maintain a complete carbon balance and a transparent approach for calculating carbon emissions from non-energy uses of fossil fuels, the entire calculation of carbon storage and emissions is conducted within the non-energy uses category under Energy.

[42] Methane and N_2O emissions from non-energy uses are not estimated, consistent with IPCC Guidance (2006) and the U.S. Inventory (EPA 2024b).

where,

Fuel Consumption	= total consumption by fuel type and end-use sector (Bbtu)
NEU Consumption %	= percentage of non-energy use of fuel consumption (percent)
C_{fuel}	= total mass of carbon per unit of energy in each fuel (lbs C/Bbtu)
44/12	= conversion of carbon to CO_2
C_{stored}	= carbon storage factor by fuel type (percent)

The percentage of non-energy use consumption by fuel type were obtained from the U.S. Inventory (EPA 2024b) and applied to total consumption values for fuels by end use sector obtained from EIA's SEDS (EIA 2024b).[43] Carbon content coefficients for estimating CO_2 emissions, which are specific to each fuel type, were taken from the U.S. Inventory (EPA 2024b). The percentage of C stored in non-energy uses of fuels were also obtained from EPA (2024b).

Changes in Estimates since the Previous Inventory Report

Changes that were implemented relative to the 2021 inventory report include the following:

- The percentage of non-energy use consumption by fuel type were updated for historical years to match updates made in the U.S. Greenhouse Gas Inventory.
- In the 2021 Inventory report, the carbon storage factor from 2017 was inadvertently applied to propane in 2005 and 2018 through 2021. While the propane carbon storage factor does not vary significantly year-to-year, it is annually variable. The correct annual carbon storage factor has been applied to the timeseries in the 2022 inventory.
- The CO_2, CH_4, and N_2O emission factors were updated to reflect the same significant figures as the values publicly available in the U.S. Inventory (EPA 2024b). This resulted in very slight changes across the timeseries.

The resulting changes in historical emission estimates are presented in Table 3-9.

Table 3-9: Change in Emissions from Non-Energy Uses Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990	2005	2007	2017	2018	2019	2020	2021
2021 Inventory Report	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03
This Inventory Report	0.04	0.04	0.04	0.05	0.05	0.04	0.04	0.04
Percent Change	(0.5%)	0.1%	(0.3%)	13.1%	21.8%	21.8%	30.2%	18.7%

[43] Consumption values for fuels included in the stationary combustion source category from EIA's SEDS (EIA 2024b) were adjusted to subtract non-energy uses.

Uncertainties

Uncertainties associated with non-energy use estimates include the following:

- Non-energy use CO_2 emission factors are not available from the U.S. Inventory (EPA 2024b), therefore industrial sector emission factors, by fuel type are used.
- Non-energy use estimates are based on U.S.-specific storage factors. The storage factor for feedstocks is based on an analysis of long-term storage and emissions. Rather than modeling the total uncertainty around each process, the current analysis addresses only the storage rates, and assumes that all C that is not stored is emitted. Further analysis may investigate Hawai'i-specific non-energy use storage factors and processes.

To estimate uncertainty associated with emissions from non-energy uses, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on IPCC (2006) and expert judgment. The following parameters contributed the most to the quantified uncertainty estimates: (1) industrial lubricant consumption, (2) transportation lubricant consumption, and (3) industrial LPG consumption.

The results of the quantitative uncertainty analysis are summarized in Table 3-10. Emissions from non-energy uses were estimated to be between 0.029 and 0.040 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 25 percent below and 1.4 percent above the emission estimate of 0.039 MMT CO_2 Eq.

Table 3-10: Quantitative Uncertainty Estimates for Emissions from Non-Energy Uses

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.039	0.029	0.040	-25%	1.4%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

3.6 International Bunker Fuels (IPCC Source Category 1: Memo Items)[44]

International bunker fuels (IBFs) are defined as marine and aviation travel originating in Hawai'i and ending in a foreign country. According to IPCC (2006), emissions from the combustion of fuels used for international transport activities, or international bunker fuels, should not be included in emission totals, but instead should be reported separately. International bunker fuel combustion produces CO_2, CH_4, and N_2O emissions from both marine and aviation fuels. In 2022, emissions from international bunker fuels in Hawai'i were 0.83 MMT CO_2 Eq., which is 46.5 percent lower than 1990 levels. Table L-10 summarizes emissions from international bunker fuels in Hawai'i by gas across the timeseries.

[44] This source category is not included in inventory totals in accordance with IPCC (2006) guidance.

Methodology

Carbon dioxide emissions were estimated using the following equation, consistent with IPCC (2006):

$$CO_2\ Emissions\ =\ [IBF\ Consumption\ ] \times C_{fuel}\ \times \frac{44}{12}$$

where,

IBF Consumption	= total consumption of international bunker fuels by fuel type (Bbtu)
C_{fuel}	= total mass of carbon per unit of energy in each fuel (lbs C/Bbtu)
44/12	= conversion of carbon to CO_2

Methane and N_2O emissions were calculated using an IPCC (2006) Tier 1 methodology. Emissions were calculated using the following equation:

$$CH_4\ and\ N_2O\ Emissions\ =\ IBF\ Consumption \times EF_{fuel}$$

where,

IBF Consumption	= total amount of International Bunker Fuel combusted (Bbtu)
EF_{fuel}	= emission factor of CH_4 and N_2O by fuel type (MT/Bbtu)

Carbon dioxide emission factors were obtained from the U.S. Inventory (EPA 2024b), while CH_4 and N_2O emission factors were obtained from IPCC (2006). The following sections describe how IBF consumption was derived for aviation and marine bunker fuel.

Aviation Bunker Fuel

Aviation bunker fuel consumption was calculated based on the estimated amount of jet fuel used for international trips in each year. Aircraft-specific fuel efficiency estimates (miles/gal) and mileage data were used to calculate the ratio of domestic to international fuel consumption to allocate jet fuel consumption estimates from SEDS (EIA 2024b) into domestic and international bunker fuel consumption. EIA's SEDS follows a new methodology and revised estimates for state-level jet fuel consumption for 2010 onwards (EIA 2024b). This change impacts fuel consumption for domestic and military aviation, as well as aviation international bunker fuels. The method employed to back-cast SEDS consumption data prior to 2010 is described in Section 3.2.

The annual fuel efficiency for each aircraft type for both domestic and international flights was calculated using Airline Data Inc.'s (ADI) Form 41 Fuel Statistics dataset (ADI 1990 to 2022)[45]. Annual fuel efficiencies per aircraft type were calculated by dividing annual miles traveled by annual gallons consumed. International flights are those labeled as "Atlantic", "Latin America", and "Pacific", while

[45] Airline Data Inc.'s Form 41 Fuel Statistics dataset (ADI 1990 to 2022) is a cleaned and user-friendly version of the same data available from BTS (1990 to 2022).

domestic flights are those labeled as "Domestic" in this dataset. The calculated year-specific fuel efficiencies by aircraft type were then multiplied by the total distance traveled by year for domestic and international flights originating in Hawai'i to back-calculate total gallons consumed (BTS 1990 to 2022). That percentage of international consumption out of total consumption (i.e., international and domestic consumption) was multiplied by total non-military jet fuel consumption in Hawai'i, as derived from EIA (2019 and 2024a), to calculate aviation international bunker fuel consumption.

$$IBF\ Consumption\ =\ [Jet\ Fuel_T - Jet\ Fuel_M] \times [\frac{Gallons_I}{Gallons_I +\ Gallons_D}]$$

where,

IBF Consumption	= total consumption of international bunker fuels from jet fuel (Bbtu)
Jet $Fuel_T$	= total jet fuel consumption from SEDS (Bbtu)
Jet $Fuel_M$	= military jet fuel consumption (Bbtu)
$Gallons_I$	= gallons consumed for international trips originating in Hawai'i
$Gallons_D$	= gallons consumed for domestic trips originating in Hawai'i

Marine Bunker Fuel

Marine bunker fuel consumption was calculated based on the estimated amount of diesel and residual fuel consumption used for international trips. Fuel consumption is included for both vessels flying American and foreign flags. For all inventory years except 1990, marine bunker fuel consumption for Hawai'i was obtained directly from the Census Bureau (DOC 2005, 2007, 2010, 2015 through 2022). For 1990, marine bunker fuel consumption for all international traveling vessels was estimated by applying the average of 2006 and 2007 Hawai'i marine bunker fuel consumption (the earliest available years for Hawai'i marine bunker fuel) to apportion U.S. consumption in 1990. An average of the two years was used to account for annual fluctuations in consumption. National marine bunker fuel consumption was obtained from the U.S. Inventory (EPA 2024b).

Changes in Estimates since the Previous Inventory Report

The CO_2 emission factors were updated to contain the same number of decimals as are publicly available in the U.S. Inventory (EPA 2024b). This resulted in very slight changes across the timeseries. The resulting changes in historical emission estimates are presented in Table 3-11 and Table 3-12.

Table 3-11: Change in Emissions from Marine Bunker Fuels Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	0.11		0.79		0.05		0.12	0.20	0.11	0.11	0.08
This Inventory Report	0.11		0.79		0.05		0.12	0.20	0.11	0.11	0.08
Percent Change	0.0%		0.0%		0.0%		+%	(+%)	(+%)	(+%)	(+%)

+ Does not exceed 0.05 percent. (+) Does not exceed -0.05 percent.

Table 3-12: Change in Emissions from Aviation Bunker Fuels Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	1.45		1.44		1.04		1.64	1.57	1.53	0.57	0.32
This Inventory Report	1.45		1.44		1.04		1.64	1.57	1.53	0.57	0.32
Percent Change	0.0%		0.0%		(+%)		0.0%	0.0%	0.0%	0.0%	0.0%

(+) Does not exceed -0.05 percent

Uncertainties

Uncertainties associated with international bunker fuel estimates include the following:

- Due to a SEDS methodology change for years prior to 2010, SEDS kerosene-type jet fuel for 1990, 2005, and 2007 was back casted to remain compatible with data for years after and including 2010. Jet fuel consumption was then disaggregated into domestic and international for all years.
- Kerosene-type jet fuel consumption for military was not available from EIA. For 1990 and 2007, the analysis used kerosene-type jet fuel consumption data for military as collected by DBEDT. As DBEDT is the conduit of this data but not the source, there is also uncertainty associated with data collected by DBEDT. The data collected by DBEDT were used to disaggregate total jet fuel consumption from EIA into military or non-military for all years. Non-military jet fuel consumption was then disaggregated into domestic and international for all years.
- There is some uncertainty associated with estimating jet fuel consumption for international trips based on the international flight to total flight fuel efficiency ratio. This approach was used because data on jet fuel consumption for international trips originating in Hawai‘i were not available.
- There is some uncertainty with estimating marine bunker fuel consumption in 1990 due to a lack of available data and use of the average of 2006 and 2007 data to apportion total U.S. consumption.
- Uncertainties exist with the reliability of Census Bureau (DOC 2008 and 2018) data on marine vessel fuel consumption reported at U.S. customs stations due to the significant degree of inter-annual variation, as discussed further in the U.S. Inventory (EPA 2024b).

To estimate uncertainty associated with emissions from international bunker fuels, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on IPCC (2006) and expert judgment. Uncertainty ranges for activity data were developed using the *2006 IPCC Guidelines* due to lack of available information from EIA. The *2006 IPCC Guidelines* provide default uncertainty bounds for activity data based on the type of energy data system from which the activity data were obtained. Because SEDS is a robust national dataset based on data from thousands of industry-specific surveys, these data were assumed to fall under the “Well developed statistical systems: Surveys” category. The highest range of uncertainties were used for this analysis. This value may change as additional analysis is conducted in the future.

The following parameters contributed the most to the quantified uncertainty estimates: (1) percent of total aviation consumption for international bunker fuels, (2) jet fuel consumption, and (3) CO_2 emission factor for jet fuel. The results of the quantitative uncertainty analysis are summarized in Table 3-13. Emissions from international bunker fuels were estimated to be between 0.74 and 0.93 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 11 percent below and 12 percent above the emission estimate of 0.83 MMT CO_2 Eq.

Table 3-13: Quantitative Uncertainty Estimates for Emissions from International Bunker Fuels

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.83	0.74	0.93	-11%	12%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

3.7 CO_2 from Wood Biomass and Biofuel Consumption (IPCC Source Categories 1A)[46]

Ethanol, biodiesel, and other types of biomass release CO_2 emissions when combusted.[47,48] According to IPCC (2006), since these emissions are biogenic, CO_2 emissions from biomass in combustion should be estimated separately from fossil fuel CO_2 emissions and should not be included in emission totals. This is to avoid double-counting of biogenic CO_2 emissions from the AFOLU sector. In 2022, CO_2 emissions from wood biomass and biofuel consumption in Hawai‘i were 1.19 MMT CO_2 Eq., which is 51.0 percent lower than 1990 levels. Table L-11 summarizes CO_2 emissions from wood biomass and biofuel consumption in Hawai‘i across the timeseries.

Methodology

Biofuels

Carbon dioxide emissions from biofuel (ethanol or biodiesel) combustion were calculated using the following equation:

$$CO_2\ Emissions\ =\ Biofuel\ Consumption\ \times\ HHV_{biofuel}\ \times\ EF_{biofuel}$$

[46] This source category is not included in inventory totals in accordance with IPCC (2006) guidance.

[47] Ethanol is blended with motor gasoline at oil refineries. Hawai‘i began blending ethanol into motor gasoline supply in 2006.

[48] In addition to CO_2, small amounts of CH_4 and N_2O are also emitted from biomass sources. Unlike CO_2 emissions from biomass, these CH_4 and N_2O emissions are not accounted for in a separate process, and thus are included in the stationary combustion and transportation source categories and are counted towards total emissions.

where,

Biofuel Consumption	= total volumes of ethanol and biodiesel combusted (gal)
$HHV_{biofuel}$	= Default high heat values of ethanol and biodiesel (Million Btu or MMBtu/gal)
$EF_{biofuel}$	= Ethanol- and biodiesel-specific default CO_2 emission factors (kg CO_2/MMBtu)

Carbon dioxide emissions from RNG combustion were calculated using the following equation:

$$CO_2\ Emissions\ =\ RNG\ Consumption\ \times\ EF_{RNG}$$

where,

RNG Consumption	= total amount of RNG combusted (Bbtu)
EF_{RNG}	= RNG gas default CO_2 emission factor (lb CO_2/MMBtu)

Biogenic carbon dioxide emissions from the incineration of waste at the H-POWER plant for 2010 and 2015 to 2022 were obtained directly from EPA's GHGRP (EPA 2024c).

Wood Biomass

Carbon dioxide emissions from wood biomass combustion were calculated using the following equation:

$$CO_2\ Emissions\ =\ Wood\ Biomass\ Consumption\ \times\ EF_{wood\ biomass}$$

where,

Wood Biomass Consumption	= total amount of wood biomass combusted (Bbtu)
$EF_{wood\ biomass}$	= Wood biomass default CO_2 emission factor (lb CO_2/MMBtu)

Ethanol, biodiesel, and wood biomass consumption data were obtained from SEDS (EIA 2024b) for all years. RNG consumption data was obtained from City & County of Honolulu (2024) and City & County of Honolulu (2022) and assumed to be consumed 50% by the residential sector and 50% by the commercial sector (City & County of Honolulu 2024). Carbon dioxide combustion emission factors for ethanol and biodiesel were obtained from the U.S. Inventory (EPA 2024b), and carbon dioxide combustion emission factors for wood biomass and RNG consumption were obtained from U.S. EPA (EPA 2024a). Biogenic carbon dioxide emissions from the incineration of waste were obtained directly from EPA's GHGRP (EPA 2024c).

Changes in Estimates since the Previous Inventory Report

Changes that were implemented relative to the 2021 inventory report include the following:

- A new SEDS category for other petroleum products consumed by the transportation sector was added with biodiesel consumption consumed by the transportation sector. This new SEDS category was determined to contain only biodiesel consumption for the state of Hawai'i and was not duplicative of other biodiesel consumption already being incorporated in the inventory.

Consumption data for this new SEDS category is available starting in 2021. Therefore, this methodological change only impacts 2021 historical estimates.

- Emissions from the consumption of RNG was incorporated into the inventory. As of 2018, this RNG is produced by the Honouliuli WWTP and captured by Hawai'i Gas natural gas for injection into their synthetic natural gas (SNG) distribution system (Hawai'i Free Press 2018). Therefore, this methodological change impacts 2018 through 2021 historical estimates.
- The emission factor for CO_2 emissions from wood biomass was updated.

The resulting changes in historical emission estimates are presented in Table 3-14.

Table 3-14: Change in CO_2 Emissions from Wood Biomass and Biofuel Consumption Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990	2005	2007	2017	2018	2019	2020	2021
2021 Inventory Report	2.43	0.59	0.88	1.28	1.30	1.25	1.16	1.15
This Inventory Report	2.43	1.04	0.88	1.28	1.30	1.25	1.16	1.18
Percent Change	0.0%	74.8%	0.0%	0.0%	+%	0.2%	0.1%	2.7%

+ Does not exceed 0.05 percent.

Uncertainties

There are uncertainties around the data collected by DBEDT and SEDS data; while significant effort has been made to validate each dataset and make a determination regarding which dataset has lower uncertainty, this remains an area of uncertainly. The current dataset excludes the Mahipapa Biomass Facility, the inclusion of this facility is a priority improvement to be researched for future inventories.

To estimate uncertainty associated with CO_2 emissions from wood biomass and biofuel consumption, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on IPCC (2006) and expert judgment. The following parameters contributed the most to the quantified uncertainty estimates: (1) H-Power plant biogenic CO_2 emissions, (2) transportation ethanol consumption, and (3) CO_2 emission factor for ethanol.

The results of the quantitative uncertainty analysis are summarized in Table 3-15. Carbon dioxide emissions from wood biomass and biofuel consumption were estimated to be between 1.08 and 1.31 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 10 percent below and 10 percent above the emission estimate of 1.19 MMT CO_2 Eq.

Table 3-15: Quantitative Uncertainty Estimates for Emissions from Wood Biomass and Biofuel Consumption

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
1.19	1.08	1.31	-10%	10%

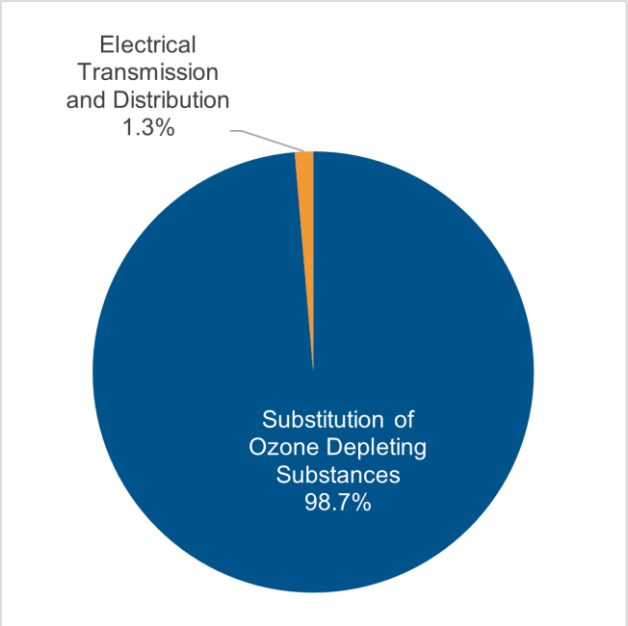
[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

4. Industrial Processes and Product Use (IPPU)

This chapter presents GHG emissions that occur from industrial processes and product use (IPPU). For the state of Hawai'i, IPPU sector emissions are estimated from the following sources: cement production (IPCC Source Category 2A1), electrical transmission and distribution (IPCC Source Category 2G1), and substitution of ozone depleting substances (IPCC Source Category 2F).[49]

In 2022, emissions from the IPPU sector were 0.85 MMT CO_2 Eq., accounting for 4.2 percent of total Hawai'i emissions. Emissions from the substitution of ozone depleting substances accounted for the majority of emissions from the IPPU sector, representing 98.7 percent of IPPU emissions and 4.1 percent of statewide total emissions (excluding sinks). The remaining 1.3 percent of IPPU emissions are from electrical transmission and distribution. Clinker production in Hawai'i ceased in 1996 and, as a result, emissions from cement production in 2022 were zero. Figure 4-1 and Figure 4-1 show emissions (% and MMT CO_2 Eq.) from the IPPU sector by source for 2022.

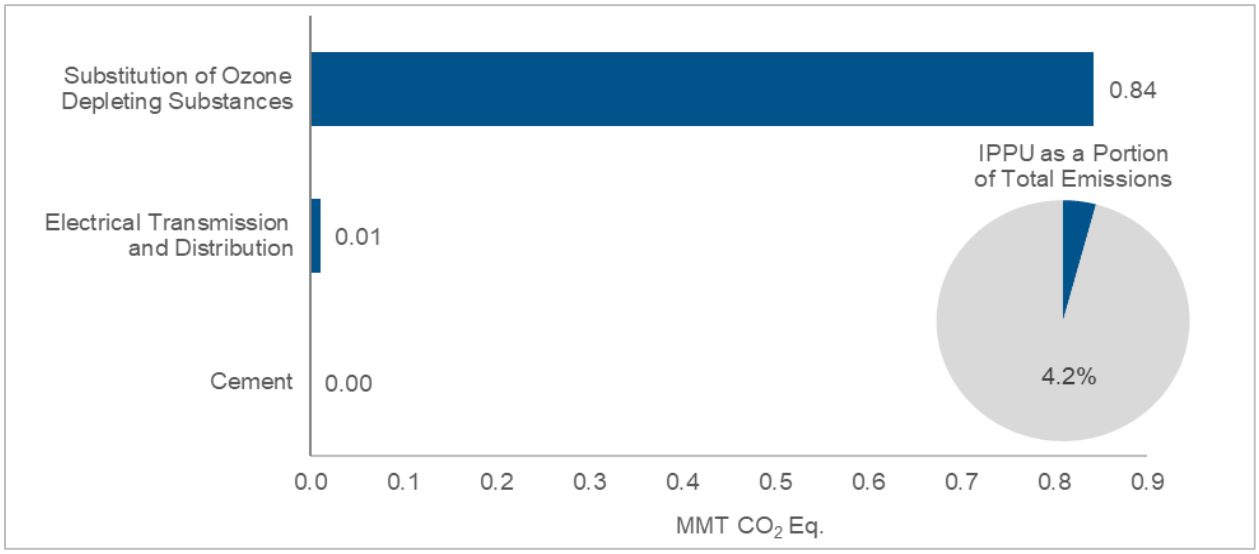
Figure 4-1: 2022 IPPU Emissions (%) by Source



Note: Totals may not sum due to independent rounding.

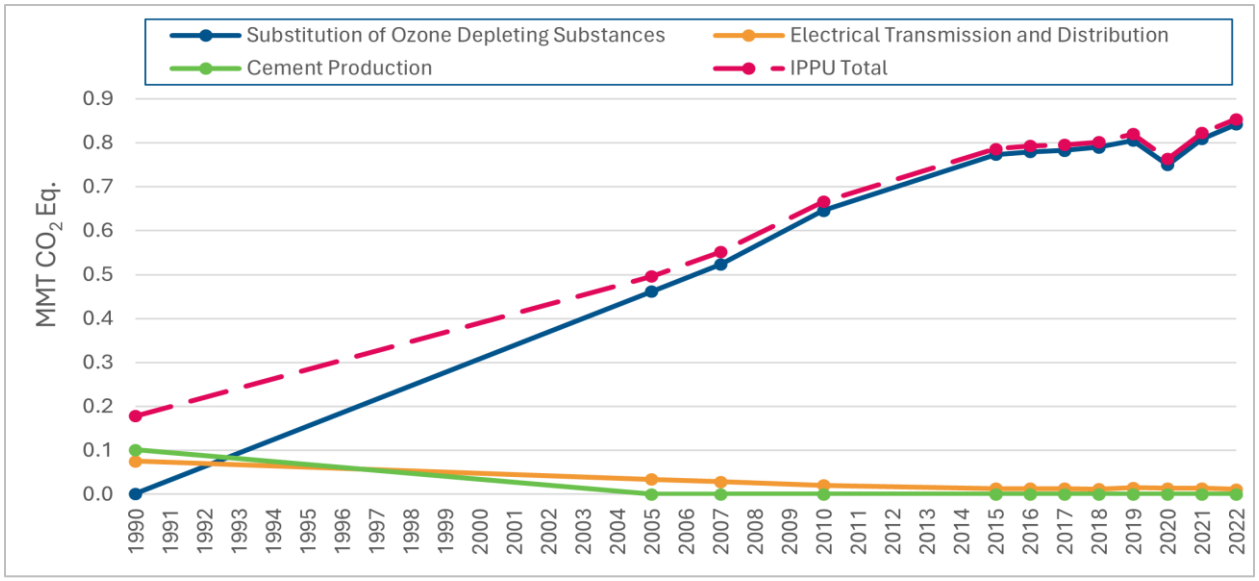
[49] IPCC Source Categories for which emissions were not estimated for the state of Hawai'i include: lime production (2A2), glass production (2A3), other process uses of carbonates (2A4), chemical industry (2B), metal industry (2C), electronics industry (2E), SF_6 and PFCs from other product uses (2G2), and N_2O from product uses (2G3). Appendix A provides information on why emissions were not estimated for these IPCC Source Categories.

Figure 4-1: 2022 IPPU Emissions by Source (MMT CO_2 Eq.)



Relative to 1990, emissions from the IPPU sector in 2022 were higher by nearly 378.4 percent. The increase is due entirely to the growth in HFC and PFC emissions, which are used as a substitute for ODS used primarily in refrigeration and air conditioning. These substitutes have grown steadily in line with national emissions as ODS are phased out under the Montreal Protocol (EPA 2024b). Sulfur hexafluoride emissions from electrical transmission and distribution decreased by 84.9 percent from 1990 to 2022, also consistent with national emissions. This decrease is attributed to increasing SF_6 prices and industry efforts to reduce emissions (EPA 2024b). Figure 4-3 below shows IPPU sector emissions by source category for each inventory year. Emissions by source and year are also summarized in Table L-12.

Figure 4-3: IPPU Emissions by Source and Year (MMT CO_2 Eq.)



Notes: Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

The remainder of this chapter describes the detailed emission results by source category, including a description of the methodology and data sources used to prepare the inventory. Activity data and emission factors used in the analysis are summarized in Appendix F and Appendix G, respectively.

4.1 Cement Production (IPCC Source Category 2A1)

Carbon dioxide emissions are released as a by-product of the clinker production process, an intermediate product used primarily to make portland cement. In Hawaiʻi, clinker was produced on-site in Oʻahu until production ceased in 1996, after which clinker was imported (Wurlitzer 2008). Portland cement production ended in Hawaiʻi in 2001 (Wurlitzer 2008). As a result, in 2022, emissions from cement production in Hawaiʻi were zero. Table L-13 summarizes emissions from cement production in Hawaiʻi across the timeseries.

Methodology

Process-related CO_2 emissions from cement production were estimated using IPCC (2006) Tier 2 methodology, plant-specific clinker production provided by Hawaiian Cement (Wurlitzer 2008), and default factors for calcium oxide content and cement kiln dust (CKD) from the *2006 IPCC Guidelines* (IPCC 2006). Emissions were calculated using the following equation:

$$CO_2\ Emissions = M_{clinker} \times EF_{clinker} \times CFac_{cement\ kiln\ dust}$$

where:

$M_{clinker}$ = weight (mass) of clinker produced, tonnes
$EF_{clinker}$ = emission factor for clinker
$CFac_{cement\ kiln\ dust}$ = emissions correction factor for cement kiln dust

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from cement production since the 2021 inventory report.

Uncertainties

The uncertainties around emissions from cement production were not quantitatively assessed because there is currently no cement production in the state.

4.2 Electrical Transmission and Distribution (IPCC Source Category 2G1)

Sulfur hexafluoride (SF_6) and carbon tetrafluoride (CF_4) emissions from electrical transmission and distribution systems result from leaks in transmission equipment. SF_6 is used as an electrical insulator and interrupter for equipment. CF_4 is mixed with SF_6 to avoid liquefaction at low temperatures. In 2022, emissions from electrical transmission and distribution systems in Hawaiʻi were 0.01 MMT CO_2 Eq.,

accounting for 1.3 percent of IPPU sector emissions and 0.1 percent of statewide total emissions (excluding sinks). Relative to 1990, emissions from electrical transmission and distribution systems in 2022 were lower by 84.9 percent. Nationally, these emissions have decreased over time due to a sharp increase in the price of SF_6 during the 1990s and a growing awareness of the environmental impact of SF_6 emissions (EPA 2024b). Table L-14 summarizes emissions from electrical transmission and distribution systems in Hawai‘i across the timeseries.

Methodology

Emissions were calculated by apportioning U.S. emissions from this source to Hawai‘i based on the ratio of Hawai‘i electricity sales to U.S. electricity sales. Estimates of national SF_6 and CF_4 emissions data were taken from the U.S. Inventory (EPA 2024b). National electricity sales data come from the U.S. Department of Energy (DOE), Energy Information Administration (EIA 2023). Hawai‘i electricity sales data come from the State of Hawai‘i Data Book (DBEDT 2023).

Changes in Estimates since the Previous Inventory Report

National emissions data were recently updated in the U.S. Inventory (EPA 2024b), based on revisions to reported historical data in EPA’s GHGRP and corrections to the data used to estimate SF_6 emissions from electrical equipment manufacturing as well as the data used to estimate non-reporter emissions. As the estimates for Hawai‘i are calculated by apportioning U.S. emissions from this source to Hawai‘i, this resulted in a change to the estimates.

Compared to the previous inventory from 2021, average annual change in CO_2-equivalent emissions from electrical transmission and distribution decreased 0.9 percent over the time period. The resulting changes in historical emissions estimates are presented in Table 4-1.

Table 4-1: Change in Emissions from Electrical Transmission and Distribution Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	0.08		0.03		0.03		0.01	0.01	0.01	0.01	0.01
This Inventory Report	0.08		0.03		0.03		0.01	0.01	0.01	0.01	0.01
Percent Change	0.0%		0.8%		0.0%		(3.6%)	(3.8%)	0.0%	0.0%	0.0%

Uncertainties

The apportionment method was used to estimate emissions from electrical transmission and distribution systems in Hawai‘i instead of the IPCC methodology because data on SF_6 purchases and emissions for Hawaiian utilities were not available. The apportionment method does not account for state-specific circumstances that may deviate from national trends (e.g., efforts taken by the state, or utilities within the state, to reduce SF_6 emissions from electrical transmission and distribution systems beyond the average rate of national emission reductions). These model uncertainties were not assessed as part of the quantitative uncertainty analysis.

To estimate uncertainty associated with emissions from electrical transmission and distribution, uncertainties associated with three quantities were assessed: (1) U.S. SF_6 electricity transmission and distribution emissions, (2) U.S. electricity sales, and (3) Hawai'i electricity sales. Uncertainty was estimated quantitatively around each input variable based on expert judgment. Each input variable contributed relatively evenly to the overall uncertainty of the emissions estimate.

The results of the quantitative uncertainty analysis are summarized in Table 4-2. Emissions from electrical transmission and distribution systems were estimated to be between 0.01 MMT CO_2 Eq. and 0.02 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 30 percent below and 36 percent above the emission estimate of 0.011 MMT CO_2 Eq.

Table 4-2: Quantitative Uncertainty Estimates for Emissions from Electrical Transmission and Distribution

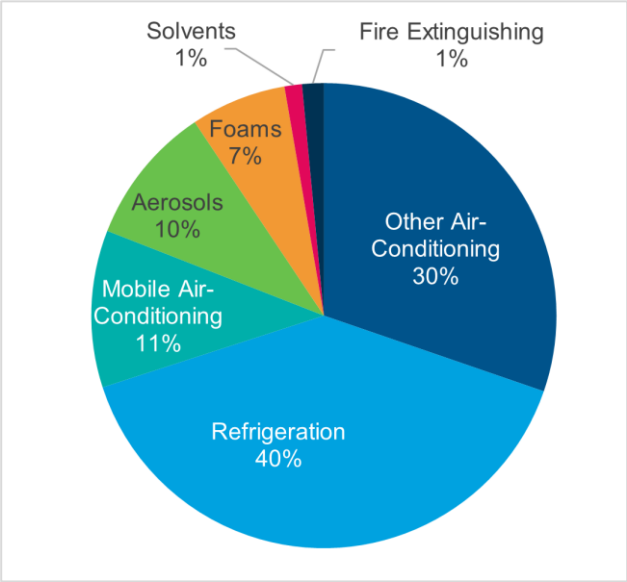
2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.011	0.01	0.02	-30%	36%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

4.3 Substitution of Ozone Depleting Substances (IPCC Source Category 2F)

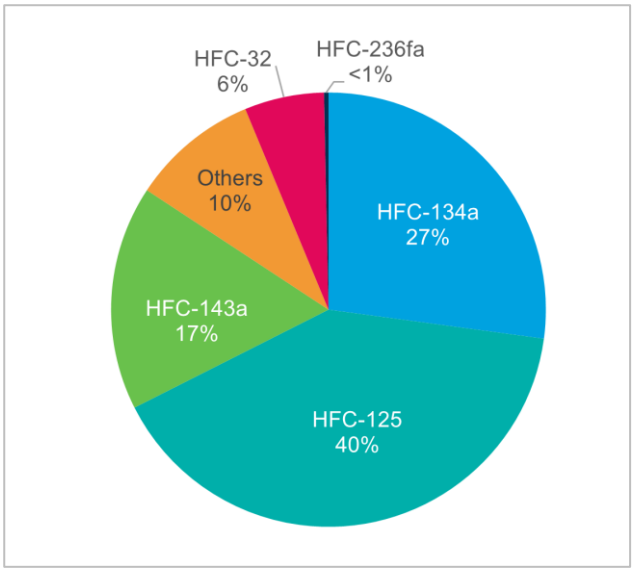
HFCs and PFCs are used as alternatives to ODS that are being phased out under the Montreal Protocol and the Clean Air Act Amendments of 1990. These chemicals are most commonly used in refrigeration and air conditioning equipment, solvent cleaning, foam production, fire extinguishing, and aerosols. In 2022, emissions from ODS substitutes in Hawai'i were 0.84 MMT CO_2 Eq., accounting for 98.7 percent of IPPU sector emissions and 4.1 percent of statewide total emissions (excluding sinks). Nationally, emissions from ODS substitutes have risen dramatically since 1990, and now represent one of the largest sources of GHG emissions from the IPPU sector (EPA 2024b). Table L-15 summarizes emissions from HFCs and PFCs that are used as substitutes of ODS in Hawai'i across the timeseries. While not included in the inventory totals, estimated emissions from ODS in Hawai'i are presented in Appendix H.[50]

Figure 4-2: 2022 Emissions (%) from ODS Substitutes by Sub-Category



Note: Totals may not sum due to independent rounding.

Figure 4-3: 2022 Emissions (%) from ODS Substitutes by Gas



Note: Totals may not sum due to independent rounding.

Methodology

In contrast to source categories in which emissions are calculated based on production data or are directly monitored at a small number of point sources, emissions of HFCs and PFCs can occur from thousands of types of equipment from millions of sources, including refrigeration

[50] Per IPCC (2006) guidelines, emissions of ODS, which are also GHGs, are not included in this inventory. For informational purposes, ODS emissions were estimated for the state of Hawai'i and are presented in Appendix H.

and air-conditioning units, aerosols, and solvents. Percentage of emissions by sub-category are shown in Figure 4-2.

At the national level, these emissions are estimated using EPA's Vintaging Model, which tracks the use characteristics of equipment currently in use for more than 70 different end-use categories and applies HFC and PFC leak rates to estimate annual emissions. In the U.S. Inventory (EPA 2024b), emissions are presented for the following sub-categories:

- Mobile air-conditioning
- Other refrigeration and air-conditioning
- Aerosols
- Foams
- Solvents
- Fire extinguishing

Hawaiʻi emissions from mobile air-conditioning systems were estimated by apportioning national emissions from the U.S. Inventory (EPA 2024b) to Hawaiʻi based on the ratio of Hawaiʻi vehicle registrations from the State of Hawaiʻi Data Book (DBEDT 2023) to U.S. vehicle registrations from the U.S. Department of Transportation, Federal Highway Administration (FHWA 2023). Hawaiʻi emissions from other air-conditioning systems (i.e., air conditioning systems excluding mobile air conditioners) were estimated by apportioning national emissions from the U.S. Inventory (EPA 2024b) to Hawaiʻi based on the ratio of the number of houses with air conditioners in Hawaiʻi to the number of houses with air conditioners in the United States. The number of houses in Hawaiʻi with air conditioners was estimated by apportioning the total number of houses with air conditioners in hot and humid climate regions in the United States using EIA's 2009, 2015, and 2020 Residential Energy Consumption Survey (RECS) and U.S. Department of Energy's (DOE) Guide to Determining Climate Regions by County (DOE 2015; EIA 2013; EIA 2018; EIA 2022). For the remaining sub-categories, national emissions from the U.S. Inventory (EPA 2024b) were apportioned to Hawaiʻi based on the ratio of Hawaiʻi population from DBEDT (2024a) to U.S. population from the U.S. Census Bureau (2023). Percentage of emissions by gas are shown in Figure 4-3.

Changes in Estimates since the Previous Inventory Report

Changes to emission estimates were minor. National emissions data were updated based on updated values published by EPA (2024b). Specifically, U.S. emissions estimates were updated based on updates to the Vintaging Model that is used to calculate emissions from substitutes of ODS. These updates included revisions to various assumptions in the refrigeration, air conditioning and fire suppression sectors. Updates were made to various assumptions for unitary air conditioners, window units, and streaming agents. Additionally, two new end-uses were added to the Vintaging Model to represent multi-split air-conditioning units. The impact of these updates had very little effect on total emissions across the timeseries (EPA 2024b).

Compared to the 2021 inventory, the average annual change in CO_2-equivalent emissions from Substitution of ODS over the time period is a decrease of 0.1 percent. The resulting changes in historical emissions estimates are presented in Table 4-3.

Table 4-3: Change in Emissions from Substitutes of ODS Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990	2005	2007	2017	2018	2019	2020	2021
2021 Inventory Report	+	0.46	0.52	0.79	0.79	0.81	0.75	0.80
This Inventory Report	+	0.46	0.52	0.78	0.79	0.80	0.75	0.81
Percent Change	0.8%	(+%)	0.1%	(0.4%)	(0.4%)	(0.8%)	(0.4%)	0.7%

+ Does not exceed 0.005 MMT CO_2 Eq. (+) Does not exceed -.005 MMT CO_2 Eq. or -0.05 percent.

Uncertainties

This emissions estimate is calculated using the disaggregation of national emissions totals. As a result, it is insensitive to Hawai'i-specific trends and Hawai'i-specific activities that may result in emissions reductions. The apportionment method was used instead of the IPCC methodology due to the complexity of the source category and lack of sufficient data. This approach is consistent with the approach used in EPA's State Inventory Tool (EPA 2024d). Because emissions from substitutes of ODS are closely tied to the prevalence of the products in which they are used, in the absence of state-specific policies that control the use and management of these chemicals, emissions from this source closely correlate with vehicles registered and population. These model uncertainties were not assessed as part of the quantitative uncertainty analysis.

To estimate uncertainty associated with emissions from substitutes of ODS, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on expert judgment. The following parameters contributed the most to the quantified uncertainty estimates: (1) U.S. emissions from substitutes of ODS from Aerosols, (2) U.S. emissions from substitutes of ODS from refrigeration and air conditioning, and (3) U.S. homes in hot and humid climates with air conditioners.

The results of the quantitative uncertainty analysis are summarized in Table 4-4. Emissions from substitutes of ODS were estimated to be between 0.80 and 0.88 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately four percent below and five percent above the emission estimate of 0.84 MMT CO_2 Eq.

Table 4-4: Quantitative Uncertainty Estimates for Emissions from Substitutes of ODS

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.84	0.80	0.88	-4%	5%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

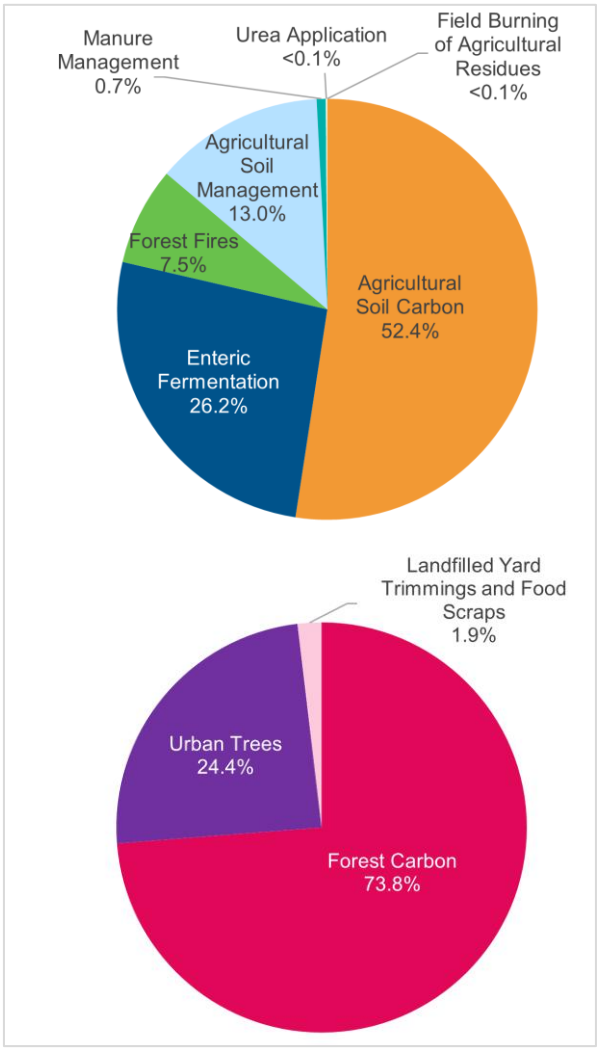
5. Agriculture, Forestry and Other Land Uses (AFOLU)

This chapter presents GHG emissions and GHG removals from sinks from agricultural activities, land use, changes in land use, and land management practices. Agricultural activities are typically GHG emissions "sources," which emit GHGs into the atmosphere. Land use, changes in land use, and land management practices may either be GHG "sources" or GHG "sinks" (sinks remove CO_2 from the atmosphere).

For the state of Hawai'i, emissions and removals from agriculture, forestry, and other land uses (AFOLU) are estimated from the following source and sink categories:[51] enteric fermentation (IPCC Source Category 3A1); manure management (IPCC Source Category 3A2 and 3C6); agricultural soil management (IPCC Source Categories 3C4 and 3C5); field burning of agricultural residues (IPCC Source Category 3C1b); urea application (IPCC Source Category 3C3); agricultural soil carbon (IPCC Source Categories 3B2 and 3B3); forest fires (IPCC Source Category 3C1a); landfilled yard trimmings and food scraps (IPCC Source Category 3B5a); urban trees (IPCC Source Category 3B5a); and forest carbon (IPCC Source Category 3B1a). In Hawai'i, landfilled yard trimmings and food scraps, urban trees, and forest carbon are CO_2 sinks. The remaining AFOLU categories presented in this chapter are sources of GHGs. Figure 5-1 shows emissions from the AFOLU sector by source, and then by sink, for 2022 (percentages).

In 2022, total emissions (excluding sinks) from the AFOLU sector were 1.11 MMT CO_2 Eq., accounting for 5.5 percent of total Hawai'i emissions.

Figure 5-1: 2022 AFOLU Emissions (%) by Source (Excluding Sinks) and AFOLU Removals (%) by Carbon Sink

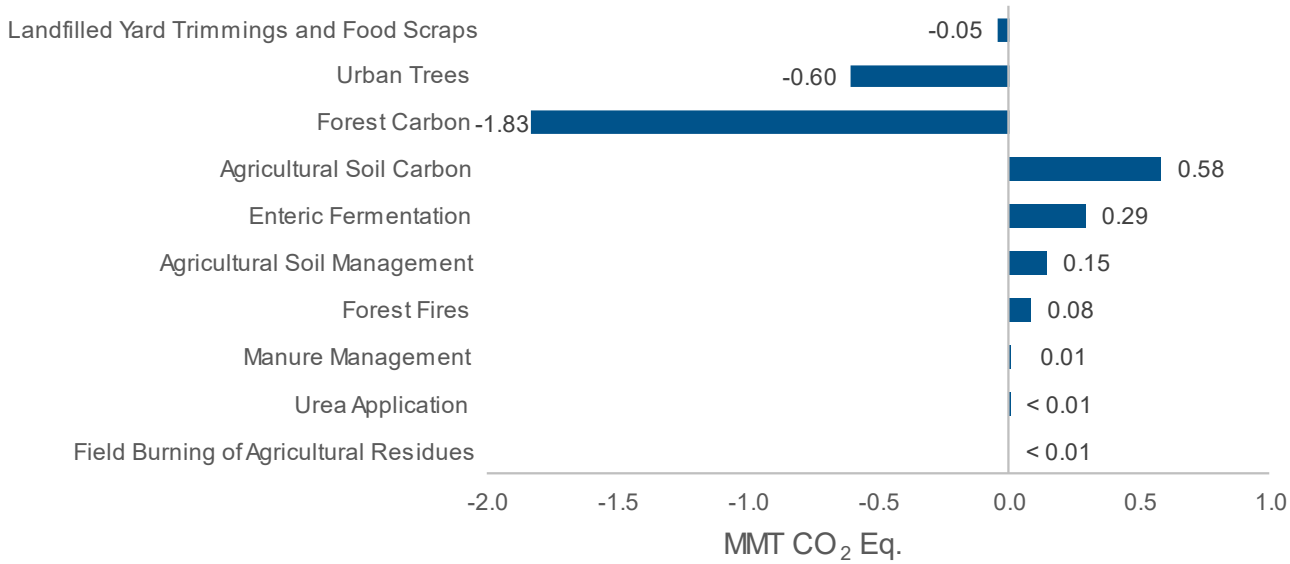


Notes: Totals may not sum due to independent rounding. Percentages represent the percent of AFOLU emissions not including emission sinks.

[51] IPCC Source and Sink Categories for which emissions were not estimated for the state of Hawai'i include: land converted to forest land (3B1b), wetlands (3B4), land converted to settlements (3B5b), other land (3B6), biomass burning in grassland (3C1c), biomass burning in all other land (3C1d), liming (3C2), rice cultivation (3C7), and harvested wood products (3D1). Appendix A provides information on why emissions were not estimated for these IPCC source categories.

Agricultural soil carbon accounted for the largest share of AFOLU emissions, followed by enteric fermentation, agricultural soil management, forest fires, manure management, urea application, and field burning of agricultural residues. Figure 5-2 shows emissions from the AFOLU sector by source for 2022 (MMT CO_2 Eq.).

Figure 5-2: 2022 AFOLU Emissions by Source (MMT CO_2 Eq.) (Excluding Sinks)

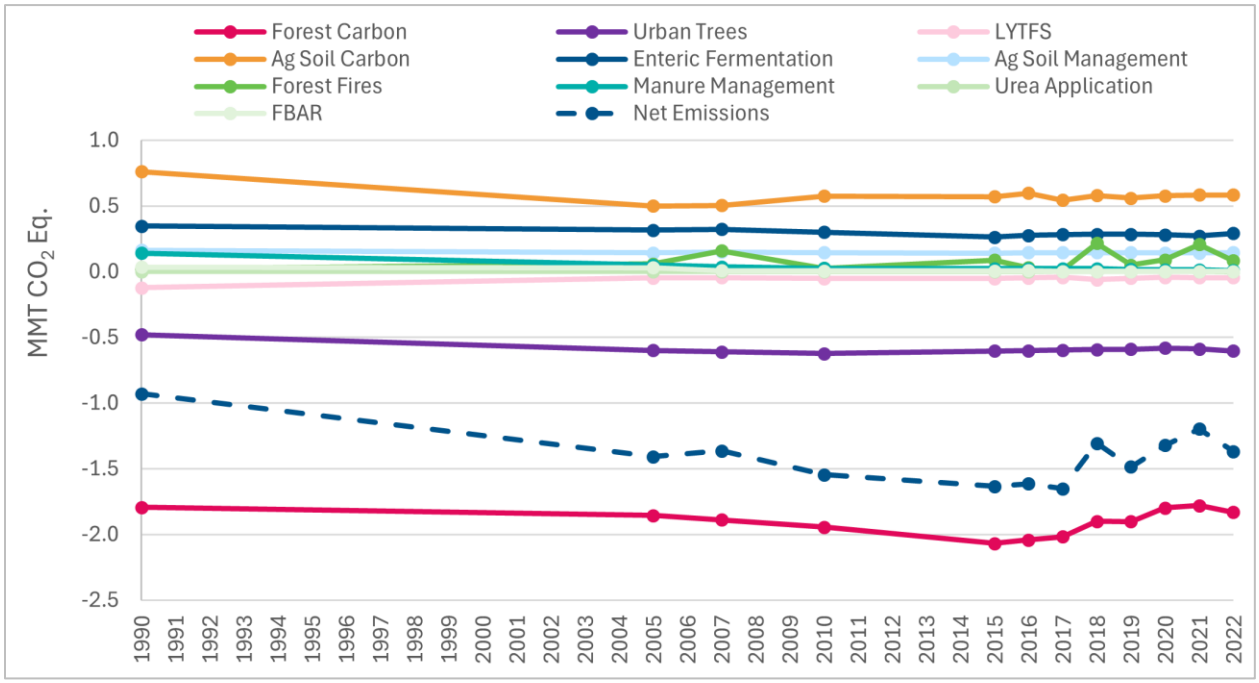


Notes: AFLOLU sources represent 5.5 percent of total gross emissions. Overall, AFOLU sector net total (including both sources and sinks) is a net sink and offsets 7 percent of total gross emissions in Hawai'i.

Carbon removals by sinks were 2.48 MMT CO_2 Eq. in 2022. Therefore, the AFOLU sector resulted in a net increase in carbon stocks (i.e., net CO_2 removals) of 1.37 MMT CO_2 Eq. in 2022. Forest carbon accounted for the largest carbon sink, followed by urban trees, and landfilled yard trimmings and food scraps.

Relative to 1990, emissions from AFOLU sources in 2022 were lower by roughly 24.0 percent. Carbon removals from AFOLU sinks in 2022 decreased by roughly 3.6 percent relative to 1990 sinks. As a result, net removals (including sources and sinks) from AFOLU increased by 47.2 percent in 2022 compared to 1990 (i.e., this sector "removes" more carbon than it did in 1990). Figure 5-3 presents AFOLU emissions and removals by source and sink category in Hawai'i for each inventory year. Emission sources and sinks by category and year are also summarized in Table L-16.

Figure 5-3: AFOLU Emissions and Removals by Source and Sink Category and Year (MMT CO_2 Eq.)



Notes: Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

The remainder of this chapter describes the detailed emission results by source category, including a description of the methodology and data sources used to prepare the inventory. Activity data and emission factors used in the analysis are summarized in Appendix F and Appendix G, respectively.

5.1 Enteric Fermentation (IPCC Source Category 3A1)

Methane is produced as part of the digestive processes in ruminant animals, which is a microbial fermentation process referred to as enteric fermentation. The amount of CH_4 emitted by an animal depends both upon the animal's digestive system, and the amount and type of feed it consumes (EPA 2024b). This source includes CH_4 emissions from enteric fermentation in dairy and beef cattle, sheep, goats, swine, and horses.

In 2022, CH_4 emissions from enteric fermentation were 0.29 MMT CO_2 Eq., accounting for 26.2 percent of AFOLU sector emissions and 1.4 percent of statewide total emissions (excluding sinks). Table L-17 summarizes emissions from enteric fermentation in Hawai'i across the timeseries.

Methodology

The IPCC (2006) Tier 1 methodology was used to estimate emissions of CH_4 from enteric fermentation. Emissions were calculated using the following equation:

$$CH_4\ Emissions = \sum for\ each\ animal\ type\ (\mathrm{P} \times EF_{enteric})$$

where,

P	= animal population (head)
$EF_{enteric}$	= animal-specific emission factor for CH_4 from cattle, sheep, goats, swine and horses (kg CH_4 per head per year)

Animal population data were obtained from various sources, as described below.

- Population data for swine were obtained directly from the U.S. Department of Agriculture's (USDA) National Agriculture Statistics Service (NASS) (USDA 2024a).
- Population data for cattle were obtained from the US Inventory through a data request to EPA (EPA 2024b) and were scaled to the county level using scaling factors developed from USDA NASS cattle populations. County level cattle population data from USDA NASS was released annually from 1990 to 2012. After 2012, USDA stopped reporting annual county level population estimates for Hawai'i and switched to reporting county level cattle populations in the Census of Agriculture, which are released every 5 years. County scaling factors were interpolated between 2012 and 2017 and set equal to 2017 for all years after 2017.
- Population data for sheep, goats, and horses were obtained directly from and estimated using the USDA Census of Agriculture (USDA 1989, 1994, 1999a, 2004a, 2009, 2014, 2019, and 2024b), which is compiled every five years. Specifically, population data for 1987, 1992, 1997, 2002, 2007, 2012, 2017, and 2022 were obtained directly from USDA (2009, 2019, and 2024b) while population estimates for 1990, 2005, 2010, and 2015 to 2021 were interpolated and extrapolated based on available data.

Yearly emission factors for all cattle types available for the state of Hawai'i for all years were obtained from the U.S. Inventory through a data request to U.S. EPA (EPA 2024b).[52] Constant emission factors for sheep, goats, horses, and swine were also obtained from the U.S. Inventory (EPA 2024b).

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from enteric fermentation since the 2021 inventory report.

Uncertainties

Uncertainties associated with enteric fermentation estimates include the following:

- There is uncertainty associated with animal population data. Population data for sheep, goats, and horses are reported every five years in the USDA Census of Agriculture, with the latest data available in 2017. As a result, population data for these animals were interpolated between

[52] The U.S. Inventory includes annually variable emission factors for the following cattle types: dairy cows, beef cows, dairy replacement heifers 7-11 months, dairy replacement heifers 12-23 months, other dairy heifers, beef replacement heifers 7-11 months, beef replacement heifers 12-23 months, heifer stockers, heifer feedlot, steer stockers, steer feedlot, beef calves and dairy calves.

census years to obtain estimates for 1990, 2010, 2015, 2016 and extrapolated for 2018,2019, and 2021.

- There is some uncertainty associated with state-level cattle populations. USDA NASS does not maintain detailed cattle data by age, class, and diet. As a result, Hawaiʻi specific cattle population data by class (e.g., steer stocker, dairy heifer) was obtained through a data request to EPA (2024a).
- Specifically, there is uncertainty associated with the emission factor for beef cattle, as obtained from the U.S. Inventory, due to the difficulty in estimating the diet characteristics for grazing members of this animal group (EPA 2024a). In addition, the emission factors for non-cattle animal types, also obtained from the U.S. Inventory, are not specific to Hawaiʻi.

To estimate uncertainty associated with emissions from enteric fermentation, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on expert judgment and IPCC (2006). The following parameters contributed the most to the quantified uncertainty estimates: (1) enteric emission factor for beef cows (2) beef replacement heifers emission factor: 12-24 months, and (3) sheep emission factor. The quantified uncertainty estimated for the enteric emission factor for beef cows contributed the vast majority to the quantified uncertainty estimates, while the remaining input variables contributed relatively evenly to the overall uncertainty of the emissions estimate.

The results of the quantitative uncertainty analysis are summarized in Table 5-1. Emissions from enteric fermentation were estimated to be between 0.25 and 0.34 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 16 percent below and 15 percent above the emission estimate of 0.29 MMT CO_2 Eq.

Table 5-1: Quantitative Uncertainty Estimates for Emissions from Enteric Fermentation

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.29	0.25	0.34	-16%	15%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

5.2 Manure Management (IPCC Source Category 3A2 and 3C6)

The main GHGs emitted by the treatment, storage, and transportation of livestock manure are CH_4 and N_2O. Methane is produced by the anaerobic decomposition of manure. Direct N_2O emissions are produced through the nitrification and denitrification of the organic nitrogen (N) in livestock dung and urine. Indirect N_2O emissions result from the volatilization of N in manure and the runoff and leaching of N from manure into water (EPA 2024b). This category includes CH_4 and N_2O emissions from dairy and beef cattle, sheep, goats, swine, horses, and chickens. In 2022, emissions from manure management were 0.01 MMT CO_2 Eq., accounting for 0.7 percent of AFOLU sector emissions and less than 0.1 percent of statewide total emissions (excluding sinks). Table L-18 summarizes emissions from manure management in Hawaiʻi across the timeseries.

Methodology

The IPCC (2006) Tier 2 method was employed to estimate emissions of both CH_4 and N_2O using the following equations:

$$CH_4\ Emissions = P \times TAM \times VS \times B_O \times wMCF \times 0.67$$

where,

P	= animal population (head)
TAM	= typical animal mass (kg per head per year)
VS	= volatile solids excretion per kilogram animal mass (kg VS/1000 kg animal mass/day)
B_0	= maximum methane producing capacity for animal waste (m^3 CH_4 / kg VS)
wMCF	= weighted methane conversion factor (percent)
0.67	= conversion factor of m^3 CH_4 to kg CH_4

$$N_2O\ Emission = P \times \sum for\ each\ WMS\ [TAM \times Nex \times 365 \times (1 - V) \times WMS\ VS \times EF_{WMS} \times \frac{44}{28}]$$

where,

WMS	= waste management system
P	= animal population (head)
TAM	= typical animal mass (kg per head per year)
Nex	= nitrogen excretion rate (kg N/kg animal mass per day)
V	= volatilization (percent)
WMS VS	= fraction volatile solids distribution by animal type and waste management system (percent)
EF_{WMS}	= emission factor for waste management system (kg N_2O-N/kg N)
44/28	= conversion from N_2O-N to N_2O

Animal population data were obtained from various sources, as described below.

- Cattle population data at the state level for all years was obtained from the U.S. Inventory and scaled to the county level using scaling factors developed from USDA NASS cattle populations. County level cattle population data from USDA NASS was released annually from 1990 to 2012. After 2012, USDA stopped reporting annual county level population estimates for Hawai‘i and switched to reporting county level cattle populations in the Census of Agriculture, which are released every 5 years. County scaling factors were interpolated between 2012 and 2017 and set equal to 2017 for all years after 2017.
- Swine population data for all years were obtained directly from USDA NASS (USDA 2022a).
- Chicken population data for 1990 through 2010, for all subgroups except broilers, were obtained from USDA NASS (USDA 2024c). Chicken population data for 2012, 2017, and 2022 were obtained from USDA Census of Agriculture (USDA 2014, 2019, and 2024b) and population data for 2015, 2016, and 2018 to 2021 were estimated by extrapolating data available from 2012 and 2017.

Broiler population data was obtained from the USDA Census of Agriculture for 1997, 2002, 2007, 2017, and 2022 (USDA 1999, 2004a, 2009, 2014, 2019, and 2024b). Population data for 1990 to 1997, 2001 to 2005, 2008 to 2011, 2013 to 2016 were interpolated based on available data and population data for 2015, 2016, and 2018 to 2021 were extrapolated based on historic data.

- Population data for sheep, goats, horses, and broiler chickens were obtained directly from and estimated using the USDA Census of Agriculture (USDA 1989, 1994, 1999a, 2004a, 2009, 2014, 2019, and 2024b), which is compiled every five years. Specifically, population data for 1987, 1992, 2007, 2012, 2017, and 2022 were obtained directly from USDA and population estimates for 1990, 2010, 2015, 2016, and 2018 to 2021 were interpolated based on available data.

To calculate CH_4 emissions from manure management, typical animal mass (TAM) and maximum potential emissions (B_0) by animal for all animal types were obtained from the U.S. Inventory through a data request to EPA (EPA 2024b). Weighted methane conversion factors (MCFs) for all cattle types, sheep, goats, horses, swine, and chicken by waste management system were obtained from the U.S. Inventory (EPA 2024b). Volatile solids (VS) excretion rates by animal type and year for Hawai‘i were obtained from the U.S. Inventory (EPA 2024b).

To calculate N_2O emissions from manure management, nitrogen excretion (Nex) rates for all animal types for Hawai‘i were obtained from the U.S. Inventory (EPA 2024b). The distributions of waste by animal in different waste management systems (WMS) for Hawai‘i were obtained from the U.S. Inventory (EPA 2024b). Weighted MCFs take into account the percent of manure for each animal type managed in different WMS. Emission factors for the different WMS were obtained from the *2006 IPCC Guidelines* (IPCC 2006).

The weighted averages of chicken and broiler VS rates, Nex rates, TAM and B_0 factors, based on the percentage of each chicken type in Hawai‘i from USDA (2024c), were applied to total Hawai‘i chicken population data. Similarly, the weighted averages of swine VS rates, Nex rates, TAM and B_0 factors, based on the percentage of each swine type from the U.S. Inventory (EPA 2024b), were applied to total Hawai‘i swine population data.

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from manure management since the 2021 inventory report.

Uncertainties

Uncertainties associated with manure management estimates include the following:

- There is uncertainty associated with animal population data. Population data for sheep, goats, horses, and broiler chickens are reported every five years in the USDA Census of Agriculture, with the latest data available in 2017. As a result, population data for these animals were interpolated between years to obtain estimates for 1990, 2010, 2015, and 2016 and extrapolated to obtain estimates for 2018,2019, and 2021. Similarly, chicken population data (excluding broilers) are available through 2010 from USDA NASS and then from the USDA Census

of Agriculture for years 2012 and 2017; population estimates for broilers were interpolated to obtain estimates for 2015, 2016 and extrapolated to obtain estimates for 2018, 2019, and 2021.

- There is some uncertainty associated with state-level cattle populations. USDA NASS does not maintain detailed data on cattle by age, class, and diet. As a result, Hawai'i specific cattle population data by class (e.g., steer stocker, dairy heifer) was obtained through a data request to EPA (2024a).
- Due to different animal groupings in the U.S. Inventory and this inventory, emission factors for other dairy heifers are proxied to those for dairy replacement heifers.
- There is some uncertainty associated with the manure management emission factors. Specifically, the static emission factors for non-cattle animal types do not reflect potential changes in animal management practices. In addition, certain emission factors (i.e., Nex rates for calves and TAM) that were obtained from the U.S. Inventory are not specific to Hawai'i. Finally, according to the U.S. Inventory, B_0 data used to estimate emissions from manure management are dated (EPA 2024a).

To estimate uncertainty associated with emissions from manure management, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on expert judgment and IPCC (2006). The following parameters contributed the most to the quantified uncertainty estimates: (1) the emission factors for dry lot manure systems, (2) typical animal mass for chickens, and (3) the B_0 for beef cows.

The results of the quantitative uncertainty analysis are summarized in Table 5-2. Emissions from manure management were estimated to be between 0.009 and 0.013 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 19 percent below and 21 percent above the emission estimate of 0.01 MMT CO_2 Eq.

Table 5-2: Quantitative Uncertainty Estimates for Emissions from Manure Management

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.01	0.009	0.013	-19%	21%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

5.3 Agricultural Soil Management (IPCC Source Categories 3C4 and 3C5)

Although nitrous oxide is produced naturally in soils through the nitrogen (N) cycle, many agricultural activities increase the availability of mineral N in soils, which leads to direct N_2O emissions from nitrification and denitrification (EPA 2024b). An example of such an activity would be the application of N fertilizers to agricultural soils. This category includes N_2O emissions from synthetic fertilizer, organic fertilizer, manure N, as well as crop residue inputs from sugarcane, pineapples, sweet potatoes, ginger root, taro, corn for grain, and seed production. In 2022, emissions from agricultural soil management

were 0.15 MMT CO_2 Eq., accounting for 13.0 percent of AFOLU sector emissions and 0.7 percent of statewide total emissions (excluding sinks). Table L-19 summarizes emissions from agricultural soil management in Hawai'i across the timeseries.

Methodology

The IPCC (2006) Tier 1 approach was used to calculate N_2O emissions from agricultural soil management. The overall equation for calculating emissions is as follows:

$$N_2O\ Emissions = Direct\ N_2O\ Emissions + Indirect\ N_2O\ Emissions$$

The following equations were used to calculate direct emissions:

$$Direct\ N_2O\ Emissions = [(N_F \times EF_F) + (N_O \times EF_F) + (N_{CR} \times EF_{CR}) + (N_{PRP1} \times EF_{PRP1}) + (N_{PRP2} \times EF_{PRP2})] \times \frac{44}{28}$$

where,

$$N_{CR} = AG_{DM} \times A \times (N_{AG} + R_{BGBIO} \times N_{BG})$$

$$AG_{DM} = Yield \times DRY \times slope + intercept$$

where,

N_F	= N inputs to agricultural soils from synthetic fertilizers
N_O	= N inputs to agricultural soils from organic fertilizers
N_{CR}	= N inputs to agricultural soils from crop residues
N_{PRP1}	= N inputs to agricultural soils from pasture, range, and paddock manure from cattle, swine, and poultry
N_{PRP2}	= N inputs to agricultural soils from pasture, range, and paddock manure from sheep, goats, and horses
EF_F	= emission factor for direct N_2O emissions from synthetic and organic fertilizers and crop residues (kg N_2O-N/kg N input)
EF_{CR}	= emission factor for direct N_2O emissions from crop residues (kg N_2O-N/kg N input)
EF_{PRP1}	= emission factor for direct N_2O emissions from pasture, range, and paddock manure from cattle, swine, and poultry (kg N_2O-N/kg N input)
EF_{PRP2}	= emission factor for direct N_2O emissions from pasture, range, and paddock manure from sheep, goats, and horses (kg N_2O-N/kg N input)
AG_{DM}	= aboveground residue dry matter (Mg/hectares)
A	= crop area (hectares)
N_{AG}	= N content of aboveground residue (kg N/dry matter)
N_{BG}	= N content of belowground residues (kg N/dry matter)
$R_{BG\text{-}BIO}$	= Ratio of belowground residues to harvested yield for crop
Yield	= fresh weight yield (kg fresh weight harvested/hectares)
DRY	= dry matter fraction of harvested product

Slope	= default slope value for AG_{DM} for each crop type
Intercept	= default intercept value for AG_{DM} for each crop type
44/28	= conversion from N_2O-N to N_2O

The following equations were used to calculate indirect emissions:

$$Indirect\ N_2O\ Emissions = Indirect\ Emissions\ from\ Volatilization + Indirect\ Emissions\ from\ Leaching/runoff$$

where,

$$Indirect\ Emissions\ from\ Volatilization = [(N_F \times L_{vol-F}) + (N_O \times L_{vol-O}) + (N_{PRP} \times L_{vol-O})] \times EF_{vol} \times \frac{44}{28}$$

$$Indirect\ Emissions\ from\ Leaching/Runoff = (N_F + N_O + N_{CR} + N_{PRP}) \times L_{leach} \times EF_{leach} \times \frac{44}{28}$$

where,

N_F	= N inputs to agricultural soils from synthetic fertilizers
N_O	= N inputs to agricultural soils from organic fertilizers
N_{CR}	= N inputs to agricultural soils from crop residues
N_{PRP}	= N inputs to agricultural soils from pasture, range, and paddock manure from all animals
L_{vol-F}	= fraction N lost through volatilization from synthetic fertilizer inputs
L_{vol-O}	= fraction N lost through volatilization from organic fertilizer and manure inputs
L_{leach}	= fraction N lost through leaching/runoff from all N inputs
EF_{vol}	= emission factor for indirect N_2O emissions from N volatilization (kg N_2O-N / kg NH_3–N + NO_x–N volatilized)
EF_{leach}	= emission factor for N_2O emissions from pasture, range, and paddock manure from cattle, swine, and poultry (kg N_2O-N / kg N leached/runoff)
44/28	= conversion from N_2O-N to N_2O

Annual sugarcane area and production estimates used to estimate emissions from crop residue N additions were obtained directly from USDA NASS (USDA 2018b). For other crops (i.e., pineapples, sweet potatoes, ginger root, taro, and corn for grain), data were obtained directly from and estimated using the USDA Census of Agriculture (USDA 1989, 1994, 1999a, 2004a, 2009, 2014, 2019, and 2024b), which is compiled every five years. Specifically, data for 1987, 1992, 1997, 2007, 2012, 2017, and 2022 were obtained directly from USDA while production estimates for 1990, 2005, 2010, 2015, 2016, and 2018 to 2021 were interpolated and extrapolated based on available data. Pineapple crop production and crop acreage were not available in the 2007 or 2012 Census of Agriculture, so pineapple data for 2010, 2015, and 2016, and 2018 to 2022 were estimated by interpolating and extrapolating data between 2002 and 2017 (USDA 2004a and USDA 2019). Percent distribution of waste to various animal waste management

systems for Hawai‘i, used to estimate manure N additions to pasture, range, and paddock soils, were obtained from the U.S. Inventory (EPA 2024b).

Seed crop acreage for 1990 through 2022 were obtained from the USDA (USDA 2004b, 2015, 2022). According to the USDA, seed corn accounts for over 95 percent of the value of Hawai‘i’s seed industry (USDA 2022b). Therefore, crop residue factors for corn for grain from IPCC (2006) were applied to seed production data to estimate emissions from nitrogen applied from crop residues. Seed crop acreage data were used to estimate total seed production by using the average production per acre of corn for grain as a proxy.

Synthetic and organic fertilizer N application data were obtained from the annual *Commercial Fertilizers* publication by the Association of American Plant Food Control Officials (AAPFCO 1995 through 2019, TVA 1991 through 1994, EPA 2023a). Synthetic fertilizer N application data were not available after 2017, so 2018 to 2022 data were extrapolated based on the trend from the last 5 years of available data, 2013 to 2017. According to these data sources, commercial organic fertilizer is not applied in Hawai‘i.

Crop residue factors for corn were obtained from the *2006 IPCC Guidelines* (IPCC 2006). Crop residue factors for tubers were used for sweet potatoes, ginger root, and taro. No residue factors nor adequate proxy factors were available for pineapples or sugarcane, so crop residue N inputs from these crops were not included. However, as nearly 100 percent of aboveground sugarcane residues are burned in Hawai‘i, there is little crop residue N input from sugarcane. All emission and other factors are IPCC (2006) defaults.

Animal population data are used to calculate the N inputs to agricultural soils from pasture, range, and paddock manure from all animals. Animal population data were obtained from the following sources:

- Swine population data for all years were obtained directly from USDA NASS (USDA 2024a).
- Cattle population data at the state level for all years was obtained from the U.S. Inventory and scaled to the county level using scaling factors developed from USDA NASS cattle populations. County level cattle population data from USDA NASS was released annually from 1990 to 2012. After 2012, USDA stopped reporting annual county level population estimates for Hawai‘i and switched to reporting county level cattle populations in the Census of Agriculture, which are released every 5 years. County scaling factors were interpolated between 2012, 2017, and 2022.
- Chicken population data was available from USDA NASS for 1990 to 2010, 2012, 2017, and 2022. Population estimates for 2011, and 2013 to 2016 were interpolated and 2018 to2022 were extrapolated based on available population data. Broiler chicken population data were obtained directly from and estimated using the USDA Census of Agriculture (USDA 1989, 1994, 1999a, 2004a, 2009, 2014, 2019, and 2024b).
- Population data for sheep, goats, and horses were obtained directly from and estimated using the USDA Census of Agriculture (USDA 1989, 1994, 1999a, 2004a, 2009, 2014, 2019, and 2024b), which is compiled every five years. Specifically, population data for 2007, 2017, and 2022 were obtained directly from USDA (2009), USDA (2019), and USDA (2024b) respectively,

while population estimates for 1990, 2005, 2010, 2015, 2016, and 2018 to 2021 were interpolated based on 1987, 1992, 2007, 2012, 2017, and 2022 data.

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from agricultural soil management since the 2021 inventory report.

Uncertainties

Uncertainties associated with agricultural soil management estimates include the following:

- There is uncertainty associated with animal population data. Population data for sheep, goats, horses, and broiler chickens are reported every five years in the USDA Census of Agriculture, with the latest data available in 2017. As a result, population data for these animals were interpolated between years to obtain estimates for 1990, 2005, 2010, 2015 and 2016 and extrapolated to obtain estimates for 2018, 2019, and 2021. Similarly, chicken population data (excluding broilers) are available through 2010 from USDA NASS and then from the USDA Census of Agriculture for years 2012 and 2017; population estimates for broilers were interpolated to obtain estimates for 2015, 2016 and extrapolated to obtain estimates for 2018, 2019, and 2021.
- There is some uncertainty associated with state-level cattle populations. USDA NASS does not maintain detailed data on cattle data by age, class, and diet. As a result, Hawaiʻi specific cattle population data by class (e.g., steer stocker, dairy heifer) was obtained through a data request to EPA (2024a).
- There is also some uncertainty associated with crop area and crop production data. Crop area and production data from the USDA Census of Agriculture are not reported every year. As a result, data were interpolated between census years. In particular, pineapple production and crop acreage data were not available in the 2007 Census of Agriculture or 2012 Census of Agriculture, so data through 2021 were extrapolated using 1997 and 2002 data.
- There is uncertainty associated with the extrapolation of synthetic fertilizer N application data to 2021 as well as the apportioning of fertilizer sales from the fertilizer year (i.e., July previous year to June current year) to the inventory calendar year (e.g., January to December).
- Crop residue factors were obtained from sources published over 10 years ago and may not accurately reflect current practices.
- There is uncertainty associated with seed production data since the USDA provides seed production data only for out-shipments of seed. Data on out-shipments of seed are not representative of total seed production in Hawaiʻi because the majority of the seeds produced are not sold but instead are used for ongoing research or for further propagation before sale (USDA 1999). Therefore, seed crop acreage data were used to estimate total seed production by using the average production per acre of corn for grain as a proxy. It is also unclear whether seed producers report fertilizer consumption to AAPFCO.

To estimate uncertainty associated with emissions from agricultural soil management, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on the U.S. Inventory (EPA 2024b), IPCC (2006), and expert judgment. The following

parameters contributed the most to the quantified uncertainty estimates: (1) total fertilizer consumption in 2017; (2) beef cows N excretion rate; and (3) total fertilizer consumption in 2016.

The results of the quantitative uncertainty analysis are summarized in Table 5-3. Emissions from agricultural soil management were estimated to be between 0.10 and 0.26 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 33 percent below and 77 percent above the emission estimate of 0.15 MMT CO_2 Eq.

Table 5-3: Quantitative Uncertainty Estimates for Emissions from Agricultural Soil Management

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.15	0.10	0.26	-33%	77%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

5.4 Field Burning of Agricultural Residues (IPCC Source Category 3C1b)

Field burning is a method that farmers use to manage the vast amounts of agricultural crop residues that can be created during crop production. Crop residue burning is a net source of CH_4 and N_2O, which are released during combustion (EPA 2024b).[53] This source includes CH_4 and N_2O emissions from sugarcane burning, which is the only major crop in Hawaiʻi whose residues are regularly burned (Hudson 2008). There are no large-scale burnings of other agricultural products that would make a material impact on emissions estimates, although Hawaii DOH offers Agricultural Burning Permits to burn green waste[54]. The Hawaiian Commercial & Sugar Company plant closed in December 2016, so sugarcane crop area and production decreased significantly from 2016 to 2017. In 2022, emissions from field burning of agricultural residues were 0.0 MMT CO_2 Eq., due to the closure of the last sugarcane mill in Hawaiʻi in 2016. Table L-20 summarizes emissions from field burning of agricultural residues in Hawaiʻi across the timeseries.

Methodology

The IPCC/UNEP/OECD/IEA (1997) Tier 1 approach was used to calculate CH_4 and N_2O emissions from field burning of agricultural residues. The IPCC/UNEP/OECD/IEA (1997) method was used instead of the

[53] Carbon dioxide is also released during the combustion of crop residue. These emissions are not included in the inventory totals for field burning of agricultural residues because CO_2 from agricultural biomass is not considered a net source of emissions. This is because the carbon released to the atmosphere as CO_2 from the combustion of agricultural biomass is assumed to have been absorbed during the previous or a recent growing season (IPCC 2006).

[54] Additional information on agricultural burning permits can be found here: https://www.nrcs.usda.gov/sites/default/files/2022-10/9-Agricultural-Burning-in-Hawaii.pdf

IPCC (2006) approach because it is more flexible for incorporating country-specific data and therefore is considered more appropriate for conditions in the United States (EPA 2024b). Emissions were calculated using the following equation:

$$CH_4 \text{ and } N_2O \text{ Emissions} = Crop \times R_{RC} \times DMF \times Frac_{BURN} \times BE \times CE \times C \text{ or } N \text{ content of residue} \times R_{emissions} \times F_{conversion}$$

where,

Crop	= crop production; annual weight of crop produced (kg)
R_{RC}	= residue-crop ratio; amount of residue produced per unit of crop production
DMF	= dry matter fraction; amount of dry matter per unit of biomass
$Frac_{BURN}$	= fraction of crop residue burned amount of residue which is burned per unit of total residue
BE	= burning efficiency; the proportion of pre-fire fuel biomass consumed
CbE	= combustion efficiency; the proportion of C or N released with respect to the total amount of C or N available in the burned material
C or N content of residue	= amount of C or N per unit of dry matter
$R_{emissions}$	= emissions ratio; g CH_4-C/g C released or g N_2O-N/g N release (0.0055 and 0.0077, respectively)
$F_{conversion}$	= conversion factor; conversion of CH_4-C to C or N_2O-N to N (16/12 and 44/28, respectively)

Annual sugarcane area and production estimates were obtained directly from USDA NASS (USDA 2024d). The residue/crop ratio and burning efficiency were taken from Kinoshita (1988). Dry matter fraction, fraction of C and N, and combustion efficiency were taken from Turn et al. (1997). The fraction of residue burned was taken from Ashman (2008).

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from field burning of agriculture residues since the 2021 inventory report.

Uncertainties

This analysis assumes that sugarcane is the only major crop in Hawai‘i whose residues were regularly burned and that sugarcane burning is no longer practiced as the last sugarcane mill closed in 2016 (Hudson 2008). Therefore, emissions from the field burning of crop residues are assumed to be zero.

5.5 Urea Application (IPCC Source Category 3C3)

Urea ($CO(NH_2)_2$) is a nitrogen fertilizer that is often applied to agricultural soils. When urea is added to soils, bicarbonate forms and evolves into CO_2 and water (IPCC 2006). In 2022, emissions from urea application were 0.001 MMT CO_2 Eq., accounting for less than 0.1 percent of AFOLU sector emissions

and statewide emissions. Table L-21 summarizes emissions from urea application in Hawai‘i across the timeseries.

Methodology

The IPCC (2006) Tier 1 methodology was used to estimate emissions from urea application. Emissions were calculated using the following equation:

$$CO_2\ Emissions = M \times EF_{urea} \times \frac{44}{12}$$

where:

M	= annual amount of urea fertilization, metric tons
EF_{urea}	= emission factor, metric tons C/metric ton urea
44/12	= conversion of carbon to CO_2

Fertilizer sales data were obtained from the annual *Commercial Fertilizers* publication by the Association of American Plant Food Control Officials (AAPFCO 1995 through 2019, TVA 1991 through 1994). AAPFCO reports fertilizer sales data for each fertilizer year (July through June).[55] Historical usage patterns were used to apportion these sales to the inventory calendar years (January through December). Urea fertilizer application data were not available after 2016, so 2017 to 2022 were estimated based on 2016 data.

The *2006 IPCC Guidelines* default emission factor was used to estimate the carbon emissions, in the form of CO_2, that result from urea application.

Changes in Estimates since the Previous Inventory Report

No updates were made to emissions from historical urea fertilizer consumption compared to the 2021 inventory.

Uncertainties

There is uncertainty associated with the extrapolation of urea fertilizer application data to 2022 as well as the apportioning of fertilizer sales from the fertilizer year (i.e., July previous year to June current year) to the inventory calendar year (e.g., January to December).

To estimate uncertainty associated with emissions from urea application, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on expert judgment. The following parameters contributed the most to the quantified uncertainty

[55] Fertilizer sales are reported by fertilizer year, corresponding to the growing season. The 2010 fertilizer year, for example, runs from July 2009 to June 2010.

estimates: (1) Urea consumption in 2016, (2) Urea consumption in 2012 and (3) urea consumption in 2015.

The results of the quantitative uncertainty analysis are summarized in Table 5-4. Emissions from urea application were estimated to be between 0.0007 and 0.0014 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 44 percent below and six percent above the emission estimate of 0.001 MMT CO_2 Eq.

Table 5-4: Quantitative Uncertainty Estimates for Emissions from Urea Application

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.001	0.0007	0.0014	-44%	6%

+ Does not exceed 0.005 MMT CO_2 Eq.

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

5.6 Agricultural Soil Carbon (IPCC Source Categories 3B2, 3B3)

Agricultural soil carbon refers to the change in carbon stock in agricultural soils—either in cropland or grasslands—that have been converted from other land uses. Agricultural soils can be categorized into organic soils, which contain more than 12 to 20 percent organic carbon by weight, and mineral soils, which typically contain one to six percent organic carbon by weight (EPA 2024b). Organic soils that are actively farmed tend to be sources of carbon emissions as soil carbon is lost to the atmosphere due to drainage and management activities. Mineral soils can be sources of carbon emissions after conversion, but fertilization, flooding, and management practices can result in the soil being either a net source or net sink of carbon. Nationwide, increased carbon sequestration by agricultural soils is due to employment of sustainable practices, such as: enrollment in the Conservation Reserve Program, conservation tillage practices, increased hay production, and intensified crop production. In 2022, emissions from agricultural soils were 0.58 MMT CO_2 Eq., accounting for 52.4 percent of AFOLU sector emissions 2.9 percent of statewide total emissions (excluding sinks). Table L-22 summarizes emissions from agricultural soils in Hawaiʻi across the timeseries.

Methodology

Emission estimates from Hawaiʻi's agricultural soils are based on state-level data obtained from the 1990 to 2022 U.S. Inventory (EPA 2024b). All the emissions and sinks from mineral and organic sources from land converted to grassland, grassland remaining grassland, land converted to cropland, and cropland remaining cropland for the state of Hawaiʻi were summed to get the net carbon emissions from agricultural soil carbon in Hawaiʻi. State-level emission estimates from the U.S. Inventory (EPA 2024b) developed using the DAYCENT model continue to reflect the best available estimates of emissions from agricultural soil carbon in Hawaiʻi.

Changes in Estimates since the Previous Inventory Report

Relative to the 2021 inventory report, agricultural soil emissions were revised based on the latest U.S. Inventory data through 2022 (EPA 2024b). Additionally, the methodology used to attribute state-level soil carbon emissions between counties was revised to calculate the percent of pastureland and cropland in each county using data from NASS Census (NASS 2024). Changes in historical emissions estimates are detailed in Table 5-5.

Table 5-5: Change in Emissions from Agricultural Soil Carbon Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990	2005	2007	2017	2018	2019	2020	2021
2021 Inventory Report	0.80	0.68	0.67	0.82	0.82	0.82	0.81	0.81
This Inventory Report	0.76	0.50	0.50	0.54	0.58	0.56	0.58	0.58
Percent Change	(4.2%)	(26.2%)	(24.5%)	(33.9%)	(29.4%)	(31.8%)	(29.2%)	(28.3%)

Uncertainties

According to the U.S. Inventory, areas of uncertainty include changes in certain carbon pools (biomass, dead wood, and litter), which are only estimated for forest land converted to cropland or grassland and not estimated for other land types converted to cropland or grassland (EPA 2024b).

To estimate uncertainty associated with emissions from agricultural soil carbon, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on EPA (2024a) and Selmants et al. (2017). The following parameters contributed the most to the quantified uncertainty estimates: (1) carbon stock changes in organic soils in grassland (from 1990 to2022 U.S. Inventory estimates), (2) carbon stock changes in mineral soils in grassland (from 1990 to2022 U.S. Inventory estimates), and (3) carbon stock changes in organic soils in cropland (from 1990 to2022 U.S. Inventory estimates).

The results of the quantitative uncertainty analysis are summarized in Table 5-6. Emissions from agricultural soil carbon were estimated to be between -2.08 and 2.99 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 457 percent below and 412 percent above the emission estimate of 0.58 MMT CO_2 Eq.

Table 5-6: Quantitative Uncertainty Estimates for Emissions from Agricultural Soil Carbon

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.58	(2.08)	2.99	-457%	412%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

5.7 Forest Fires (IPCC Source Category 3C1a)

Forest and shrubland fires (herein referred to as forest fires) emit CO_2, CH_4, and N_2O as biomass is combusted. This source includes emissions from forest fires caused by lightning, campfire, smoking, debris burning, arson, equipment, railroads, children, and other miscellaneous activities reported by the Pacific Fire Exchange (PFE) (1990 to 2022) (Trauernicht et al., 2015).[56] In 2022, emissions from forest fires were 0.08 MMT CO_2 Eq., accounting for 7.5 percent of AFOLU sector emissions. Table L-23 summarizes emissions from forest fires in Hawaiʻi across the timeseries.

Methodology

Emissions from forest fires were estimated by multiplying the area burned for each vegetation class (in hectares) by an emission factor specific to that vegetation class and moisture scenario. These emission factors are based on USGS data, which generated emission factors for each vegetation class, moisture scenario, and biomass pool using the First-Order Wildland Fire Effect Model (FOFEM) (Selmants 2017). Forest/shrubland area burned was derived by multiplying wildland area burned by a ratio of forestland area to wildland area. Area burned for years 1990 to 2022 was obtained from *Hawaii Annual Area Burned 1904-2022,* published by the PFE (Trauernicht et al. 2015). The PFE was chosen as the foundation for calculating wildfire emissions in Hawaii because it provides a complete, statewide dataset released annually. This dataset also has the benefit of being Hawaiʻi focused, which eliminates trend biases from the drastically different ecosystems of the rest of the U.S.. The result is a uniform dataset that can be relied upon to produce Hawaiʻi-specific estimates of acres burned by wildfires through time, thus producing a complete and consistent inventory results. Other datasets considered include:

1. The DOFAW dataset – this dataset was eliminated becaude it has been discontinued. It should be noted that the DOFAW website sites the PFE for wildfire acreage metrics.
2. NFIRS: This dataset only offers national values and therefore was not a reasonable alternative.
3. LANDIFRE DisturbanceL this dataset provides estimates of disturbance for the state of Hawaiʻi for 2001, 2022, and 2023. Due to the large gap in data years, this dataset was eliminated in fvor of the annualized and Hawaiʻi -specific PFE data.

The ratio of total forestland area to wildland area was developed based on data from the National Association of State Foresters (NASF), DLNR, and the State of Hawaiʻi Data Book (DBEDT 2023). The estimate of wildland area was obtained, in million acres, for years 1998 and 2002 from the National Association of State Foresters (NASF 1998 and 2002) and 2010, 2015, 2016, 2018, 2019, 2020, and 2021 from the DLNR (2011, 2015, 2016, 2017, 2018, 2019, 2020, 2021, and 2022). Data for the year 2022 was

[56] Prescribed fires are also a source of GHG emissions. Prescribed fires are intentional, controlled burning of forests to prevent wildfires and the spread of invasive forest species. Prescribed fires typically emit less GHG emissions per acre burned compared to wildfires. Emissions from prescribed fires are not included in this analysis due to limitations in data availability and because prescribed burning is not a common practice in Hawaiʻi. Emissions from this activity are expected to be marginal.

proxied to 2021 as data was not available for a more recent year. 1998 data were used as a proxy for 1990, 2002 data were used as a proxy for 2005 and 2007, and 2016 data were used as a proxy for 2017.

Managed forestland area data were obtained from the State of Hawai‘i Data Book (DBEDT 2023). Area estimates of private forestland in the conservation district were summed with reserve forestland in the conservation district, forested natural areas, and wooded farmland in order to generate total managed forested land area in Hawai‘i for 1990, 2005, 2007, and 2018 to 2022. Unmanaged forests are not included in this analysis per IPCC guidelines because the majority of anthropogenic GHG emissions occur on managed land (IPCC 2006).

To break down the total forest/shrubland burned into vegetation classes, annual percentages of area burned by vegetation class and moisture scenario were obtained from USGS (Selmants 2020). These percentages were available for 1999 to 2019. The average for each vegetation class from this timeseries was applied to the years 1990 through 1998 and 2020 on. The total area burned for each vegetation class and moisture scenario was then multiplied by the associated emission factor to calculate CO_2 emissions. Emission factors for CH_4 and N_2O emissions were obtained from IPCC (2006).

Changes in Estimates since the Previous Inventory Report

The current Inventory relies on data from the Pacific Fire Exchange as the sole source of data for reported area burned for years 1990 to 2022 (Trauernicht et al., 2015). The result of this change are minor disagreements in emissions magnitude for certain data years as compared to previous inventory reports. The resulting change in historical emissions estimates is presented in Table 5-7.

Table 5-7: Change in Emissions from Forest Fires Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Emission Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	0.10		0.03		0.12		0.01	0.20	0.04	0.02	0.21
This Inventory Report	0.02		0.06		0.16		0.01	0.22	0.05	0.09	0.21
Percent Change	(79.1%)		74.9%		30.2%		10.0%	5.9%	36.5%	274.6%	0.0%

Uncertainties

Uncertainties associated with forest fire estimates include the following:

- Wildfire acres burned data and the area of wildland under protection were not available for all inventory years. As a result, estimates for these data were proxied based on the available data. There is significant annual variability in wildfire acres burned data, so 1994 data may not accurately represent wildfire acres burned in 1990.
- The ratio of forest and shrubland area is also a source of uncertainty for all inventory years because the ratios are estimated based on land cover data for years 1999 through 2021.
- The carbon emissions from each vegetation class and moisture scenario are a source of uncertainty because they are used to calculate the emission factors for each land class (in CO_2 Eq.) by taking an average of each moisture scenario.

- According to the United States Forest Service (USFS 2019b), emissions from prescribed fires are expected to be marginal, because prescribed burning is not common in Hawai'i. However, emission estimates from prescribed fires in Hawai'i that are published by EPA's National Emission Inventory (NEI) program indicate that emissions from prescribed fires in Hawai'i were 1.92 MMT CO_2 Eq. in 2014 and 0.08 MMT CO_2 Eq. in 2017.[57] The NEI additionally does not report any emissions from wildfires in Hawai'i during these years. Given that prescribed fires are not common in Hawai'i and that the NEI data for prescribed fires are inconsistent with the wildfire data obtained from DLNR, NEI data were not used to estimate emissions from forest fires in this report (See Appendix C for additional discussion).

To estimate uncertainty associated with emissions from forest fires, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on USFS (2019a), IPCC (2006), and expert judgment. The following parameters contributed the most to the quantified uncertainty estimates: (1) 2021 reported forest area burned, (2) 2021 Hawai'i private forested area in conservation district, and (3) CH_4 emission factor.

The results of the quantitative uncertainty analysis are summarized in Table 5-8. Emissions from forest fires were estimated to be between 0.07 and 0.10 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 15 percent below and 16 percent above the emission estimate of 0.08 MMT CO_2 Eq.

Table 5-8: Quantitative Uncertainty Estimates for Emissions from Forest Fires

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.08	0.07	0.10	-15%	16%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

5.8 Landfilled Yard Trimmings and Food Scraps (IPCC Source Category 3B5a)

Under natural conditions, almost all organic material decomposes aerobically, releasing biogenic CO2; however, this process is prevented when materials are stored in landfills. Yard trimmings (i.e., grass clippings, leaves, and branches) and food scraps continue to store carbon for long periods of time after they have been discarded in landfills. The carbon stored in these products does not completely decompose in landfills as it would under natural conditions such as composting. Therefore, carbon is removed from the global carbon cycle, stored, and, thus, considered a sink. The long-term stored carbon in Solid Waste Disposal Sites (SWDS) is reported as an informational item under the IPPC guidance in the Waste sector (EPA 2010). Harvested wood products (HWP), including paper and cardboard, wood and

[57] Available online at: https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei.

garden, and park waste is equal to the carbon stock change of HWP from domestic consumption disposed into SWDS (EPA 2010). The First Order Decay (FOD) model provides a waste composition option to calculate the long-term stored carbon from HWP in SWDS. As this is the portion of degradable matter not lost through decay. Carbon sequestered from landfilled yard trimmings and food scraps are considered under the AFOLU sector (rather than the Waste sector), according to the IPCC Guidelines for National Greenhouse Gas Inventories and EPA's US GHG Inventory methods. Hawaii-specific data, while limited, indicates that not all harvested wood products are composted within the State. In 2022, landfilled yard trimmings sequestered 0.05 MMT CO_2 Eq., accounting for 1.9 percent of carbon sinks. Table L-24 summarizes changes in carbon stocks in landfilled yard trimmings and food scraps in Hawai'i across the timeseries.

Methodology

Estimates of the carbon sequestration in landfilled yard trimmings and food scraps for Hawai'i were generated using a methodology consistent with the EPA's State Inventory Tool (EPA 2024d). The State Inventory Tool calculates carbon stock change from landfilled yard trimmings and food scraps based on IPCC (2003) and IPCC (2006) Tier 2 methodologies using the following equation:

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

where:

t	= the year for which carbon stocks are being estimated
$LFC_{i,t}$	= the stock of carbon in landfills in year t, for waste i (grass, leaves, branches, and food scraps)
$W_{i,n}$	= the mass of waste i 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	= the proportion of carbon that is stored permanently in waste i
ICC_i	= the initial carbon content of waste i
e	= the natural logarithm
k	= the first order rate constant for waste i, and is equal to 0.693 divided by the half-life for decomposition

The State Inventory Tool uses data on the generation of food scraps and yard trimmings for the entire United States. Additionally, it uses data on the amounts of organic waste composted, incinerated, and landfilled each year to develop an estimate of the yard trimmings and food scraps added to landfills each year nationwide. State and national population data are then used to scale landfilled yard trimmings and food scraps down to the state level. These annual additions of carbon to landfills and an estimated decomposition rate for each year are then used, along with carbon conversion factors, to calculate the carbon pool in landfills for each year.

Default values from the State Inventory Tool (EPA 2024d) for the composition of yard trimmings (i.e., amount of grass, leaves, and branches that are landfilled), food scraps, and their carbon content were used to calculate carbon inputs into landfills. Waste generation data for each year, also obtained from the State Inventory Tool (EPA 2024d), were used to calculate the national-level estimates. Hawai‘i population data were obtained from the State of Hawai‘i Data Book (DBEDT 2023).

Changes in Estimates since the Previous Inventory Report

Relative to the 2021 inventory report, the State of Hawai‘i population estimates were updated in the 2022 Hawai‘i Data Book and U.S. population estimates were updated from the U.S. Census Bureau (2024). The resulting changes in historical sink estimates from landfilled yard trimmings and food scraps are presented in Table 5-9.

Table 5-9: Change in Sinks from Landfilled Yard Trimmings and Food Scraps Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Sink Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	(0.12)		(0.05)		(0.05)		(0.04)	(0.06)	(0.05)	(0.04)	(0.05)
This Inventory Report	(0.12)		(0.05)		(0.05)		(0.04)	(0.06)	(0.05)	(0.04)	(0.05)
Percent Change	+		+		+		+	+	+	0.1%	(0.4%)

+ Does not exceed 0.05 percent.
Note: Parentheses indicate negative values or sequestration.

Uncertainties

The methodology used to estimate carbon sequestration in landfilled yard trimmings and food scraps is based on the assumption that the portion of yard trimmings or food scraps in landfilled waste in Hawai‘i is consistent with national estimates. This emissions estimate is calculated using a population-based disaggregation of a national emissions total. As a result, it is insensitive to Hawai’i-specific trends and Hawai’i-specific activities that may result in emissions reductions. For example, the City and County of Honolulu prohibits commercial and government entities from disposing yard trimmings in landfills (City & County of Honolulu 2005).

In addition, there are uncertainties associated with scaling U.S. sequestration to Hawai‘i based on population only. Sequestration in landfilled yard trimmings and food scraps may vary by climate and composition of yard trimmings (e.g., branches, grass) for a particular region in addition to waste generation, which is assumed to increase with population.

To estimate uncertainty associated with carbon sequestration in landfilled yard trimmings and food scraps, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on expert judgment. The following parameters

contributed the most to the quantified uncertainty estimates: (1) the proportion of carbon stored permanently in food scraps, (2) 2018 yard trimming generation, (3) and 2017 yard trimming generation.

The results of the quantitative uncertainty analysis are summarized in Table 5-10. Sinks from landfilled yard trimmings and food scraps were estimated to be between -0.09 and -0.02 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 98 percent below and 63 percent above the sink estimate of -0.05 MMT CO_2 Eq.

Table 5-10: Quantitative Uncertainty Estimates for Sinks from Landfilled Yard Trimmings and Food Scraps

2022 Emissions Estimate ($MMT\ CO_2$ Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	($MMT\ CO_2$ Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
(0.05)	(0.09)	(0.02)	98%	-63%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.
Note: Parentheses indicate negative values or sequestration.

5.9 Urban Trees (IPCC Source Category 3B5a)

Trees in urban areas (i.e., urban forests) sequester carbon from the atmosphere. Urban areas in Hawai‘i represented approximately five percent of Hawai‘i’s total area in 1990, six percent of Hawai‘i’s total area in 2010, and six percent in 2020 (U.S. Census Bureau 1990a, 2012, and 2022). In 2022, urban trees sequestered 0.60 MMT CO_2 Eq., accounting for 24.4 percent of carbon sinks. Table L-25 summarizes carbon flux from urban trees across the timeseries.

Methodology

Carbon flux from urban trees was calculated using a methodology consistent with the U.S. Inventory (EPA 2024b) and the IPCC (2006) default Gain-Loss methodology. Carbon flux estimates from urban trees were calculated using the following equation.

$$CO_2\ Flux = A\ \times T_{Percent}\ \times S_c\ \times \frac{44}{12}$$

where:

A	= total urban area (including clusters), km^2
$T_{percent}$	= percent of urban area covered by trees, dimensionless
S_c	= C sequestration rates of urban trees, metric tons C/km^2
44/12	= conversion of carbon to CO_2

The 1990 to 2022 U.S. Inventory provides state-level carbon sequestration rates from trees in *Settlements Remaining Settlements*, a land-use category that includes urban areas (EPA 2024b). Using the Hawai‘i-specific estimates, a rate of annual carbon sequestration per square kilometer of tree canopy (MT C/km^2 tree cover) was calculated.

Census-defined urbanized areas were used to calculate urbanized area in Hawai'i.[58] State-level urban area estimates were adapted from the U.S. Census Bureau (1990a) to be consistent with the definition of urban area and clusters provided in the 2000 U.S. Census (Nowak et al. 2005). Urban area and cluster data for 2000 and 2010 were provided directly from the U.S. Census Bureau (2002, 2012). A linear trend was fitted to the 2000 and 2010 data to establish a timeseries from 2001 to 2009. Then, a linear trend was fitted to the 2010 and 2020 data to establish a timeseries from 2011 to 2019. After 2020, urban area was projected based on projected changes in developed area from 2011 to 2017 by the USGS (Selmants et al. 2017). Because of the changes in the definitions of urban areas from the different Census years, any urban areas that appeared in the 2000 or 2010 Census, but not in subsequent Censuses, were proxied to the last year that they appeared. For example, Hawaiian Paradise Park appeared as an urban cluster in the 2010 Census, but did not appear in the 2020 Census, so its 2010 area was proxied to 2020. Urban area in square kilometers for 1990, 2005, 2007, and 2018 to 2022 are summarized in Table 5-11.

Table 5-11: Statewide Urban Area (sq.km)

Area	1990		2005		2007		2018	2019	2020	2021	2022
Urban Area	757.0		981.7		1,006.1		975.5	967.1	958.7	972.7	986.9

Data from the National Land Cover Database (NLCD) was used to derive an estimate of tree cover by county percent for the years 2011, 2013, 2015, 2017, 2019, and 2021 (USFS 2023). Then tree cover estimates were interpolated throughout the timeseries based on available data. According to Nowak (2012), 30.4 percent of urban areas in Hawai'i were covered by trees circa 2005, whereas state-wide urban tree cover in NLCD was 29.71% in 2011. The change in state-level urban tree cover in 2005 was used to scale down county-level urban tree cover for the last year of NLCD data and interpolate between 2005 and 2011. Urban tree cover by county was held constant at 2005 levels for prior years.

With an estimate of total urban tree cover for Hawai'i by year, the Hawai'i-specific sequestration factor (MT C/km^2 tree cover) was applied to this area to calculate total C sequestration by urban trees (MT C/year).

[58] Definitions for urbanized area changed between 2000 and 2010 and between 2010 and 2020. In 2000, the U.S. Census replaced the 'urban places' category with the new category of called an 'urban cluster.,' 'Urban clusters' included areas with more than 500 people per square mile. In 2010 Census, 'urban areas' were updated to encompass Census tract delineated cities with 50,000 or more people and 'urban clusters' were updated to contain Census tract delineated locations with between 2,500 and 50,000 people (U.S. Census Bureau 2021). In the 2020 Census, the minimum population threshold to qualify as urban increased from 2,500 to 5,000 and the alternative option of qualifying based on minimum housing unit threshold was added. The 2020 Census also uses housing unit density instead of population density and no longer distinguishes between urban clusters and urban areas (U.S. Census Bureau 2022).

Changes in Estimates since the Previous Inventory Report

A new methodology for estimating urban tree cover is used in this inventory report. Where the 2021 inventory, distinguished urban tree cover between Honolulu County and the rest of Hawai'i only, this new method distinguishes between all counties. Additionally, this new method relies on data from the NLCD, which is a more complete dataset. The resulting changes in historical emissions estimates from urban trees are presented in Table 5-12.

Table 5-12: Change in Sinks from Urban Trees Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Sink Estimates	1990	2005	2007	2017	2018	2019	2020	2021
2021 Inventory Report	(0.51)	(0.67)	(0.65)	(0.55)	(0.55)	(0.55)	(0.54)	(0.56)
This Inventory Report	(0.48)	(0.60)	(0.61)	(0.60)	(0.59)	(0.59)	(0.58)	(0.59)
Percent Change	6.5%	9.9%	6.4%	(7.8%)	(8.1%)	(7.4%)	(8.1%)	(4.5%)

Note: Parentheses indicate negative values or sequestration.

Uncertainties

Uncertainties associated with urban tree CO_2 flux estimates include the following:

- The methodology used to estimate urban area in 2015, 2016, 2017, 2018, 2019, and 2021 is based on USGS projections of area that are specific to Hawai'i and consider land transitions, impacts of climate change, and other factors under a BAU scenario (Selmants et al. 2017). This methodology does not consider potential changes in the rate of urbanization over time.
- The average and net sequestration rates are based on estimates of the settlement area in Hawai'i and the associated percent tree cover in developed land. This methodology has associated uncertainty resulting from the land cover data used to generate the area and tree cover estimates.

To estimate uncertainty associated with sinks from urban trees, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on Nowak et al. (2005, 2012, 2018a, and 2018b), Selmants et al. (2017), U.S. Census (2023), EPA (2024a), and expert judgment. The following parameters contributed the most to the quantified uncertainty estimates: (1) net carbon sequestration per area of urban tree cover in Hawai'i, (2) Hawai'i tree cover, and (3) 2020 urban area in Honolulu. The quantified uncertainty estimated for net carbon sequestration per area of urban tree cover in Hawai'i contributed the vast majority to the quantified uncertainty estimates. The remaining input variables contributed relatively evenly to the overall uncertainty of the sink estimate.

The results of the quantitative uncertainty analysis are summarized in Table 5-13. Sinks from urban trees were estimated to be between -0.93 and -0.34 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 54 percent below and 44 percent above the sink estimate of -0.56 MMT CO_2 Eq.

Table 5-13: Quantitative Uncertainty Estimates for Sinks from Urban Trees

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
(0.60)	(0.93)	(0.34)	54%	-44%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.
Note: Parentheses indicate negative values or sequestration.

5.10 Forest Carbon (IPCC Source Category 3B1a)

Hawai'i forests and shrubland contain carbon stored in various carbon pools, which are defined as reservoirs with the capacity to accumulate or release carbon (IPCC 2006). This category includes estimates of carbon sequestered in forests and shrubland aboveground biomass, which is defined as living vegetation above the soil, and belowground biomass, which is defined as all biomass below the roots (IPCC 2006). This analysis only considers managed forests and shrubland per IPCC (2006) guidelines to discriminate between anthropogenic and non-anthropogenic sources and sinks because the majority of anthropogenic GHG emissions and sinks occur on managed land.[59] In 2022, forests and shrubland sequestered 1.83 MMT CO_2 Eq., accounting for 73.8 percent of carbon sinks. Table L-26 summarizes carbon flux from forests and shrubland in Hawai'i for 1990, 2005, 2007, 2010, and 2015 to 2022.

Methodology

The Tier 1 Gain Loss Method as outlined by the *2006 IPCC Guidelines* (IPCC 2006) was used to calculate carbon flux in managed Hawai'i forests. Unmanaged forests are not included in this analysis per IPCC guidelines. This method requires forestland acreage data as well as annual net C sequestration per unit area. The Gain Loss method calculates annual increase in carbon stocks using the following equation:

$$Forest\ CO_2\ Flux = \sum_i (A_i \times S_{Net,i}) \times \frac{44}{12}$$

where,

A	= forest land area, hectares
$S_{Net,i}$	= net C sequestration rate, tonnes of C/hectare/year
44/12	= conversion of carbon to CO_2
i	= forest type (forest or shrubland in Hawai'i)

[59] Managed forests, under IPCC (2006) guidelines, are deemed to be a human-influenced GHG sink and, accordingly, are included here. This encompasses any forest that is under any sort of human intervention, alteration, maintenance, or legal protection. Unmanaged forests are not under human influence and thus out of the purview of this inventory.

Managed forestland acreage data were obtained from the State of Hawaiʻi Data Book (DBEDT 2023). Area estimates of private forestland in the conservation district were summed with reserve forestland in the conservation district, forested natural areas and wooded farmland in order to generate total managed forested land area in Hawaiʻi for 1990, 2005, 2007, and 2018 to 2022.

Forestland was divided into two sub-categories: forest and shrub/scrubland using the island-specific forestland to shrubland ratios derived from the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (NOAA-CCAP) land cover study in 2000 and the USGS assessment of land cover in 2014 (NOAA-CCAP 2000; Selmants et al. 2017).

According to NOAA-CCAP, roughly half of Hawaiʻi's forestland in 2000 was shrub/scrubland, defined as land with vegetation less than 20 feet tall (NOAA-CCAP 2000). In 2014, the share of shrubland in Hawaiʻi decreased to approximately 32 percent according to USGS (Selmants et al. 2017). 2000 data on the ratio of forest to shrubland area were used as a proxy for 1990, and 2014 data were used as a proxy for 2015 to 2022. For 2005, 2007, and 2010, the ratio of forest to shrubland area was interpolated using forest and shrubland area in 2000 (NOAA-CCAP) and 2014 (Selmants et al. 2017).

Net ecosystem production for forest and shrubland in Hawaiʻi were obtained from USGS for 2011 through 2025 (Selmants 2020). Net ecosystem production represents the net carbon accumulation from all carbon fluxes in an ecosystem, including storage in aboveground and belowground biomass, losses from oxidation, and exportation to other systems (Randerson, et al., 2002). Net C sequestration rates were calculated by dividing annual net ecosystem production for each land class by the associated area to obtain a yearly rate (MT C/ha/year). Each year's net C sequestration rate for forest and shrubland were applied to the respective land area. For years prior to 2011, the average sequestration rate across the entire timeseries was used.

Changes in Estimates since the Previous Inventory Report

No changes were made to emissions from forest carbon since the 2021 inventory report.

Uncertainties

The methodology used to estimate carbon flux from forests and shrubland is based on the ratio of forest and shrubland area. The ratio of forest and shrubland area is a source of uncertainty for all inventory years because the ratios are estimated based on land cover data for years 2000 and 2014. In addition, the net sequestration rate for forest and shrubland are calculated based on the average net ecosystem production per year across four unique modeling scenarios for different land-use/climate change projections. Yearly forest and shrubland sequestration rates are only available after 2011; all years prior to 2011 use an average rate across the available timeseries (Selmants 2020).

To estimate uncertainty associated with sinks from forest carbon, uncertainties associated with all input variables were assessed. Uncertainty was estimated quantitatively around each input variable based on IPCC (2006), Selmants (2020), and expert judgment. The following parameters contributed the most to the quantified uncertainty estimates: (1) 2022 forest net ecosystem production, (2) 2022 Hawaiʻi private forested area in conservation district, and (3) 2022 total forest area.

The results of the quantitative uncertainty analysis are summarized in Table 5-14. Sinks from forest carbon were estimated to be between -2.19 and -1.52 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 20 percent below and 17 percent above the sink estimate of -1.83 MMT CO_2 Eq.

Table 5-14: Quantitative Uncertainty Estimates for Sinks from Forest Carbon

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
(1.83)	(2.19)	(1.52)	20%	-17%

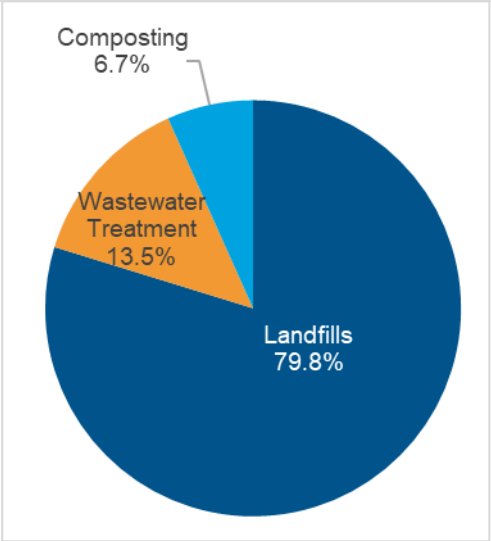
[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.
Note: Parentheses indicate negative values or sequestration.

6. Waste

This chapter presents GHG emissions from waste management and treatment activities. For the state of the Hawai'i, waste sector emissions are estimated from the following sources: landfills (IPCC Source Category 4A1), composting (IPCC Source Category 4B), and wastewater treatment (IPCC Source Category 4D).[60] Emissions from the incineration of waste are reported under the Energy sector, consistent with the U.S. Inventory, since the incineration of waste generally occurs at facilities where energy is recovered.

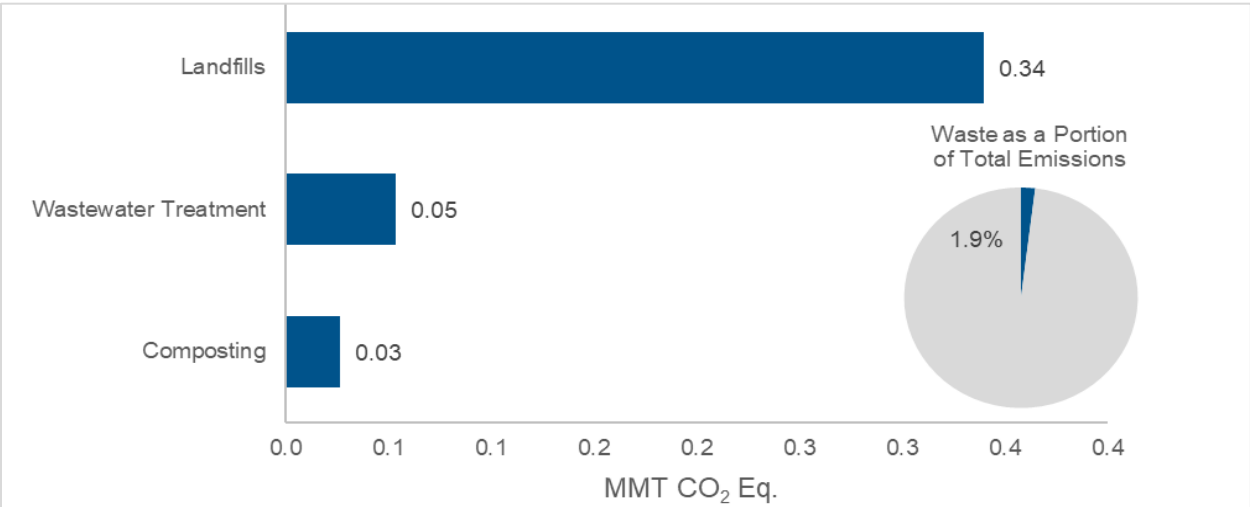
In 2022, emissions from the Waste sector were 0.4 MMT CO_2 Eq., accounting for 1.9 percent of total Hawai'i emissions. Emissions from landfills accounted for the largest share of Waste sector emissions, followed by emissions from wastewater treatment, and composting. Figure 6-1 and Figure 6-2 show emissions (% and MMT CO_2 Eq.) from the Waste sector by source for 2022.

Figure 6-1: 2022 Waste Emissions (%) by Source



Note: Totals may not sum due to independent rounding.

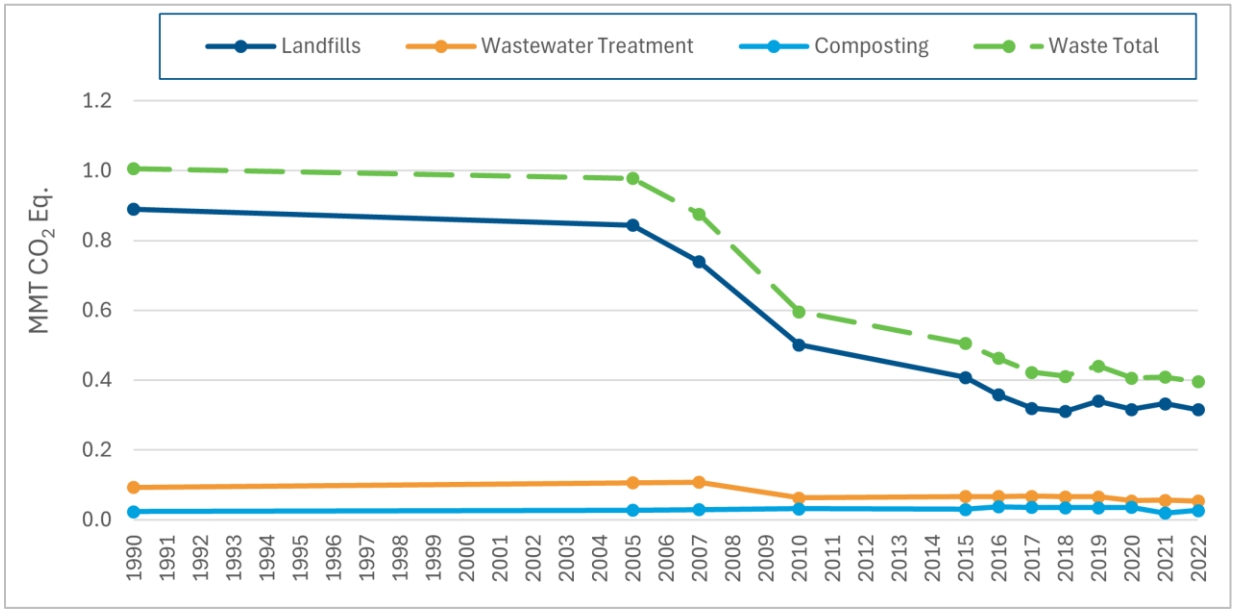
Figure 6-2: 2022 Waste Emissions by Source (MMT CO_2 Eq.)



[60] In Hawai'i, incineration of MSW occurs at waste-to-energy facilities and thus emissions from incineration of waste for energy purposes (IPCC Source Category 1A1a) are accounted for in the Energy sector.

Emissions from the Waste sector have decreased since their 1990 peak and in 2022 were lower by 60.7 percent relative to 1990. This trend is driven by emissions from landfills, which accounted for the largest share of emissions from the Waste sector in all inventory years. These emissions decreased between 1990 and 2022 as a result of an increase in the volume of landfill gas recovered for flaring. Landfill flaring is a process used to safely dispose of landfill gas – mainly CH_4 and CO_2— by burning it instead of letting it escape into the atmosphere. During flaring, CH_4 is converted to CO_2 (a GHG with a lower global warming potential), water vapor, and trace compounds. Figure 6-3 below shows Waste sector emissions by source category for each inventory year. Emissions by source and year are also summarized in Table L-27.

Figure 6-3: Waste Sector Emissions by Source and Year (MMT CO_2 Eq.)



Notes: Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

The remainder of this chapter describes the detailed emission results by source category, including a description of the methodology and data sources used to prepare the inventory. Activity data and emission factors used in the analysis are summarized in Appendix F and Appendix G, respectively.

6.1 Landfills (IPCC Source Category 4A1)

When placed in landfills, organic material in municipal solid waste (MSW) (e.g., paper, food scraps, and wood products) is decomposed by both aerobic and anaerobic bacteria. As a result of these processes, landfills generate biogas consisting of approximately 50 percent biogenic CO_2 and 50 percent CH_4, by volume (EPA 2024b). Consistent with IPCC (2006), biogenic CO_2 from landfills is not reported under the Waste sector. In 2022, CH_4 emissions from landfills in Hawai‘i were 0.32 MMT CO_2 Eq., accounting for 79.8 percent of Waste sector emissions and 1.6 percent of statewide total emissions (excluding sinks). Emissions from landfills have decreased since their 1990 peak and in 2022 were lower by roughly 64.5

percent relative to 1990. This trend is attributed to a relative increase in the volume of landfill gas recovered for flaring in Hawaiʻi which reduces CH_4 emissions. Changes in emissions year over year at individual landfills can also be attributed to landfill gas recovery due to technologies coming online or technological difficulties based on location. Table L-28 summarizes CH_4 emissions from landfills in Hawaiʻi for across the timeseries.

Consistent with the methodology used for the U.S. Inventory (EPA 2024b), potential MSW landfill emissions were calculated using a combination of reported emissions data from EPA's Greenhouse Gas Reporting Program (GHGRP) (EPA 2024c), waste in place data provided by EPA's LMOP (EPA 2022b), and annual amounts of waste landfilled in Hawaiʻi. Data on the tons of waste landfilled per year in Hawaiʻi for 1995 through 2022 were provided by the Hawaiʻi Department of Health (DOH), Solid Waste Branch (Hawaiʻi DOH 2024 and Otsu 2008). Historical MSW generation and disposal volumes from 1960 through 1994 were calculated using default waste generation and disposal data for the state of Hawaiʻi from EPA's State Inventory Tool – Municipal Solid Waste Module (EPA 2024d).

For the years 2010 to 2022, direct measurements of CH_4 emissions were obtained from EPA's GHGRP database, using Equation HH-8 for MSW landfills and Equation TT-6 for Hawaiʻi's one industrial landfill (EPA 2024c). GHGRP emissions are considered an IPCC Tier 3 approach (IPCC 2006) that consider flared and captured CH_4 from the landfill's operations, hours of operation of capturing technology, and the collection efficiency of the system. Since only landfills that surpass 25,000 MT CO_2 Eq. of emissions annually are required to report to GHGRP, a scaling factor, which changes annually based on the amount of waste in place in facilities, the GHGRP provided waste in place data, and island population numbers, is applied to most county emissions to account for the municipal landfills that fall under the GHGRP reporting threshold.[61] No scaling factor was applied to Honolulu County due to the general consistency between the GHGRP and the waste in place data from LMOP. The scaling factor is based on the difference between the amount of waste disposed at GHGRP reporting landfills and the total amount of waste at the county level for each year, calculated using LMOP's waste in place data and annual tipping amounts from Hawaiʻi DOH.

Annual reporting requirements to EPA's GHGRP for applicable landfills began in 2010. Therefore, reported CH_4 generation obtained from GHGRP were back-casted to the years 1990, 2005, and 2007 and the total amount of flared CH_4 for each year was subtracted. Emissions from the Waimanalo Gulch landfill in Kapolei were excluded from the 1990 estimate because the landfill began operation in 1989. Emissions in the first year are assumed to be zero, as it typically takes one year for anaerobic conditions to be established and methane-producing bacteria to start decomposing waste (EPA 2023b).

Equation HH-8 for MSW landfills as described by GHGRP is as follows:

[61] The scale up factor is determined by the difference between one and the quotient of the GHGRP waste in place and island waste in place data. By using this formula, the scale up factor is based on annual year to year waste and population data and the formula takes into account changes year over year.

$$E = \left(\frac{R}{CE \ * f_{Rec}} - R\right) * \ (1 - OX) + \ R * \ \left(1 - \ (DE \ * f_{Dest})\right)$$

where,

E = amount of CH_4 emitted

R = quantity of recovered CH_4 from GHGRP equation HH-4 (metric tons)

CE = collection efficiency estimated at landfill

f_{Rec} = fraction of hours the recovery system was operating

OX = oxidation factor

DE = destruction efficiency

f_{Dest} = fraction of hours the destruction device was operating

Equation TT-6 for industrial landfills as described by GHGRP is as follows:

$$MG = G_{CH4} * \ (1 - OX)$$

where,

MG = amount of CH_4 generated, adjusted for oxidation

G_{CH4} = modeled methane generation from GHGRP Equation TT-1

OX = oxidation factor (default of 0.1)

Changes in Estimates since the Previous Inventory Report

Previous inventory reports utilized data from GHGRP on landfill operation and gas collection systems to back-cast emissions for the years 1990, 2005, and 2007. The current report includes 2022 GHGRP values to improve back-casted estimates. Additionally, updated population numbers for years 2011 to 2022 were incorporated into this inventory report. The resulting changes in historical emission estimates are presented in Table 6-1.

Table 6-1: Change in Emissions from Landfills Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Sink Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	0.89		0.85		0.74		0.32	0.31	0.34	0.32	0.33
This Inventory Report	0.89		0.84		0.74		0.32	0.31	0.34	0.32	0.33
Percent Change	(+%)		(0.4%)		(0.2%)		0.0%	0.0%	0.0%	0.0%	0.0%

(+) Does not exceed -0.05 percent.

Uncertainties

To estimate uncertainty associated with emissions from landfills, uncertainties for several sources and activity data were assessed, including: (1) landfill methane emissions from GHGRP, (2) landfill waste-in-place data from EPA's LMOP, (3) methane generation potential, (4) methane generation rate constant, (5) Hawai'i state population, and (6) landfill disposal rates. Uncertainty was estimated quantitatively around each input variable based on expert judgment, IPCC (2006), and EPA (2024a). The following parameters contributed the most to the quantified uncertainty estimates for MSW landfills: (1) reported methane emissions from the South Hilo landfill, (2) Maui county's population, and (3) reported methane emissions from the Central Maui landfill. Since Hawai'i only has one industrial landfill and methane emissions are taken directly from the GHGRP report, this parameter was the only one that contributed to the uncertainty estimate for industrial landfills.

The results of the quantitative uncertainty analysis are summarized in Table 6-2 for MSW landfills and Table 6-3 for industrial landfills. Emissions from MSW landfills were estimated to be between 0.26 and 0.28 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately three percent below and four percent above the emission estimate of 0.27 MMT CO_2 Eq. Emissions from industrial landfills were estimated to be between 0.046 and 0.051 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately five percent below and five percent above the emission estimate of 0.05 MMT CO_2 Eq.

Table 6-2: Quantitative Uncertainty Estimates for Emissions from MSW Landfills

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.27	0.26	0.28	-3%	4%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

Table 6-3: Quantitative Uncertainty Estimates for Emissions from Industrial Landfills

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.05	0.046	0.051	-5%	5%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

6.2 Composting (IPCC Source Category 4B)

Composting involves the aerobic decomposition of organic waste materials, wherein large portions of the degradable organic carbon in the waste materials are converted into CO_2. The remaining solid portion is often recycled as fertilizer and soil amendment or disposed of in a landfill. During the composting process, trace amounts of CH_4 and N_2O can form, depending on how the compost pile is managed (EPA 2024b). In 2022, emissions from composting in Hawai'i were 0.03 MMT CO_2 Eq.,

accounting for 6.7 percent of Waste sector emissions and 0.1 percent of statewide total emissions (excluding sinks). Relative to 1990, emissions from composting in 2022 were 13.6 percent higher. This trend is attributed to an increase in population and an increase in the quantity of composted waste. In 2022, composting emissions increased by 35.2 percent, relative to 2021. Table L-29 summarizes emissions from composting in Hawai‘i across the timeseries.

Methodology

Methane and N_2O emissions from composting were calculated using the IPCC default (Tier 1) methodology, summarized in the equations below (IPCC 2006).

$$CH_4\ Emissions = (M * EF) - R$$

where,

M = mass of organic waste composted in inventory year
EF = emission factor for composting
R = total amount of CH_4 recovered in inventory year

$$N_2O\ Emissions = M * EF$$

where,

M = mass of organic waste composted in inventory year
EF = emission factor for composting

Tons of waste composted per year and by county were provided by the Office of Solid Waste Management within Hawai‘i’s Department of Health (Hawai‘i DOH 2024). This data is an annual report of composting facilities permitted by the Solid Hazardous Waste Branch for facilities that process more than 3,000 tons of green waste. The emission factors for composting were obtained from IPCC (2006). It was assumed that CH_4 recovery did not occur at composting operations in Hawai‘i.

Changes in Estimates since the Previous Inventory Report

This inventory report incorporated updated population numbers for years 2011 to 2022. The resulting changes in historical emission estimates are presented in Table 6-4.

Table 6-4: Change in Emissions from Composting Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Sink Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	0.02		0.03		0.03		0.04	0.03	0.03	0.04	0.02
This Inventory Report	0.02		0.03		0.03		0.04	0.03	0.03	0.04	0.02
Percent Change	0.0%		0.0%		0.0%		0.0%	0.0%	0.0%	0.0%	0.0%

Uncertainties

To estimate uncertainty associated with emissions from composting, uncertainties for the following were assessed: (1) CH_4 emission factor, (2) N_2O emission factor, (3) waste composted by county, and (4)

Hawai‘i population data. Uncertainty was estimated quantitatively around each input variable based on expert judgment, IPCC (2006), and EPA (2024a). The following parameters contributed the most to the quantified uncertainty estimates: (1) CH_4 emission factor, (2) N_2O emission factor, and (3) Honolulu County composting tonnage amount.

The results of the quantitative uncertainty analysis are summarized in Table 6-5. Emissions from composting were estimated to be between 0.01 and 0.04 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 51 percent below and 63 percent above the emission estimate of 0.03 MMT CO_2 Eq.

Table 6-5: Quantitative Uncertainty Estimates for Emissions from Composting

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.03	0.01	0.04	-51%	63%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval.

6.3 Wastewater Treatment (IPCC Source Category 4D)

Wastewater produced from domestic, commercial, and industrial sources is treated either on-site (e.g., in septic systems) or in central treatment systems to remove solids, pathogenic organisms, and chemical contaminants (EPA 2024b). During the wastewater treatment process, CH_4 is generated when microorganisms biodegrade soluble organic material in wastewater under anaerobic conditions. The generation of N_2O occurs during both the nitrification and denitrification of the nitrogen present in wastewater. Over 20 centralized wastewater treatment plants operate in Hawai‘i, serving most of the state’s population. The remaining wastewater is treated at on-site wastewater systems. In 2022, emissions from wastewater treatment in Hawai‘i were 0.05 MMT CO_2 Eq., accounting for 13.5 percent of Waste sector emissions and 0.3 percent of statewide total emissions (excluding sinks). Relative to 1990, emissions from wastewater treatment in 2022 were lower by 42.5 percent. Table L-30 summarizes emissions from wastewater treatment in Hawai‘i across the timeseries.

Methodology

Wastewater treatment emissions were calculated using a methodology consistent with the methodology used for the U.S. Inventory (EPA 2024b) and EPA’s State Inventory Tools – Wastewater Module (EPA 2024d). Wastewater emissions from municipal wastewater treatment, septic tank treatment, and wastewater biosolids were quantified using data on population, septic tank use, biochemical oxygen demand (BOD) production and flow rate at wastewater treatment plans, and biosolids fertilizer use practices.

To calculate CH_4 emissions from municipal wastewater treatment, the total annual 5-day biochemical oxygen demand (BOD_5) production in metric tons was multiplied by the fraction that is treated anaerobically and by the CH_4 produced per metric ton of BOD_5:

$$CH_4\ Emissions = BOD_5 * EF * AD$$

where,

BOD_5 = total annual 5-day biochemical oxygen demand production
EF = emission factor for municipal wastewater treatment
AD = percentage of wastewater BOD_5 treated through anaerobic digestion

Municipal wastewater treatment direct N_2O emissions were calculated by determining total population served by wastewater treatment plants (adjusted for the share of the population on septic) and multiplying by an N_2O emission factor per person per year:

$$Direct\ N_2O\ Emissions = Septic * EF$$

where,

Septic = percentage of the population by region not using septic wastewater treatment
EF = emission factor for municipal wastewater treatment

Municipal wastewater N_2O emissions from biosolids were calculated using the equation below:

$$Biosolids\ N_2O\ Emissions = \left((P * N_P * F_N) - N_{Direct}\right) * (1 - Biosolids) * EF$$

where,

P = total annual protein consumption
N_P = nitrogen content of protein
F_N = fraction of nitrogen not consumed
N_{Direct} = direct N_2O emissions
Biosolids = percentage of biosolids used as fertilizer
EF = emission factor for municipal waste treatment

Biosolids, a type of sewage sludge that has been treated and processed to meet specific regulatory standards for land application, are often applied to agricultural fields as fertilizer; emissions from this use are accounted for under the AFOLU sector. Therefore, the wastewater calculations exclude the share of sewage sludge applied to agricultural soils so that emissions are not double counted. For all inventory years, it was assumed that no biosolids were used as fertilizer.

Data on National Pollutant Discharge Elimination System (NPDES) and non-NPDES wastewater treatment plants, including flow rate and BOD_5, were provided by Hawaiʻi DOH, Wastewater Branch (Pruder 2008, Hawaiʻi DOH 2017, Hawaiʻi DOH 2018, and Hawaiʻi DOH 2022a, 2022b, 2022c, 2022d, 2022e) or obtained from EPA's Enforcement and Compliance History Online (ECHO) Database (EPA 2022d). Where sufficient data were available, it was used to characterize BOD_5 for a given island and inventory year. When sufficient data were not available, data for a particular WWTP were either proxied to the most recent year with data, or to the Hawaiʻi default BOD_5 value from the 1997 inventory of 0.1356 due to it being the best available data that is Hawaiʻi-specific and sourced from the Hawaiʻi State Department of Health (DBEDT and DOH 1997). Specifically, because of incomplete historical data, the Hawaiʻi default

BOD_5 value from the 1997 inventory was used across all counties for the 1990, 2005, and 2007 inventory years.

Population data from the State of Hawai‘i Data Book (DBEDT 2023), U.S. Census Bureau data (1990b), and Pruder (2008) were used to calculate wastewater treatment volumes and the share of households on septic systems. For the full timeseries comprehensive data on the number of households on septic systems were unavailable. Therefore, annually variable data on the percentage of the population using centralized wastewater treatment facilities from the U.S. GHG Inventory were used to estimate the percent of Hawai‘i’s population using septic systems for all inventory years (EPA 2024b). Emission factors were obtained from EPA’s State Inventory Tool (EPA 2024d).

Changes in Estimates since the Previous Inventory Report

This inventory updated historical emission estimates by incorporating newly obtained flow rates and BOD_5 for NPDES WWTPs, from Hawai‘i DOH Wastewater Branch and from EPA’s ECHO Database, respectively. In addition, this inventory report incorporated updated population numbers for years 2011 to 2022. The resulting changes in historical emission estimates are presented in Table 6-6.

Table 6-6. Change in Emissions from Wastewater Treatment Relative to the 2021 Inventory Report (MMT CO_2 Eq.)

Sink Estimates	1990		2005		2007		2017	2018	2019	2020	2021
2021 Inventory Report	0.09		0.11		0.11		0.07	0.07	0.07	0.05	0.06
This Inventory Report	0.09		0.11		0.11		0.07	0.07	0.07	0.05	0.06
Percent Change	0.0%		0.0%		0.0%		0.0%	0.0%	0.0%	+%	0.3%

+ Does not exceed 0.005 MMT CO_2 Eq. or 0.05 percent.

Uncertainties

Due to the lack of Hawai‘i-specific data, default emission factors from EPA’s State Inventory Tools – Wastewater Module were used to calculate emissions. This includes the share of wastewater solids anaerobically digested and the percentage of biosolids used as fertilizer. In addition, data on the share of household septic systems were unavailable, so a U.S. country average was used in its place. For instances where BOD or flow rate data from 2022 were not available, data from the most recent available year was used to estimate emissions for 2022. This emissions estimate is calculated using averages and disaggregations of national values. As a result, it is insensitive to Hawai’i-specific trends and Hawai’i-specific activities that may result in emissions reductions.

To estimate uncertainty associated with emissions from wastewater treatment, uncertainties for six quantities were assessed: (1) wastewater treatment plan flow rates, (2) BOD_5 values, (3) direct N_2O emissions rate, (4) biosolid N_2O emission factor, (5) CH_4 emission factor, and (6) percentage of biosolids used as fertilizer. Uncertainty was estimated quantitatively around each input variable based on expert judgment and IPCC (2006). The following parameters contributed the most to the quantified uncertainty

estimates: (1) N_2O emission factor, (2) CH_4 emission factor, (3) fraction of non-consumption nitrogen, and (4) fraction of nitrogen in protein.

The results of the quantitative uncertainty analysis are summarized Table 6-7. Emissions from wastewater treatment were estimated to be between 0.04 and 0.07 MMT CO_2 Eq. at the 95 percent confidence level. This confidence level indicates a range of approximately 26 percent below and 29 percent above the emission estimate of 0.05 MMT CO_2 Eq.

Table 6-7: Quantitative Uncertainty Estimates for Emissions from Wastewater Treatment

2022 Emissions Estimate (MMT CO_2 Eq.)	Uncertainty Range Relative to Emissions Estimate[a]			
	(MMT CO_2 Eq.)		(percent)	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
0.05	0.04	0.07	-26%	29%

[a] Range of emission estimates predicted by Monte Carlo Stochastic Simulation for a 95 percent confidence interval

7. Emission Projections

This chapter presents projections for Hawaiʻi statewide and county-level GHG emissions and sinks for 2025, 2030, 2035, 2040, and 2045. This chapter includes a summary of the baseline projection results and the methodology used to develop these projections. This chapter also includes scenario-based statewide GHG projections due to variations in (1) world oil prices, (2) renewable energy deployment, and (3) ground transportation technology adoption.

Statewide emissions projections provide an estimate against which the effectiveness of implemented GHG mitigation policies can be tracked, including overall progress toward emissions reduction goals. The alternate scenarios provide an understanding of how different economic factors, technology, and policy influence GHG emissions.

7.1 Methodology Overview

Methodology

GHG emissions result from economic activities occurring within Hawaiʻi. These emissions are impacted by the overall level of economic activities, the types of energy and technologies used, land use decisions, and other factors. Estimating future GHG emissions relies on projections of economic activities as well as an understanding of policies and programs that impact the production of GHG emissions.

The analysis uses a combination of top-down and bottom-up approaches to develop baseline projections of statewide and county-level GHG emissions for the years 2025, 2030, 2035, 2040, and 2045. The projections for several sources (residential, commercial, and industrial energy use, domestic and international aviation, non-energy uses, composting and wastewater treatment) are based on either a long-range forecast for gross state/county product or future population (including visitor arrivals), using the 2022 statewide GHG inventory as a starting point. Sector-specific approaches were taken for several small sectors. For example, electricity sales forecasts were used to project GHG emissions for electrical transmission and distribution. Emissions for agriculture, forestry, and other land use (AFOLU) categories and landfill waste are projected by forecasting activity data using historical trends and published information available on future trends. Bottom-up approaches are used for GHG emitting sources with substantial federal and state policy intervention (energy industries, substitution of ozone depleting substances, and transportation). Due to policies that affect these sources, projected economic activities are only one component of future GHG emissions. Therefore, a more comprehensive sectoral approach was used to develop baseline projections for these emission sources.

There is uncertainty in forecasting GHG emissions due to economic, technology, and policy uncertainty. In addition to the **baseline scenario**[62], three major points of uncertainty were assessed by modeling six alternate scenarios for statewide GHG emissions in 2025, 2030, 2035, 2040, and 2045, as described below. Notably, these alternate scenarios are within the energy sector. In Hawaiʻi, following national trends, the energy sector is the dominant contributor to GHG emissions. In addition, the energy sector is highly susceptible to rapid changes in policy and technology factors such as renewable energy adoption, energy efficiency measures, and fluctuations in fuel prices, making it distinct from other sectors.

- **Alternate Scenario 1A and 1B**: World oil prices. Shifts in fossil fuel prices will impact consumer use of different fuels and resulting GHG emissions. This alternate scenario looks at both high (Alternate Scenario 1A) and low (Alternate Scenario 1B) future oil price pathways based on the U.S. Energy Information Administration's Annual Energy Outlook 2023 (EIA 2023).
- **Alternate Scenario 2A and 2B**: Renewable energy deployment. Hawaiʻi adopted a Renewable Portfolio Standard (RPS) that mandated electric utilities reach 30 percent of net electricity sales through renewable sources by the end of 2020, and moving forward, 40 percent by 2030, 70 percent by 2040, and 100 percent by 2045 (HRS §269-92). Alternate Scenario 2A assumes a more aggressive path for renewable energy deployment than the Baseline based on Hawaiian Electric Industries most recent planning document (Integrated Grid Plan).[63] For Alternate Scenario 2B, renewable energy deployment is projected based on the rate of deployment since 2016.
- **Alternate Scenario 3A and 3B**: Ground transportation technology adoption. To meet the State's objective of "carbon net negative" by 2045, transportation is a key sector and has been the focus of decarbonization efforts. Moreover, in 2017, Hawaiʻi's four county mayors committed to a shared goal of reaching 100 percent "renewable ground transportation" by 2045 (City & County of Honolulu 2018a). It is not yet clear the set of policy instruments that will be implemented to attain this goal, and there is considerable uncertainty in the emissions trajectory within the ground transportation sector. This alternate scenario creates a high EV adoption scenario (Alternate Scenario 3A) and a low EV adoption scenario (Alternate Scenario 3B).

A detailed description of the methodologies used to project statewide GHG emissions by source and sink categories under both the baseline scenario and the alternate scenarios, if applicable, are provided in Appendix J. The methodologies used to identify county-level estimates are also detailed in Appendix J.

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[62] A modeled emissions baseline scenario estimates emissions under current policy and trends.

[63] The baseline scenario uses the IGP Land Constrained for Oʻahu but assumes fewer renewable energy builds in 2045. All other counties follow a linear path to 100 percent renewables in 2045. A detailed description of the methodologies used to project statewide GHG emissions by source and sink categories under both the baseline scenario and the alternate scenarios, if applicable, are provided in Appendix J. The methodologies used to identify county-level estimates are also detailed in Appendix J.

Limitations of the Projections Analysis

As with all projections of emissions, uncertainty exists. This study quantitatively assessed additional scenarios that account for the impact of key uncertainties on the energy industries and transportation source categories. Other areas of uncertainty exist, as discussed in the subsequent sections of this chapter, but were not quantitatively assessed as part of this analysis. Specifically, other key areas of uncertainty include the following:

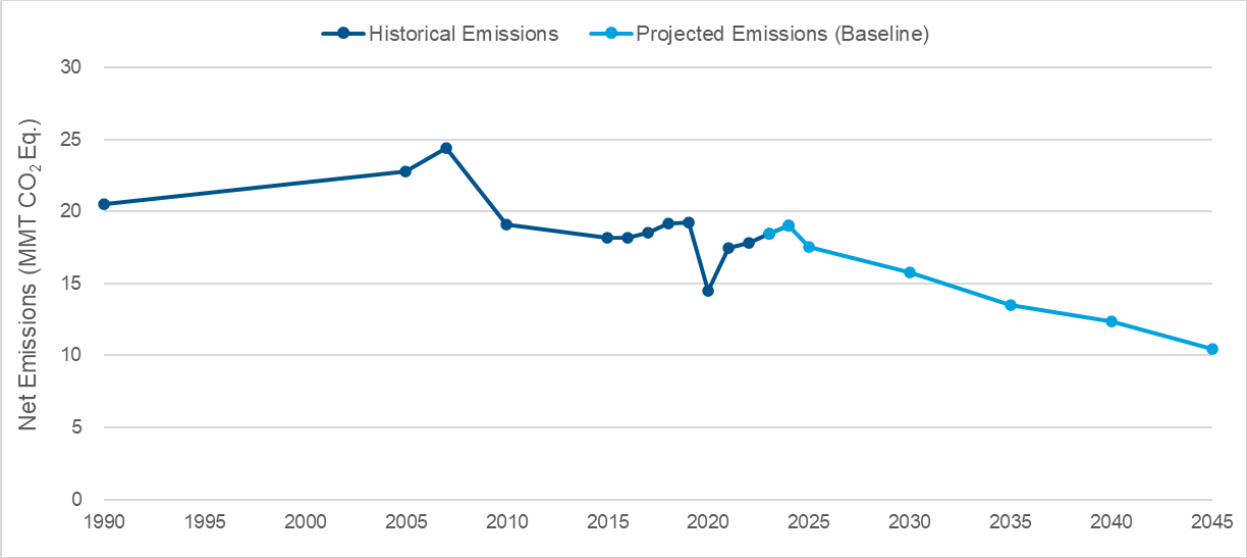
- **Inventory Estimates:** The projections were developed using the historical inventory estimates as a starting point. Any uncertainties related to quality and availability of data used to develop the historical inventory estimates similarly apply to the emission projections.
- **Macroeconomy and Population Projections:** GHG emissions are influenced by various economic factors. For Hawaiʻi, the key factors are gross state product, population, and visitor arrivals and expenditures. How these economic factors will change over time is unknown; therefore, the variability in these economic measures introduces uncertainty into emissions estimates. This analysis uses the DBEDT (2024d) short-run forecast of Gross State Product (GSP), visitor arrivals, population, and de facto population (a measure of both residents and visitors that accounts for typical visitor length of stay) through 2025 to project these respective macroeconomic statistics from 2022 to 2025. From there, the DBEDT long-term forecast is applied (DBEDT 2024e) to project these statistics from 2025 to 2045.
- **Future Technology:** Breakthroughs in technology, for example in large-scale battery storage or direct carbon air capture, will change the available suite and relative cost-effectiveness of commercially available low carbon technologies.
- **Policy:** Elements of other recently adopted policies such as Act 15, Session Law of Hawaiʻi 2018 (Act 15 of 2018), which focuses on increasing GHG sequestration in Hawaiʻi's agricultural and natural environment, and Act 16, Session Laws of Hawaiʻi 2018 (Act 16 of 2018), which establishes a framework for a carbon offset program, were not directly considered in this analysis.
- **Linear Projections:** Historical data were used as a basis for linear projections within the report. These projections relied on the assumption that future data will follow a trend consistent with the past. Confounding factors such as climate change, natural disasters, land use change limitations, the adoption rate of new technologies, changes in industry trends, and other events may cause future relationships to differ from historic patterns.

7.2 Projections Summary

Relative to 2022, total emissions under the baseline scenario are projected to decrease by two percent 36 percent by 2045. Over the same period, net emissions are projected to decrease by two percent 42 percent. And when excluding aviation, net emissions are projected to decrease by 68 percent.

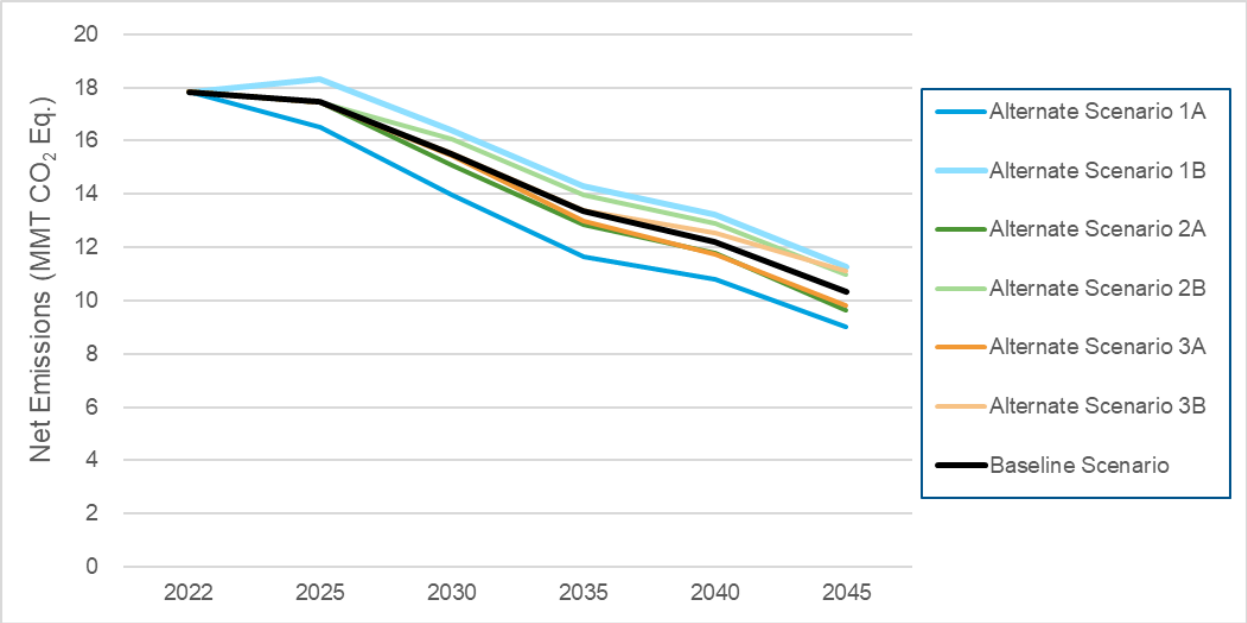
Figure 7-1 illustrates net GHG emissions for each historical and projected inventory year under the baseline scenario. A summary of the emission projections under each scenario is presented in Figure 7-2. Discussion of emission projections by sector is provided in the following sections.

Figure 7-1: Hawai'i Net GHG Emissions by Year (MMT CO_2 Eq.) (Including Sinks and Aviation)



Notes: Emission estimates include sinks and domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Figure 7-2: Projected Hawai'i GHG Net Emissions under each Scenario (MMT CO_2 Eq.) (Including Sinks and Aviation)



Note: Emission estimates include domestic aviation and sinks.

Table 7-1 summarizes emission projections of statewide emissions (excluding sinks, including aviation) for 2025, 2030, 2035, 2040, and 2045 under the baseline and each alternate scenario.

Table 7-1: Hawai'i GHG Emission Projections (Excluding Sinks) by Scenario for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Scenario	Total Emissions (Excluding Sinks)[a,b]				
	2025	2030	2035	2040	2045
Baseline Scenario	**19.89**	**17.91**	**15.79**	**14.74**	**12.95**
Alternate Scenario 1A	18.94	16.36	14.07	13.29	11.60
Alternate Scenario 1B	20.73	18.80	16.74	15.74	13.86
Alternate Scenario 2A	19.89	17.49	15.31	14.29	12.23
Alternate Scenario 2B	19.89	18.46	16.41	15.41	13.60
Alternate Scenario 3A	19.89	17.83	15.44	14.27	12.44
Alternate Scenario 3B	19.89	17.92	15.84	15.05	13.69

[a] Emissions from international bunker fuels are not included in the totals, as per IPCC (2006) guidelines.
[b] Hawai'i 's GHG emission reduction goals require the inclusion of domestic aviation emissions, which are reported under the Energy sector.

Table 7-2 summarizes net emissions (emissions including carbon sinks) under the baseline and alternate scenarios. Net emissions are included due to their relevance tracking progress toward the 2030 GHG target pursuant to Act 238 of 2022.

Table 7-2: Hawai'i GHG Emission Projections (Including Sinks) by Scenario for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Scenario	Net Emissions (Including Sinks)[a,b]				
	2025	2030	2035	2040	2045
Baseline Scenario	**17.45**	**15.51**	**13.34**	**12.23**	**10.35**
Alternate Scenario 1A	16.50	13.95	11.63	10.78	8.99
Alternate Scenario 1B	18.30	16.39	14.30	13.22	11.26
Alternate Scenario 2A	17.45	15.08	12.87	11.77	9.63
Alternate Scenario 2B	17.45	16.05	13.97	12.89	10.99
Alternate Scenario 3A	17.45	15.42	13.00	11.75	9.84
Alternate Scenario 3B	17.45	15.51	13.40	12.53	11.09

[a] Emissions from international bunker fuels are not included in the totals, as per IPCC (2006) guidelines.
[b] Hawai'i 's GHG emission reduction goals require the inclusion of domestic aviation emissions, which are reported under the Energy sector.

Table 7-3 summarizes net emissions (emissions including carbon sinks) that exclude aviation. Net emissions excluding aviation are used to track continued adherence to the 2020 GHG target pursuant to Act 234 of 2007. The act mandates that net emissions, excluding aviation, starting in 2020 emissions do not exceed 1990 levels. Results under the baseline and each alternate scenario are included.

Table 7-3: Hawai'i GHG Emission Projections (Including Sinks, Excluding Aviation) by Scenario for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Scenario	Net Emissions (Including Sinks, Excluding Aviation)[a,b]				
	2025	2030	2035	2040	2045
Baseline Scenario	**11.35**	**9.26**	**7.02**	**5.85**	**3.94**
Alternate Scenario 1A	10.92	8.55	6.27	5.36	3.64
Alternate Scenario 1B	11.68	9.66	7.44	6.29	4.29
Alternate Scenario 2A	11.35	8.84	6.55	5.40	3.22
Alternate Scenario 2B	11.35	9.81	7.64	6.51	4.59
Alternate Scenario 3A	11.35	9.18	6.68	5.37	3.43
Alternate Scenario 3B	11.35	9.27	7.07	6.16	4.69

[a] Emissions from international bunker fuels are not included in the totals, as per IPCC (2006) guidelines.
[b] Hawai'i's GHG emission reduction goal for 2020 established in Act 234 of 2007 excludes domestic aviation emissions, which are reported under the Energy sector.

Under the alternate scenarios, total and net GHG emissions are highest under the low world oil price scenario (scenario 1B), highlighting the influence of transportation subsector emissions. When excluding aviation, net emissions after 2025 are highest under the low renewable energy deployment scenario (scenario 2B).

The alternate scenarios are not additive and therefore cannot be combined to generate a low, baseline, and high scenario. Each scenario isolates the impact of the variable changes described.

7.3 Energy

For the Energy sector, projected emissions under both the baseline scenario and the alternate scenarios are presented.

Baseline Scenario

Under the baseline scenario, emissions from the Energy sector are projected account for 89 percent of total projected statewide emissions in each year. The consistent scale of energy sector emissions exemplifies how changes within this sector drive statewide emissions trends.

Projected emissions under the baseline scenario by source for 2025, 2030, 2035, 2040, and 2045 are summarized in Table 7-4.

Table 7-4: GHG Emission Projections from the Energy Sector under the Baseline Scenario by Source (MMT CO_2 Eq.)[a]

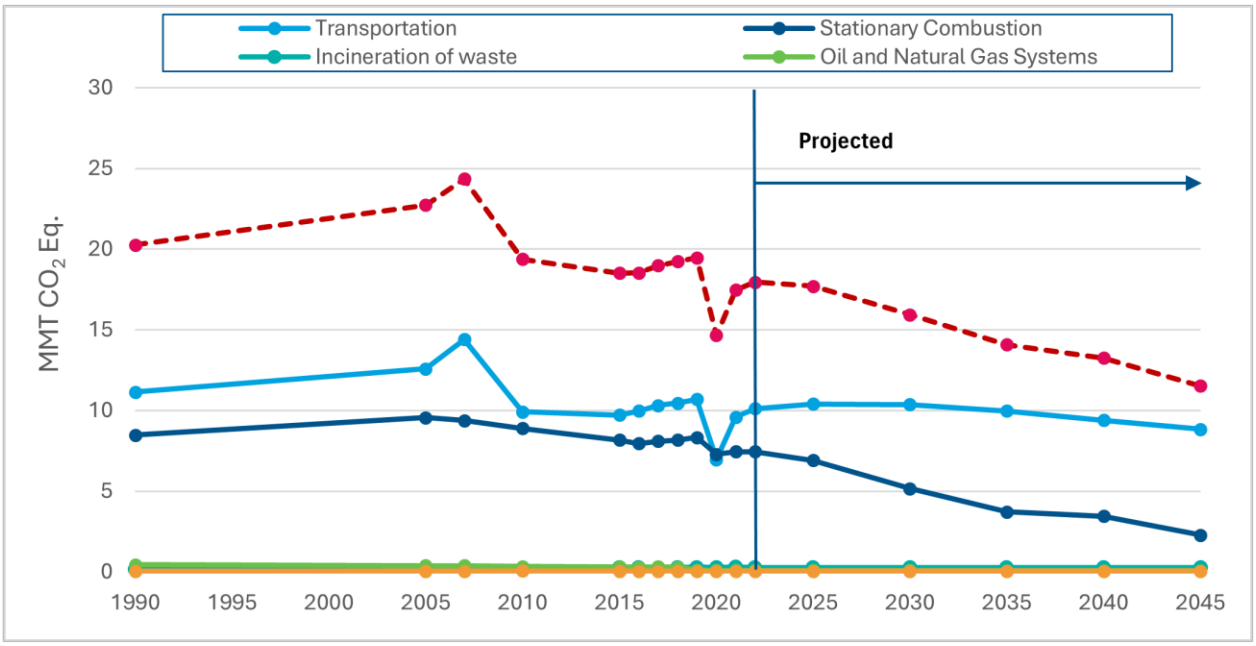
Source[b]	2022	2025	2030	2035	2040	2045
Stationary Combustion	**6.90**	**5.16**	**3.72**	**3.45**	**2.28**	**6.90**
Energy Industries[c]	5.82	4.04	2.56	2.26	1.04	5.82
Residential	0.06	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64	0.56
Industrial	0.46	0.48	0.50	0.52	0.54	0.46

Source[b]	2022	2025	2030	2035	2040	2045
Transportation	**10.40**	**10.37**	**9.96**	**9.40**	**8.84**	**10.40**
Ground	3.39	3.19	2.66	2.00	1.38	3.39
Domestic Marine[d]	0.68	0.71	0.75	0.79	0.82	0.68
Domestic Aviation	5.23	5.37	5.45	5.51	5.53	5.23
Military Aviation[e]	0.87	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[e]	0.23	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**	**0.25**
Oil and Natural Gas Systems	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**	**0.10**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**	**0.04**
Total	**17.69**	**15.92**	**14.08**	**13.25**	**11.52**	**17.69**

[a] Emissions estimates for 2022 are calculated based on reported data and are presented for comparison purposes.
[b] Emissions from international bunker fuels and CO_2 emissions from wood biomass and biofuel consumption are not projected because they are not included in the inventory total, as per IPCC (2006) guidelines.
[c] Includes fuel combustion emissions from electric power plants and petroleum refineries.
[d] The emissions are projected based on Hawai'i's forecasted GSP growth and the EIA's forecast for efficiency improvement in commercial shipping.
[e] Because decisions about military operations are not made at the state level, future emissions from military are highly uncertain; these emissions are assumed to remain constant relative to the average of 2015 through 2022 emission estimates.

Relative to 2022, baseline emissions from the Energy sector are projected to decrease less than one percent by 2025, ten percent by 2030, and 35 percent by 2045. This trend is driven by the projected decrease in emissions from energy industries (within stationary combustion source category), which includes fuel combustion emissions from electric power plants and emissions from petroleum refineries. Emissions from stationary combustion are projected to decline by 68 percent between 2022 and 2045 due to an increase in the share of electricity generated from renewable sources. Transportation emission levels are projected to be 13 percent lower in 2045 due to increases in transportation fuel efficiency. Figure 7-3 shows historical and projected emissions from the Energy sector by source category for each inventory year.

Figure 7-3: GHG Emissions and Projections from the Energy Sector under the Baseline Scenario (MMT CO_2 Eq.)



Notes: Emission estimates include domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Alternate Scenarios

Projected emissions under each scenario by source for 2025, 2030, 2035, 2040, and 2045 are summarized in Table 7-5 and graphically shown in Figure 7-4.

Table 7-5: GHG Emission Projections from the Energy Sector under the Alternate Scenarios by Source (MMT CO_2 Eq.)

Source[a]	2025	2030	2035	2040	2045
Baseline Scenario					
Stationary Combustion	**6.90**	**5.16**	**3.72**	**3.45**	**2.28**
Energy Industries[b]	5.82	4.04	2.56	2.26	1.04
Residential	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64
Industrial	0.46	0.48	0.50	0.52	0.54
Transportation	**10.40**	**10.37**	**9.96**	**9.40**	**8.84**
Ground	3.39	3.19	2.66	2.00	1.38
Domestic Marine[c]	0.68	0.71	0.75	0.79	0.82
Domestic Aviation	5.23	5.37	5.45	5.51	5.53
Military Aviation[d]	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[d]	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**
Oil and Natural Gas Systems	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**

Source[a]	2025	2030	2035	2040	2045
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Total	**17.69**	**15.92**	**14.08**	**13.25**	**11.52**
Alternate Scenario 1A					
Stationary Combustion	**6.78**	**5.02**	**3.58**	**3.33**	**2.20**
Energy Industries[b]	5.70	3.90	2.43	2.14	0.97
Residential	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64
Industrial	0.46	0.48	0.50	0.52	0.54
Transportation	**9.58**	**8.96**	**8.40**	**8.07**	**7.57**
Ground	3.09	2.62	2.06	1.64	1.15
Domestic Marine[c]	0.68	0.71	0.75	0.79	0.82
Domestic Aviation	4.71	4.53	4.49	4.55	4.49
Military Aviation[d]	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[d]	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**
Oil and Natural Gas Systems	**0.09**	**0.08**	**0.08**	**0.07**	**0.07**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Total	**16.74**	**14.36**	**12.37**	**11.80**	**10.17**
Alternate Scenario 1B					
Stationary Combustion	**7.00**	**5.24**	**3.79**	**3.52**	**2.33**
Energy Industries[b]	5.92	4.12	2.64	2.33	1.09
Residential	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64
Industrial	0.46	0.48	0.50	0.52	0.54
Transportation	**11.14**	**11.17**	**10.84**	**10.31**	**9.70**
Ground	3.61	3.50	3.01	2.37	1.67
Domestic Marine[c]	0.68	0.71	0.75	0.79	0.82
Domestic Aviation	5.75	5.86	5.99	6.05	6.10
Military Aviation[d]	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[d]	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**
Oil and Natural Gas Systems	**0.10**	**0.10**	**0.09**	**0.09**	**0.08**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Total	**18.54**	**16.81**	**15.04**	**14.24**	**12.43**
Alternate Scenario 2A					
Stationary Combustion	**6.90**	**4.74**	**3.25**	**3.00**	**1.56**
Energy Industries[b]	5.82	3.62	2.09	1.81	0.32
Residential	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64
Industrial	0.46	0.48	0.50	0.52	0.54
Transportation	**10.40**	**10.37**	**9.96**	**9.40**	**8.84**
Ground	3.39	3.19	2.66	2.00	1.38
Domestic Marine[c]	0.68	0.71	0.75	0.79	0.82

Source[a]	2025	2030	2035	2040	2045
Domestic Aviation	5.23	5.37	5.45	5.51	5.53
Military Aviation[d]	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[d]	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**
Oil and Natural Gas Systems	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Total	**17.69**	**15.50**	**13.61**	**12.80**	**10.80**
Alternate Scenario 2B					
Stationary Combustion	**6.90**	**5.70**	**4.34**	**4.12**	**2.93**
Energy Industries[b]	5.82	4.58	3.19	2.92	1.69
Residential	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64
Industrial	0.46	0.48	0.50	0.52	0.54
Transportation	**10.40**	**10.37**	**9.96**	**9.40**	**8.84**
Ground	3.39	3.19	2.66	2.00	1.38
Domestic Marine[c]	0.68	0.71	0.75	0.79	0.82
Domestic Aviation	5.23	5.37	5.45	5.51	5.53
Military Aviation[d]	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[d]	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**
Oil and Natural Gas Systems	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Total	**17.69**	**16.46**	**14.70**	**13.91**	**12.17**
Alternate Scenario 3A					
Stationary Combustion	**6.91**	**5.25**	**3.84**	**3.57**	**2.32**
Energy Industries[b]	5.83	4.12	2.68	2.37	1.08
Residential	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64
Industrial	0.46	0.48	0.50	0.52	0.54
Transportation	**10.39**	**10.20**	**9.50**	**8.80**	**8.29**
Ground	3.39	3.01	2.20	1.41	0.83
Domestic Marine[c]	0.68	0.71	0.75	0.79	0.82
Domestic Aviation	5.23	5.37	5.45	5.51	5.53
Military Aviation[d]	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[d]	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**
Oil and Natural Gas Systems	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Total	**17.69**	**15.84**	**13.74**	**12.77**	**11.01**
Alternate Scenario 3B					
Stationary Combustion	**6.90**	**5.16**	**3.70**	**3.39**	**2.23**
Energy Industries[b]	5.82	4.03	2.55	2.19	1.00

Source[a]	2025	2030	2035	2040	2045
Residential	0.06	0.06	0.06	0.06	0.06
Commercial	0.56	0.58	0.59	0.61	0.64
Industrial	0.46	0.48	0.50	0.52	0.54
Transportation	**10.40**	**10.38**	**10.04**	**9.77**	**9.63**
Ground	3.39	3.20	2.73	2.37	2.17
Domestic Marine[c]	0.68	0.71	0.75	0.79	0.82
Domestic Aviation	5.23	5.37	5.45	5.51	5.53
Military Aviation[d]	0.87	0.87	0.87	0.87	0.87
Military Non-Aviation[d]	0.23	0.23	0.23	0.23	0.23
Incineration of Waste for Energy Purposes	**0.25**	**0.26**	**0.27**	**0.27**	**0.28**
Oil and Natural Gas Systems	**0.10**	**0.09**	**0.09**	**0.08**	**0.08**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**
Total	**17.69**	**15.93**	**14.13**	**13.56**	**12.27**

[a] Emissions from international bunker fuels and CO_2 emissions from wood biomass and biofuel consumption are not projected because they are not included in the inventory total, as per IPCC (2006) guidelines.
[b] Includes fuel combustion emissions from electric power plants and petroleum refineries.
[c] The emissions are projected based on Hawai‘i’s forecasted GSP growth and the EIA’s forecast for efficiency improvement in commercial shipping.
[d] Because decisions about military operations are not made at the state level, future emissions from military are highly uncertain; these emissions are assumed to remain constant relative to the average of 2015 through 2022 emission estimates.
Notes: Totals may not sum due to independent rounding. Emission totals include aviation emissions.

Figure 7-4: GHG Projections from the Energy Sector under each Scenario by Source (MMT CO_2 Eq.)

Notes: Emission estimates include domestic aviation emissions. Incineration of waste for energy purposes and non-energy uses remain constant between scenarios.

7.4 Industrial Processes and Product use (IPPU)

Under the baseline scenario, emissions from the IPPU sector are projected to peak in 2025 at 0.80 MMT CO_2 Eq., and then drop steadily from there through 2045. These emissions account for four percent of total projected statewide emissions under the baseline scenario in 2025, four percent in 2030, and two percent in 2045. Projected emissions by source for 2025 through 2045 are summarized in Table 7-6. Emissions from the IPPU sector are not expected to vary under the six alternative energy scenarios discussed in Section 7, thus only projections from the baseline scenario are discussed in this section.

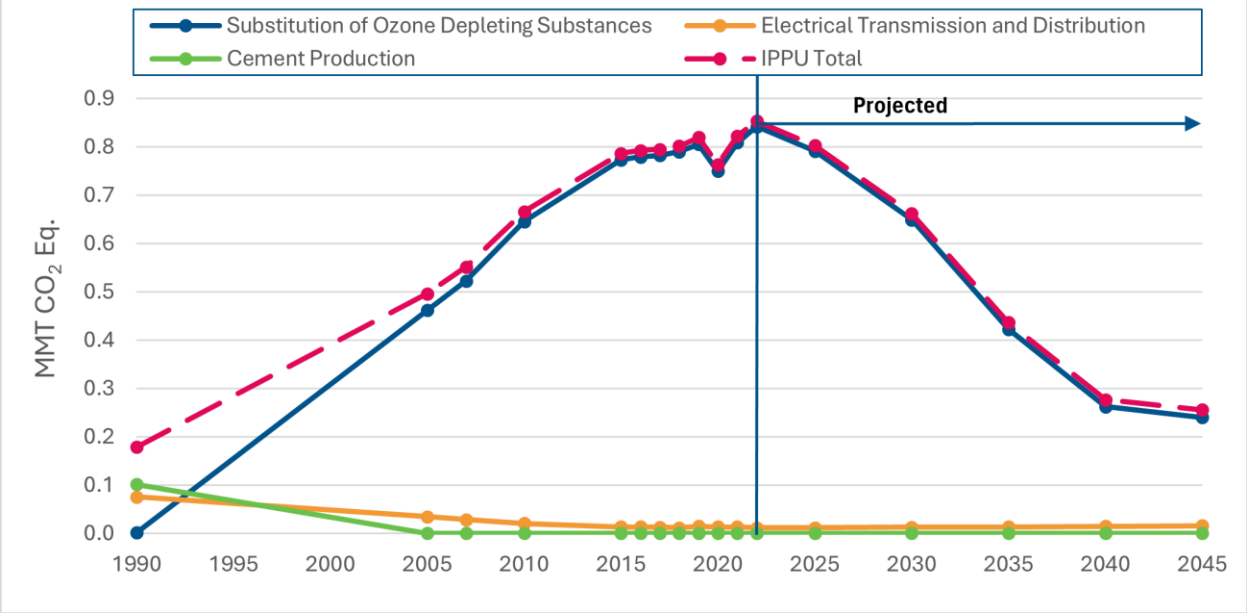
Table 7-6: GHG Emission Projections from the IPPU Sector under the Baseline Scenario by Source (MMT CO_2 Eq.)[a]

Source	2022	2025	2030	2035	2040	2045
Cement Production	NO	NO	NO	NO	NO	NO
Electrical Transmission and Distribution	0.01	0.01	0.01	0.01	0.01	0.02
Substitution of Ozone Depleting Substances	0.84	0.79	0.65	0.42	0.26	0.24
Total	**0.85**	**0.80**	**0.66**	**0.44**	**0.28**	**0.26**

[a] Emissions estimates for 2022 are calculated based on reported data and are presented for comparison purposes.
NO (emissions are Not Occurring).
Note: Totals may not sum due to independent rounding.

Emissions from the substitution of ozone depleting substances are projected to continue to represent the majority of emissions from the IPPU sector through 2045. Emissions from the substitution of ozone depleting substances are projected to decline due to the American Innovation and Manufacturing (AIM) Act, which was included in the 2021 Consolidated Appropriations Act. The AIM Act mandates a reduction in the production and consumption of listed HFCs, manages HFC substitutes, promotes the reclamation of HFCs, and encourages a transition to HFC free technologies through sector specific restrictions. Relative to 2022, electrical transmission and distribution emissions by 2045 are projected to increase slightly though this increase represents emissions lower than 0.01 MMT CO_2 Eq. (or rounding error). Emissions from cement production, which were zero in 2022, are projected to remain at zero through 2045. Figure 7-5 shows historical and projected emissions from the IPPU sector by source category for select years under the baseline scenario.

Figure 7-5: GHG Emissions and Projections from the IPPU Sector under the Baseline Scenario by Source (MMT CO_2 Eq.)



Notes: Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

7.5 Agriculture, Forestry and Other Land Uses (AFOLU)

Total emissions (excluding sinks) under the baseline scenario from the AFOLU sector are projected account for five percent, five percent, and six percent of total Hawai‘i emissions, in the years 2025, 2030, and 2045, respectively. Carbon sinks are projected to fluctuate over the timeseries, but overall, the AFOLU sector is projected to result in a net increase in carbon sinks (i.e., net CO_2 removals). Projected emissions by source and sink category for 2025, 2030, 2035, 2040, and 2045 are summarized in Table 7-7. Emissions from the AFOLU sector are not expected to vary under the six alternate energy scenarios discussed in Chapter 7, thus only projections from the baseline scenario are discussed below.

Table 7-7: GHG Emission Projections from the AFOLU Sector under the Baseline Scenario by Source and Sink Category (MMT CO_2 Eq.)[a]

Category	2022	2025	2030	2035	2040	2045
Agriculture	**0.45**	**0.43**	**0.42**	**0.42**	**0.41**	**0.40**
Enteric Fermentation	0.29	0.27	0.27	0.27	0.27	0.26
Manure Management	0.01	0.01	0.01	0.01	+	+
Agricultural Soil Management	0.15	0.14	0.14	0.14	0.14	0.14
Field Burning of Agricultural Residues	NO	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+	+

Category	2022	2025	2030	2035	2040	2045
Land Use, Land-Use Change, and Forestry	**(1.82)**	**(1.84)**	**(1.85)**	**(1.93)**	**(2.04)**	**(2.16)**
Agricultural Soil Carbon	0.58	0.55	0.51	0.47	0.43	0.40
Forest Fires	0.08	0.05	0.05	0.05	0.05	0.05
Landfilled Yard Trimmings and Food Scraps	(0.05)	(0.05)	(0.04)	(0.01)	(0.01)	(0.02)
Urban Trees	(0.60)	(0.64)	(0.70)	(0.76)	(0.84)	(0.92)
Forest Carbon	(1.83)	(1.75)	(1.67)	(1.67)	(1.67)	(1.67)
Total (Sources)	**1.11**	**1.03**	**0.98**	**0.93**	**0.89**	**0.85**
Total (Sinks)	**(2.48)**	**(2.44)**	**(2.41)**	**(2.44)**	**(2.52)**	**(2.60)**
Net Emissions	**(1.37)**	**(1.41)**	**(1.43)**	**(1.51)**	**(1.63)**	**(1.76)**

[a] Emissions estimates for 2022 are calculated based on reported data and are presented for comparison purposes.
+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Note: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Projections through 2045 suggest that emissions from AFOLU sources will ultimately decline while the amount of carbon sequestered from AFOLU sinks will continue to increase. Figure 7-6 shows historical and projected emissions from the AFOLU sector by source and sink category for select years.

The growth in carbon sequestered from AFOLU sinks is primarily driven by urban tress which are expected to sequester more carbon over time due to a growth in land area due to an assumed linear growth in urban tree cover. This trend is reflects historic trends and currently policies such as the passage of a Honolulu bill that aims to have 35 percent urban tree cover by 2035 (City & County of Honolulu 2019). Please see the urban trees methodology in Section 5.9 for more detail.

Emissions from enteric fermentation, manure management, and agricultural soil management are projected to slightly decrease based on the assumption that historical trends will continue.

Emissions from field burning of agricultural residues are projected to be zero due to the closing of the last sugar mill in Hawai‘i in 2018, while emissions from urea application are projected to remain flat.

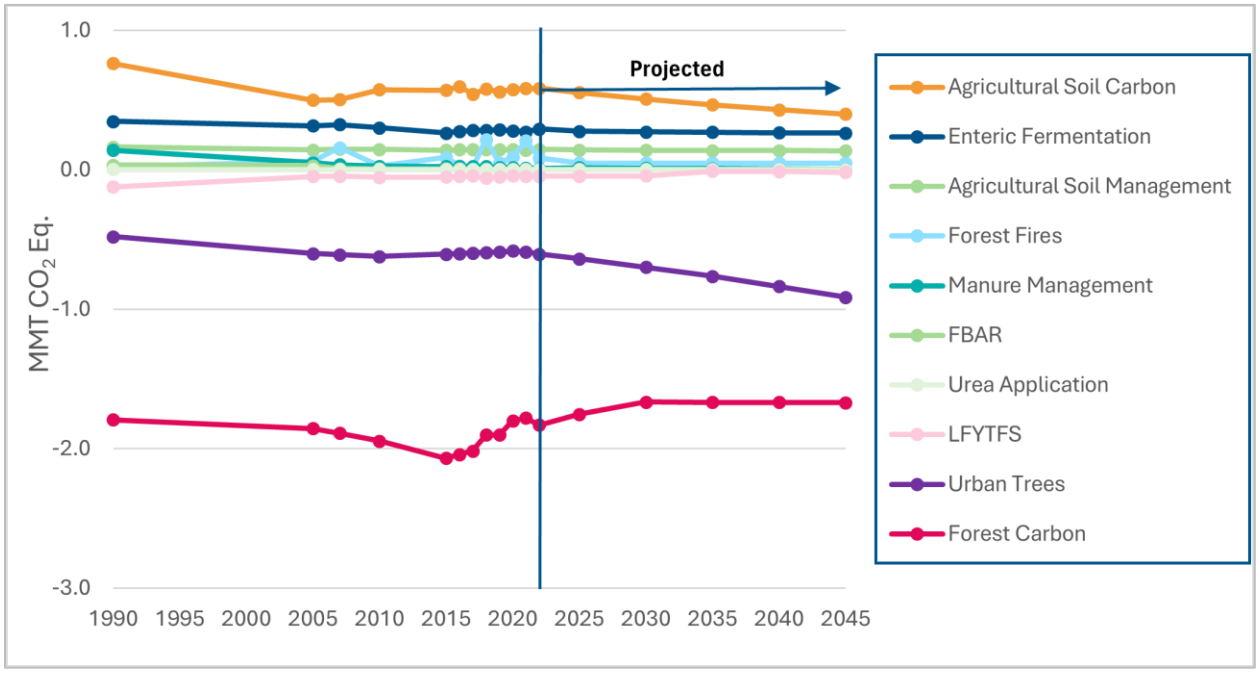
Forest carbon and agricultural soil carbon are projected to sequester less carbon (i.e., become a smaller sink) from 2022 to 2045 based on projected changes in land cover and net carbon sequestration rates (Selmants et al. 2017).

Landfilled yard trimmings and food scraps are projected to sequester less carbon from 2022 to 2035 and then increase from 2035 to 2045, driven primarily by an increase in tons of landfilled food scraps.

Statewide emissions from forest fires are projected to remain flat from 2025 onwards following an assumption from a USGS study on projected future carbon storage in Hawai‘i which assumes that wildfires would burn, on average, 41 km^2 per year (Selmants et al. 2017). However, the expected increase in catastrophic events due to climate change introduces significant uncertainty as the total area burned can vary greatly from year to year. The projected annual area burned is significantly lower than

reported data from recent high event years (2018-2022), a trend expected to continue in reported 2023 data due to large-scale wildfires occurring in the year.

Figure 7-6: GHG Emissions and Projections from the AFOLU Sector under the Baseline Scenario by Source and Sink Category (MMT CO_2 Eq.)



Notes: FBAR = Field Burning of Agricultural Residues, LFYTFS = Landfilled Yard Trimmings and Food Scraps. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

7.6 Waste

Emissions from the Waste sector are projected to decrease, accounting for two percent of total projected statewide emissions under the baseline scenario in each year. Projected emissions by source for 2025, 2030, 2035, 2040, and 2045 are summarized in Table 7-8. Emissions from the Waste sector is not expected to vary under the six alternate energy scenarios discussed in Section 7, thus only projections from the baseline scenario are discussed below.

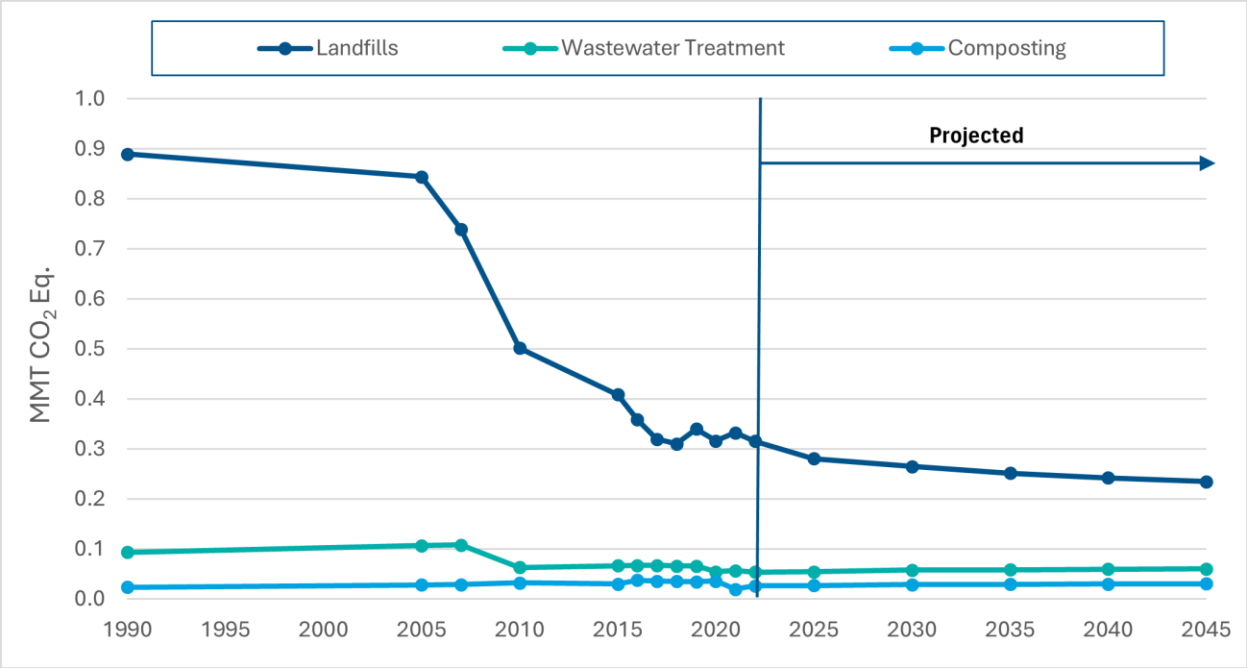
Table 7-8: GHG Emission Projections from the Waste Sector under the Baseline Scenario by Source (MMT CO_2 Eq.)[a]

Source	2022	2025	2030	2035	2040	2045
Landfills	0.32	0.28	0.26	0.25	0.24	0.23
Composting	0.03	0.03	0.03	0.03	0.03	0.03
Wastewater Treatment	0.05	0.05	0.06	0.06	0.06	0.06
Total	**0.40**	**0.36**	**0.35**	**0.34**	**0.33**	**0.32**

[a] Emissions estimates for 2022 are calculated based on reported data and are presented for comparison purposes.
Note: Totals may not sum due to independent rounding.

Relative to 2022, emissions from landfills are expected to decrease steadily, starting at 0.32 MMT CO_2 Eq. in 2022 and declining to 0.23 MMT CO_2 Eq. by 2045. In contrast, emissions from composting are and wastewater treatment are projected to increase slightly between 2025 and 2045 due to population growth over the projected period. Overall, the downward trend in landfill emissions will drive a decrease in Waste emissions. Figure 7-7 shows historical and projected emissions from the waste sector by source category for select years.

Figure 7-7: GHG Emissions and Projections from the Waste Sector under the Baseline Scenario by Source (MMT CO_2 Eq.)

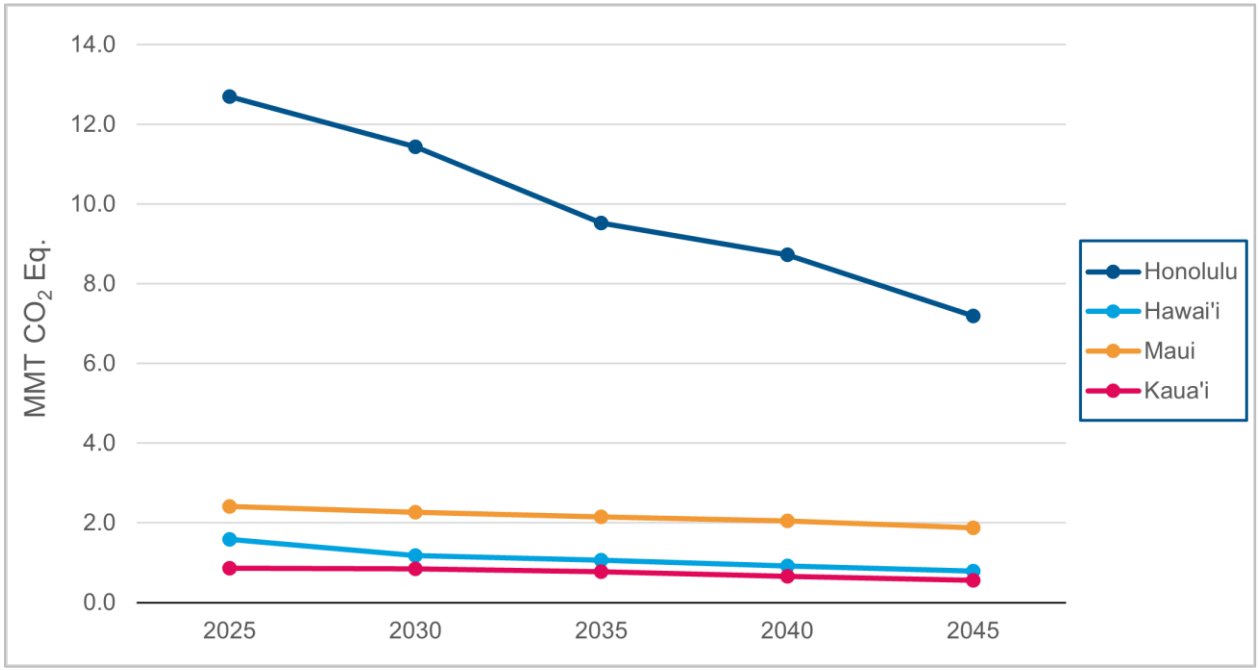


Notes: Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

7.7 Emission Projections by County

This section summarizes emission projections by county under the baseline scenario. Consistent with the historical trend, Honolulu County is projected to account for the largest share of net GHG emissions in 2025, 2030, 2035, 2040, and 2045 followed by Maui County, Hawai‘i County, and Kaua‘i County. Figure 7-8 shows net emission projections by county and year.

Figure 7-8: Projected Net GHG Emissions under the Baseline Scenario by County (MMT CO_2 Eq.) (2025, 2030, 2035, 2040, and 2045)



Emissions from the Energy sector are projected to account for the largest portion of emissions from each county across the projected timeseries. Emissions from AFOLU sources are projected to account for the second largest portion of emissions from all counties except Honolulu County, in which emissions from the IPPU and Waste sectors are projected to account for a larger share of emissions.

The methodology used to develop these projections varies by source. Methodology was determined by the availability and completeness of county-level data. To estimate data for sources where only state-level was available, emissions were allocated to each county by attributing proportional values of relevant economic data, such as county population projections, or by assuming proportional emissions consistent with the 2022 county-level estimates. Appendix J details the methodology used to quantify Hawai‘i’s projected GHG emissions by county. Emission projections by sector and year for each county are summarized in Table 7-9.

Table 7-9: GHG Emission Projections under the Baseline Scenario by Sector and County for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Sector	2022	2025	2030	2035	2040	2045
Honolulu County						
Energy	12.45	12.37	11.21	9.53	8.92	7.49
IPPU	0.56	0.52	0.43	0.28	0.18	0.16
AFOLU (Sources)	0.08	0.10	0.09	0.09	0.09	0.08
AFOLU (Sinks)	(0.50)	(0.51)	(0.54)	(0.56)	(0.60)	(0.65)
Waste	0.13	0.12	0.11	0.10	0.10	0.09
Total Emissions	**13.22**	**13.11**	**11.84**	**10.00**	**9.28**	**7.83**
Net Emissions	**12.72**	**12.60**	**11.30**	**9.45**	**8.68**	**7.18**
Hawai'i County						
Energy	1.94	1.97	1.59	1.54	1.47	1.38
IPPU	0.13	0.12	0.10	0.07	0.04	0.04
AFOLU (Sources)	0.66	0.61	0.58	0.56	0.54	0.52
AFOLU (Sinks)	(1.31)	(1.27)	(1.22)	(1.23)	(1.25)	(1.27)
Waste	0.12	0.13	0.13	0.12	0.12	0.12
Total Emissions	**2.85**	**2.83**	**2.40**	**2.29**	**2.17**	**2.05**
Net Emissions	**1.54**	**1.56**	**1.18**	**1.05**	**0.92**	**0.78**
Maui County						
Energy	2.61	2.38	2.16	2.10	2.04	1.90
IPPU	0.12	0.11	0.09	0.06	0.04	0.04
AFOLU (Sources)	0.24	0.19	0.18	0.17	0.15	0.14
AFOLU (Sinks)	(0.37)	(0.36)	(0.35)	(0.35)	(0.36)	(0.37)
Waste	0.12	0.10	0.10	0.10	0.10	0.10
Total Emissions	**3.09**	**2.78**	**2.54**	**2.43**	**2.34**	**2.18**
Net Emissions	**2.72**	**2.43**	**2.19**	**2.08**	**1.98**	**1.82**
Kaua'i County						
Energy	0.96	0.97	0.96	0.90	0.82	0.75
IPPU	0.05	0.05	0.04	0.03	0.02	0.02
AFOLU (Sources)	0.14	0.13	0.12	0.12	0.11	0.11
AFOLU (Sinks)	(0.31)	(0.30)	(0.30)	(0.30)	(0.31)	(0.32)
Waste	0.02	0.02	0.02	0.01	0.01	0.01
Total Emissions	**1.17**	**1.16**	**1.14**	**1.06**	**0.96**	**0.88**
Net Emissions	**0.86**	**0.86**	**0.84**	**0.76**	**0.65**	**0.57**

Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Figure 7-9, Figure 7-10, Figure 7-11, and Figure 7-12 show 2025, 2030, 2035, 2040, and 2045 emission projections by sector for each county. Detailed county level estimates can be found in Table 7-10, Table 7-11, Table 7-12, and Table 7-13.

Figure 7-9: Honolulu County GHG Emission Projections under the Baseline Scenario by Sector (MMT CO_2 Eq.) (2025, 2030, 2035, 2040, and 2045)

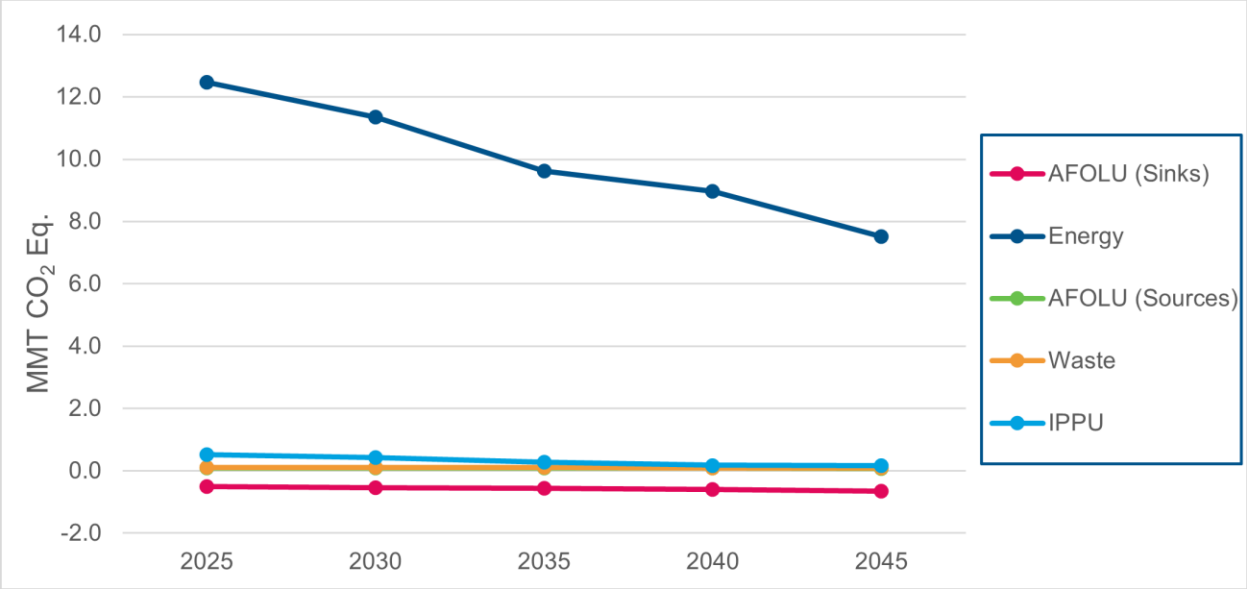


Table 7-10: Honolulu County GHG Emission Projections under the Baseline for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Sector / Sub-Category	2025	2030	2035	2040	2045
Energy [a]	**12.37**	**11.21**	**9.53**	**8.92**	**7.49**
Stationary Combustion	5.36	4.29	2.90	2.63	1.54
Energy Industries [b]	*4.59*	*3.51*	*2.09*	*1.80*	*0.68*
Residential	*0.04*	*0.04*	*0.04*	*0.04*	*0.04*
Commercial	*0.36*	*0.37*	*0.38*	*0.39*	*0.41*
Industrial	*0.36*	*0.37*	*0.39*	*0.40*	*0.42*
Transportation	6.63	6.53	6.25	5.89	5.56
Ground	*2.11*	*1.92*	*1.57*	*1.15*	*0.77*
Domestic Marine [c]	*0.68*	*0.71*	*0.75*	*0.79*	*0.82*
Domestic Aviation	*2.74*	*2.80*	*2.83*	*2.85*	*2.87*
Military Aviation [d]	*0.87*	*0.87*	*0.87*	*0.87*	*0.87*
Military Non-Aviation [d]	*0.23*	*0.23*	*0.23*	*0.23*	*0.23*
Incineration of Waste for Energy Purposes	0.25	0.26	0.27	0.27	0.28
Oil and Natural Gas Systems	0.10	0.09	0.09	0.08	0.08
Non-Energy Uses	0.03	0.03	0.03	0.04	0.04
Industrial Processes and Product Use	**0.52**	**0.43**	**0.28**	**0.18**	**0.16**

Sector / Sub-Category	2025	2030	2035	2040	2045
Cement Production	NO	NO	NO	NO	NO
Electrical Transmission and Distribution	0.01	0.01	0.01	0.01	0.01
Substitution of Ozone Depleting Substances	0.51	0.42	0.27	0.17	0.15
AFOLU (Sources)	**0.10**	**0.09**	**0.09**	**0.09**	**0.08**
Enteric Fermentation	0.03	0.03	0.03	0.03	0.03
Manure Management	+	+	+	+	+
Agricultural Soil Management	0.02	0.02	0.02	0.02	0.02
Field Burning of Agricultural Residues	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+
Agricultural Soil Carbon	0.04	0.03	0.03	0.03	0.02
Forest Fires	+	+	+	+	+
AFOLU (Sinks)	**(0.51)**	**(0.54)**	**(0.56)**	**(0.60)**	**(0.65)**
Landfilled Yard Trimmings and Food Scraps	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)
Urban Trees	(0.36)	(0.40)	(0.44)	(0.48)	(0.53)
Forest Carbon	(0.12)	(0.11)	(0.11)	(0.11)	(0.11)
Waste	**0.12**	**0.11**	**0.10**	**0.10**	**0.09**
Landfills	0.06	0.05	0.05	0.04	0.04
Composting	0.01	0.02	0.02	0.02	0.02
Wastewater Treatment	0.04	0.04	0.04	0.04	0.04
Honolulu County Total Emissions (Excluding Sinks)	**13.11**	**11.84**	**10.00**	**9.28**	**7.83**
Honolulu County Net Emissions (Including Sinks)	**12.60**	**11.30**	**9.45**	**8.68**	**7.18**

[a] Emissions from international bunker fuels and CO_2 emissions from wood biomass and biofuel consumption are not projected because they are not included in the inventory total, as per IPCC (2006) guidelines.
[b] Includes fuel combustion emissions from electric power plants and petroleum refineries.
[c] The emissions are projected based on Hawai'i's forecasted GSP growth and the EIA's forecast for efficiency improvement in commercial shipping.
[d] Because decisions about military operations are not made at the state level, future emissions from military are highly uncertain; these emissions are assumed to remain constant relative to the average of 2015 through 2022 emission estimates.
+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Figure 7-10: Hawai'i County GHG Emission Projections under the Baseline Scenario by Sector (MMT CO_2 Eq.) (2025, 2030, 2035, 2040, and 2045)

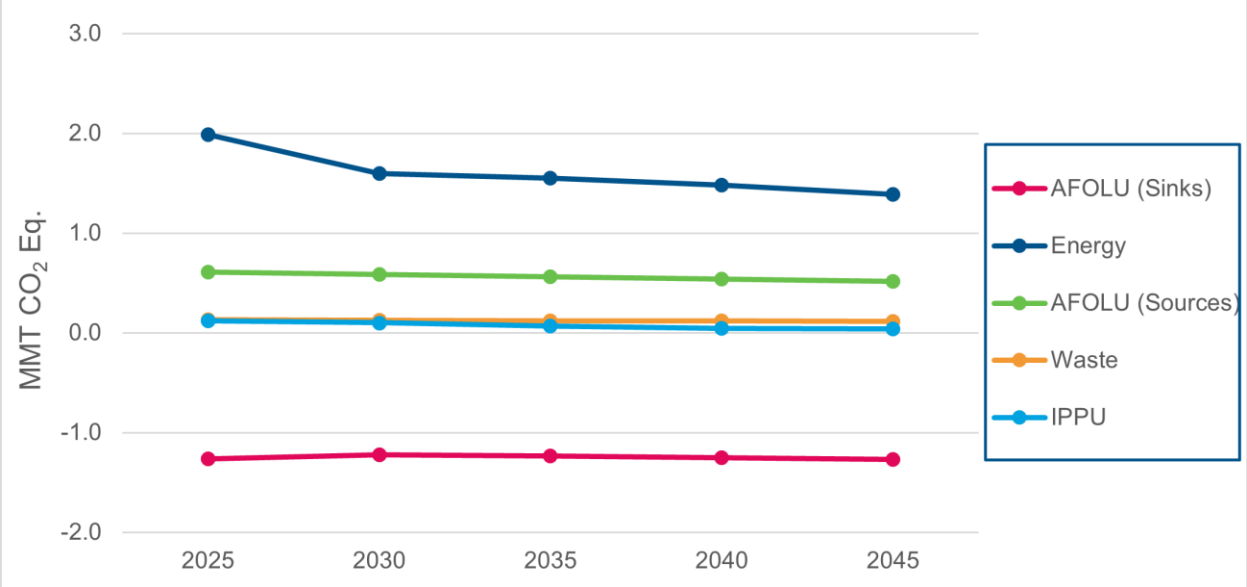


Table 7-11: Hawai'i County GHG Emission Projections under the Baseline for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Sector / Sub-Category	2025	2030	2035	2040	2045
Energy [a]	**1.97**	**1.59**	**1.54**	**1.47**	**1.38**
Stationary Combustion	0.68	0.29	0.30	0.31	0.31
Energy Industries [b]	*0.55*	*0.15*	*0.16*	*0.17*	*0.15*
Residential	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Commercial	*0.08*	*0.09*	*0.09*	*0.09*	*0.10*
Industrial	*0.04*	*0.04*	*0.05*	*0.05*	*0.05*
Transportation	1.28	1.29	1.23	1.15	1.07
Ground	*0.57*	*0.56*	*0.48*	*0.40*	*0.32*
Domestic Marine [c]	*NO*	*NO*	*NO*	*NO*	*NO*
Domestic Aviation	*0.71*	*0.74*	*0.75*	*0.75*	*0.75*
Military Aviation [d]	*NO*	*NO*	*NO*	*NO*	*NO*
Military Non-Aviation [d]	*NO*	*NO*	*NO*	*NO*	*NO*
Incineration of Waste for Energy Purposes	NO	NO	NO	NO	NO
Oil and Natural Gas Systems	NO	NO	NO	NO	NO
Non-Energy Uses	+	+	+	+	+
Industrial Processes and Product Use	**0.12**	**0.10**	**0.07**	**0.04**	**0.04**
Cement Production	NO	NO	NO	NO	NO
Electrical Transmission and Distribution	+	+	+	+	+
Substitution of Ozone Depleting Substances	0.12	0.10	0.06	0.04	0.04
AFOLU (Sources)	**0.61**	**0.58**	**0.56**	**0.54**	**0.52**
Enteric Fermentation	0.19	0.19	0.19	0.18	0.18
Manure Management	0.01	+	+	+	(+)
Agricultural Soil Management	0.08	0.08	0.08	0.08	0.08

Sector / Sub-Category	2025	2030	2035	2040	2045
Field Burning of Agricultural Residues	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+
Agricultural Soil Carbon	0.29	0.27	0.26	0.24	0.22
Forest Fires	0.03	0.03	0.03	0.03	0.03
AFOLU (Sinks)	**(1.27)**	**(1.22)**	**(1.23)**	**(1.25)**	**(1.27)**
Landfilled Yard Trimmings and Food Scraps	(0.01)	(0.01)	(+)	(+)	(+)
Urban Trees	(0.14)	(0.15)	(0.17)	(0.18)	(0.20)
Forest Carbon	(1.12)	(1.06)	(1.06)	(1.07)	(1.07)
Waste	**0.13**	**0.13**	**0.12**	**0.12**	**0.12**
Landfills	0.12	0.11	0.11	0.10	0.10
Composting	0.01	0.01	0.01	0.01	0.01
Wastewater Treatment	0.01	0.01	0.01	0.01	0.01
Hawai'i County Total Emissions (Excluding Sinks)	**2.83**	**2.40**	**2.29**	**2.17**	**2.05**
Hawai'i County Net Emissions (Including Sinks)	**1.56**	**1.18**	**1.05**	**0.92**	**0.78**

[a] Emissions from international bunker fuels and CO_2 emissions from wood biomass and biofuel consumption are not projected because they are not included in the inventory total, as per IPCC (2006) guidelines.
[b] Includes fuel combustion emissions from electric power plants and petroleum refineries.
[c] The emissions are projected based on Hawai'i's forecasted GSP growth and the EIA's forecast for efficiency improvement in commercial shipping.
[d] Because decisions about military operations are not made at the state level, future emissions from military are highly uncertain; these emissions are assumed to remain constant relative to the average of 2015 through 2022 emission estimates.
+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Figure 7-11: Maui County GHG Emission Projections under the Baseline Scenario by Sector (MMT CO_2 Eq.) (2025, 2030, 2035, 2040, and 2045)

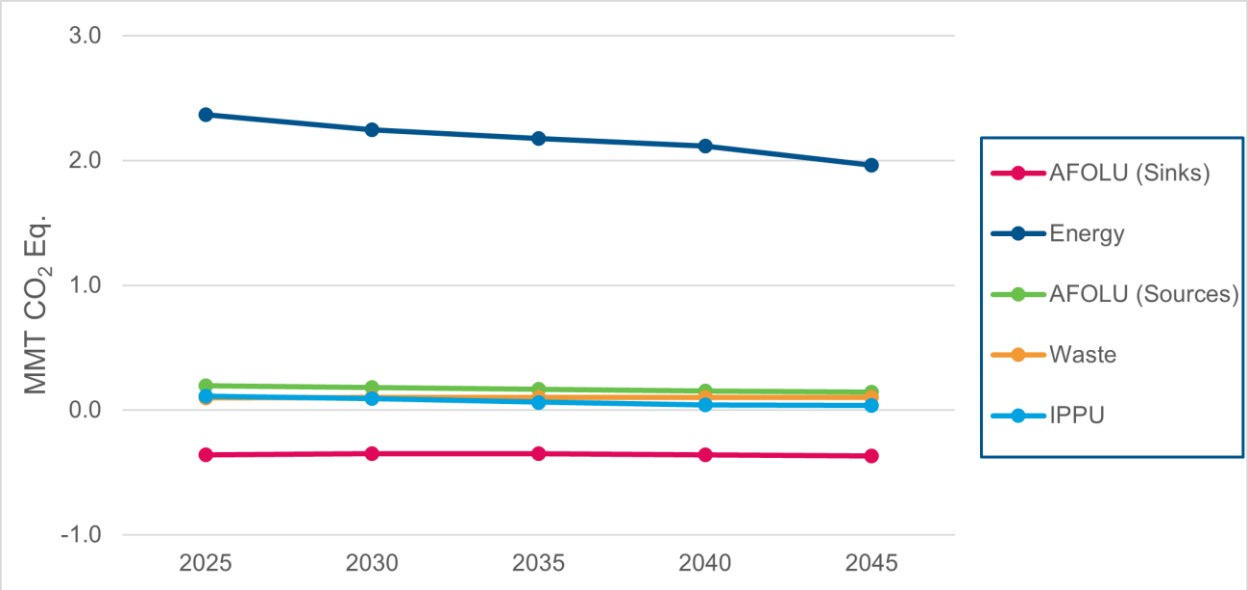


Table 7-12: Maui County GHG Emission Projections under the Baseline for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Sector / Sub-Category	2025	2030	2035	2040	2045
Energy [a]	**2.38**	**2.16**	**2.10**	**2.04**	**1.90**
Stationary Combustion	0.68	0.43	0.41	0.43	0.38
Energy Industries [b]	*0.55*	*0.29*	*0.26*	*0.27*	*0.21*
Residential	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Commercial	*0.08*	*0.08*	*0.09*	*0.09*	*0.09*
Industrial	*0.05*	*0.05*	*0.06*	*0.06*	*0.06*
Transportation	1.70	1.73	1.69	1.61	1.52
Ground	*0.48*	*0.47*	*0.40*	*0.29*	*0.19*
Domestic Marine [c]	*NO*	*NO*	*NO*	*NO*	*NO*
Domestic Aviation	*1.22*	*1.26*	*1.30*	*1.32*	*1.33*
Military Aviation [d]	*NO*	*NO*	*NO*	*NO*	*NO*
Military Non-Aviation [d]	*NO*	*NO*	*NO*	*NO*	*NO*
Incineration of Waste for Energy Purposes	NO	NO	NO	NO	NO
Oil and Natural Gas Systems	NO	NO	NO	NO	NO
Non-Energy Uses	+	+	+	0.01	0.01
Industrial Processes and Product Use	**0.11**	**0.09**	**0.06**	**0.04**	**0.04**
Cement Production	NO	NO	NO	NO	NO
Electrical Transmission and Distribution	+	+	+	+	+
Substitution of Ozone Depleting Substances	0.11	0.09	0.06	0.04	0.04
AFOLU (Sources)	**0.19**	**0.18**	**0.17**	**0.15**	**0.14**
Enteric Fermentation	0.01	0.01	0.01	0.01	0.01
Manure Management	+	+	+	+	+
Agricultural Soil Management	0.02	0.02	0.02	0.02	0.02
Field Burning of Agricultural Residues	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+
Agricultural Soil Carbon	0.15	0.14	0.13	0.12	0.11
Forest Fires	0.01	0.01	0.01	0.01	0.01
AFOLU (Sinks)	**(0.36)**	**(0.35)**	**(0.35)**	**(0.36)**	**(0.37)**
Landfilled Yard Trimmings and Food Scraps	(0.01)	(0.01)	(+)	(+)	(+)
Urban Trees	(0.07)	(0.07)	(0.08)	(0.08)	(0.09)
Forest Carbon	(0.29)	(0.27)	(0.27)	(0.27)	(0.27)
Waste	**0.10**	**0.10**	**0.10**	**0.10**	**0.10**
Landfills	0.09	0.09	0.09	0.09	0.09
Composting	+	+	+	+	+
Wastewater Treatment	0.01	0.01	0.01	0.01	0.01
Maui County Total Emissions (Excluding Sinks)	**2.78**	**2.54**	**2.43**	**2.34**	**2.18**
Maui County Net Emissions (Including Sinks)	**2.43**	**2.19**	**2.08**	**1.98**	**1.82**

[a] Emissions from international bunker fuels and CO_2 emissions from wood biomass and biofuel consumption are not projected because they are not included in the inventory total, as per IPCC (2006) guidelines.
[b] Includes fuel combustion emissions from electric power plants and petroleum refineries.
[c] The emissions are projected based on Hawai'i's forecasted GSP growth and the EIA's forecast for efficiency improvement in commercial shipping.

[d] Because decisions about military operations are not made at the state level, future emissions from military are highly uncertain; these emissions are assumed to remain constant relative to the average of 2015 through 2022 emission estimates.
+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Figure 7-12: Kaua'i County GHG Emission Projections under the Baseline Scenario by Sector (MMT CO_2 Eq.) (2025, 2030, 2035, 2040, and 2045)

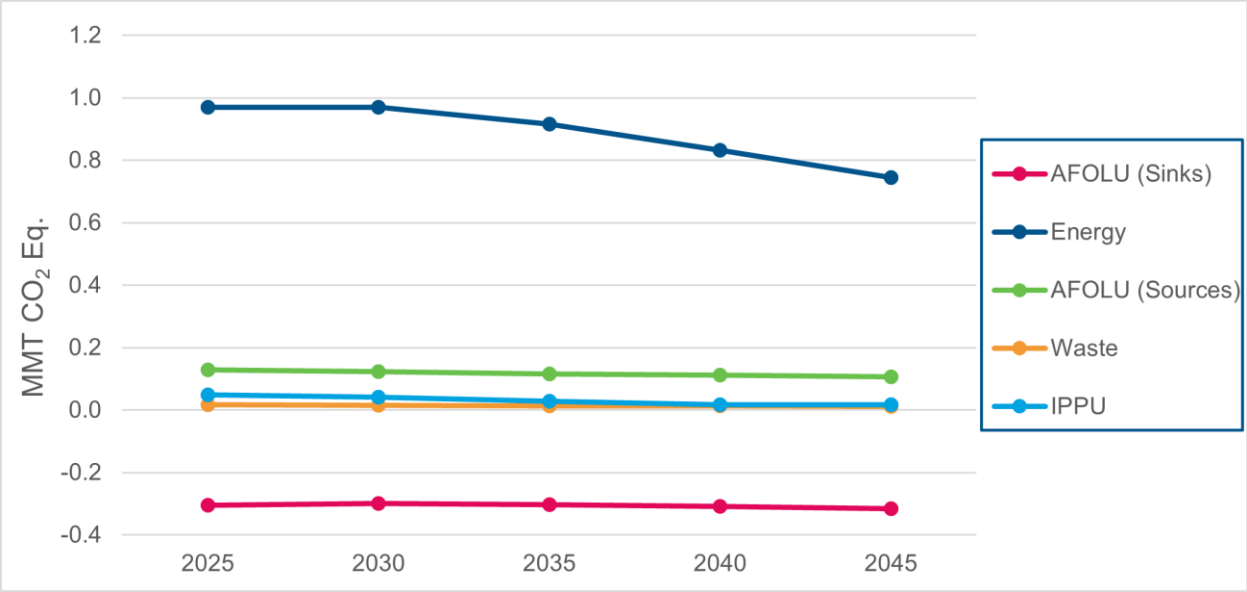


Table 7-13: Kaua'i County GHG Emission Projections under the Baseline for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Sector / Sub-Category	2025	2030	2035	2040	2045
Energy [a]	**0.97**	**0.96**	**0.90**	**0.82**	**0.75**
Stationary Combustion	0.18	0.14	0.11	0.08	0.06
Energy Industries [b]	*0.13*	*0.09*	*0.06*	*0.02*	*0.00*
Residential	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
Commercial	*0.03*	*0.04*	*0.04*	*0.04*	*0.04*
Industrial	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
Transportation	0.79	0.81	0.79	0.74	0.69
Ground	*0.23*	*0.24*	*0.21*	*0.16*	*0.10*
Domestic Marine [c]	*NO*	*NO*	*NO*	*NO*	*NO*
Domestic Aviation	*0.56*	*0.57*	*0.58*	*0.58*	*0.59*
Military Aviation [d]	*NO*	*NO*	*NO*	*NO*	*NO*
Military Non-Aviation [d]	*NO*	*NO*	*NO*	*NO*	*NO*
Incineration of Waste for Energy Purposes	NO	NO	NO	NO	NO
Oil and Natural Gas Systems	NO	NO	NO	NO	NO
Non-Energy Uses	+	+	+	+	+
Industrial Processes and Product Use	**0.05**	**0.04**	**0.03**	**0.02**	**0.02**
Cement Production	NO	NO	NO	NO	NO

Sector / Sub-Category	2025	2030	2035	2040	2045
Electrical Transmission and Distribution	+	+	+	+	+
Substitution of Ozone Depleting Substances	0.05	0.04	0.03	0.02	0.02
AFOLU (Sources)	**0.13**	**0.12**	**0.12**	**0.11**	**0.11**
Enteric Fermentation	0.04	0.04	0.04	0.04	0.04
Manure Management	+	+	+	+	+
Agricultural Soil Management	0.02	0.02	0.02	0.02	0.02
Field Burning of Agricultural Residues	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+
Agricultural Soil Carbon	0.07	0.06	0.06	0.05	0.05
Forest Fires	0.01	0.01	0.01	0.01	0.01
AFOLU (Sinks)	**(0.30)**	**(0.30)**	**(0.30)**	**(0.31)**	**(0.32)**
Landfilled Yard Trimmings and Food Scraps	(+)	(+)	(+)	(+)	(+)
Urban Trees	(0.07)	(0.08)	(0.08)	(0.09)	(0.10)
Forest Carbon	(0.23)	(0.22)	(0.22)	(0.22)	(0.22)
Waste	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**
Landfills	0.01	0.01	0.01	+	+
Composting	+	+	+	0.01	0.01
Wastewater Treatment	+	+	+	+	+
Kaua'i County Total Emissions (Excluding Sinks)	**1.16**	**1.14**	**1.06**	**0.96**	**0.88**
Kaua'i County Net Emissions (Including Sinks)	**0.86**	**0.84**	**0.76**	**0.65**	**0.57**

[a] Emissions from international bunker fuels and CO_2 emissions from wood biomass and biofuel consumption are not projected because they are not included in the inventory total, as per IPCC (2006) guidelines.
[b] Includes fuel combustion emissions from electric power plants and petroleum refineries.
[c] The emissions are projected based on Hawai'i's forecasted GSP growth and the EIA's forecast for efficiency improvement in commercial shipping.
[d] Because decisions about military operations are not made at the state level, future emissions from military are highly uncertain; these emissions are assumed to remain constant relative to the average of 2015 through 2022 emission estimates.
+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

8. GHG Reduction Goal Progress

The Hawai‘i State Legislature has set three separate GHG targets for the state:

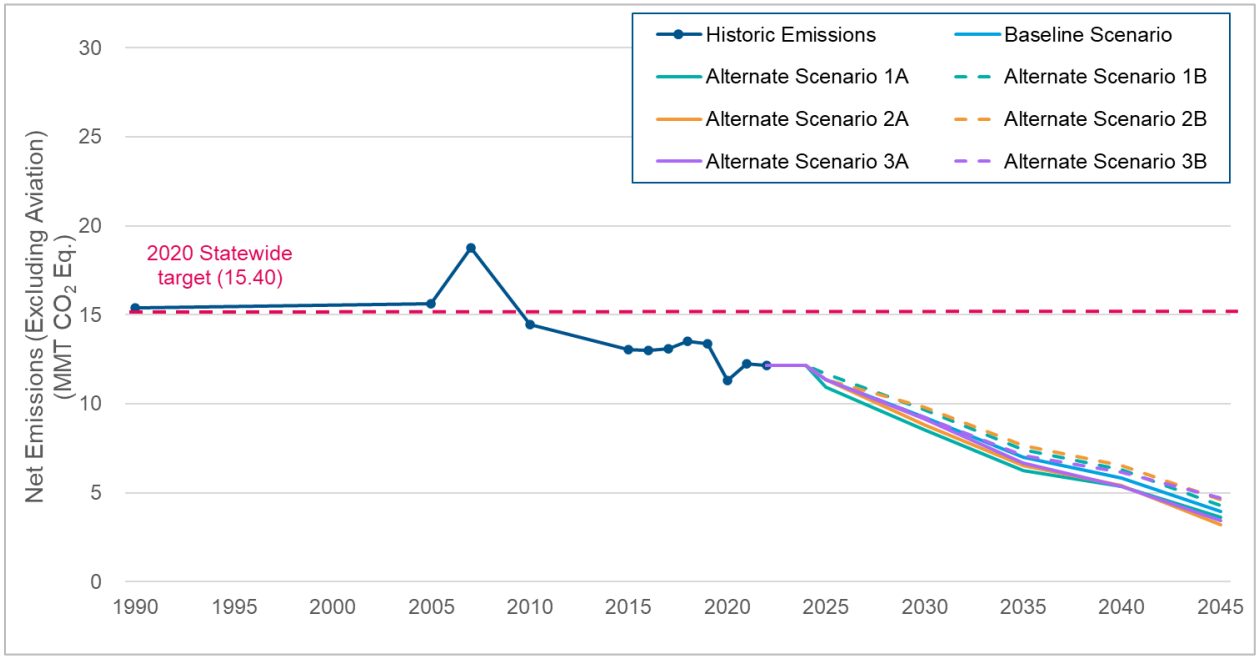
- **2020 target.** Act 234, Session Laws of Hawai‘i 2007 (Act 234 of 2007) established a statewide GHG emissions limit at or below the statewide GHG emissions levels in 1990 to be achieved by January 1, 2020 (statewide GHG emissions must be at or below this level for all years 2020 and beyond). While domestic aviation emissions are included in the inventory totals for the state of Hawai‘i, **Act 234 of 2007 specifies that emissions from airplanes (i.e., domestic aviation and military aviation) shall not be included in this target.**[64]
- **2030 target.** Act 238, Session Laws of Hawai‘i 2022 (Act 238 of 2022) established a goal for statewide GHG emissions to be at least 50 percent below 2005 levels by the year 2030, and that the **measurement of GHG emissions for the year 2005 include emissions from airplanes**.
- **2045 target.** Act 15, Session Law of Hawai‘i 2018 (Act 15 of 2018), established a statewide carbon net-negative goal. Specifically, Act 15 of 2018 calls for **more atmospheric carbon and GHGs to be sequestered than emitted within the State as quickly as practicable, but no later than 2045.**

Figure 8-1 shows net emissions (excluding aviation) in Hawai‘i for inventory years through 2022 as well as emission projections for 2025, 2030, 2035, 2040, and 2045. Figure 8-1 also shows the 2020 statewide target, which is equal to 1990 emission levels, pursuant to Act 234 of 2007: excluding aviation, 1990 statewide GHG emissions were estimated to be 15.40 MMT CO_2 Eq., which represents the 2020 emission target set by Act 234 of 2007 (statewide GHG emissions must be at or below this level for all years 2020 and beyond).

Net emissions (excluding aviation) for 2020 were 11.33 MMT CO_2 Eq. in 2020. As such, **this report finds that Hawai‘i continues to meet the 2020 statewide emissions target** set by Act 234 of 2007 (Figure 8-1).

[64] Emissions from international aviation, which are reported under the International Bunker Fuels source category, are also not included in Hawai‘i’s GHG target in accordance with IPCC (2006) guidelines for inventory development.

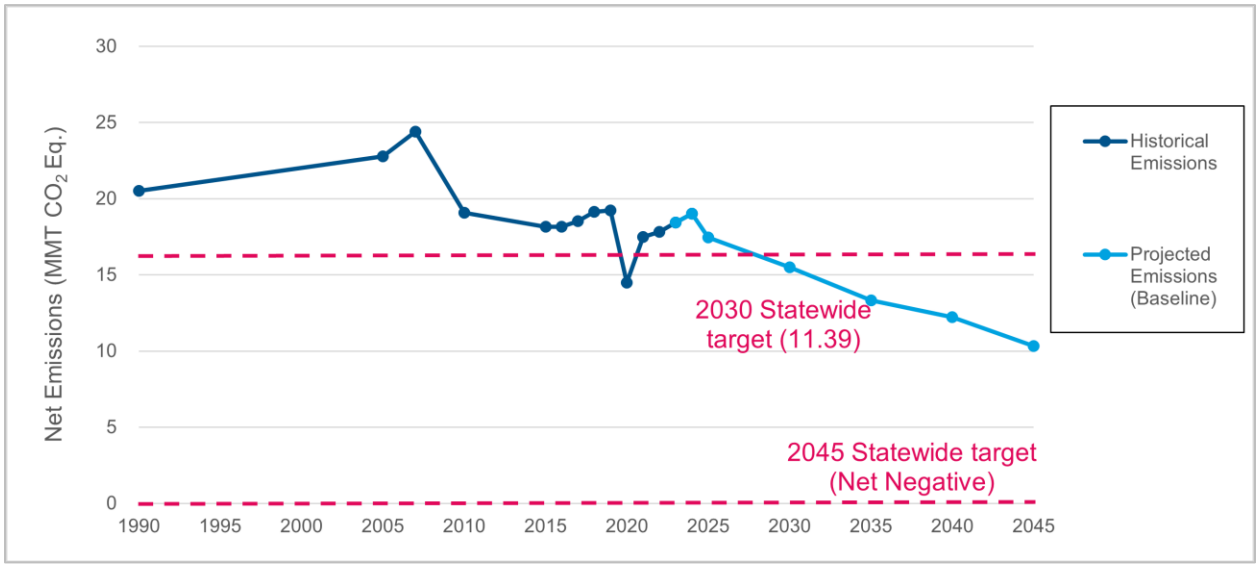
Figure 8-1: Hawai‘i GHG Emissions Inventory Estimates and Projections (MMT CO_2 Eq.) (Including Sinks, Excluding Aviation)



Note: Emission estimates include sinks but exclude domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Figure 8-2 shows net emissions (including sinks and aviation) in Hawai‘i for inventory years through 2022 as well as emission projections for 2025, 2030, 2035, 2040, and 2045. Figure 8-2 also shows the 2030 statewide target of 11.39 MMT CO_2 Eq., which is equal to 50 percent below 2005 emission levels, pursuant to Act 238 of 2022, and the 2045 carbon net-negative target pursuant to Act 15 of 2018. The target established by Act 238 of 2022 could change with future updates to the 2005 emission estimates, but it is not likely to change significantly. Net emissions (including sinks) for year 2030 are projected to be between 13.95 – 16.39 MMT CO_2 Eq. in 2030, and 8.99 – 11.26 MMT CO_2 Eq. in 2045. As such, **this report finds that Hawai‘i is currently not on track to meet the 2030 or 2045 statewide emissions targets,** set by Act 238 of 2022 and Act 15 of 2018 respectively. Table 8-1 summarizes emissions in years 1990, 2005, 2020, 2021 and 2022, and projections between 2025 and 2045.

Figure 8-2: Hawai'i Net GHG Emissions By Year (MMT CO_2 Eq.) (Including Sinks)



Note: Emission totals include sinks and domestic aviation emissions. Emissions estimates were calculated for 1990, 2005, 2007, 2010, and 2015 to 2022. Emissions estimates for interim years, as presented here, were developed through linear interpolation.

Table 8-1: Hawai'i GHG Emissions for 1990, 2005, 2020 and Projections by Sector under the Baseline Scenario for 2025, 2030, 2035, 2040, and 2045 (MMT CO_2 Eq.)

Sector	1990	2005	2020	2025	2030	2035	2040	2045
Energy[a]	20.25	22.72	14.66	17.69	15.92	14.08	13.25	11.52
IPPU	0.18	0.50	0.76	0.80	0.66	0.44	0.28	0.26
AFOLU (Sources)	1.47	1.10	1.10	1.03	0.98	0.93	0.89	0.85
AFOLU (Sinks)	(2.40)	(2.50)	(2.43)	(2.44)	(2.41)	(2.44)	(2.52)	(2.60)
Waste	1.01	0.98	0.41	0.36	0.35	0.34	0.33	0.32
Total Emissions (Excluding Sinks)	**22.92**	**25.29**	**16.93**	**19.89**	**17.91**	**15.79**	**14.74**	**12.95**
Net Emissions (Including Sinks)	**20.51**	**22.78[c]**	**14.50**	**17.45**	**15.51**	**13.34**	**12.23**	**10.35**
Aviation[b]	5.11	7.16	3.17	6.10	6.24	6.32	6.38	6.40
Net Emissions (Including Sinks, Excluding Aviation)[b]	**15.40[d]**	**15.62**	**11.33**	**11.35**	**9.26**	**7.02**	**5.85**	**3.94**

[a] Emissions from International Bunker Fuels are not included in the totals, as per IPCC (2006) guidelines.
[b] Domestic aviation and military emissions, which are reported under the Energy sector, are excluded from Hawai'i's GHG emission reduction goal established in Act 234 of 2007.
[c] Act 238 of 2022 aims for the level of statewide GHG emissions to be at least 50 percent below 2005 levels by the year 2030 (including aviation emissions).
[d] Act 234 of 2007 aims to achieve emission levels at or below Hawai'i's 1990 GHG emissions by January 1, 2020 (excluding aviation emissions).
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

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Appendix A. IPCC Source and Sink Categories

Table A-1: Summary of IPCC Source and Sink Categories Included/Excluded from the Analysis

Category Code and Name		Included in Inventory	Notes
Energy			
1A1	Fuel Combustion Activities	✓	Includes emissions from fuel combustion for electricity generation and petroleum refining.
1A2	Manufacturing Industries and Construction	✓	
1A3	Transport	✓	
1A4	Other Sectors	✓	
1A5	Non-Specified	✓	
1B1	Fugitive Emissions from Solid Fuels		NO: Solid fuels (e.g., coal) are not produced or processed in Hawaiʻi.
1B2	Oil and Natural Gas	✓	
1C	Carbon Dioxide Transport and Storage		NO: CO_2 is not transported or stored in Hawaiʻi.
IPPU			
2A1	Cement Production	✓	
2A2	Lime Production		NO: Activity is not applicable to Hawaiʻi.
2A3	Glass Production		NO: Activity is not applicable to Hawaiʻi.
2A4	Other Process Uses of Carbonates		NO: Activity is not applicable to Hawaiʻi.
2B	Chemical Industry		NO: Activity is not applicable to Hawaiʻi.
2C	Metal Industry		NO: Activity is not applicable to Hawaiʻi.
2D	Non-Energy Products from Fuels and Solvent Use	✓	IE: Included under the Energy sector.
2E	Electronics Industry		NO: Activity is not applicable to Hawaiʻi.
2F	Product Uses as Substitutes for ODS	✓	
2G1	Electrical Equipment	✓	

Category Code and Name		Included in Inventory	Notes
2G2	SF_6 and PFCs from Other Product Uses		NO: Activity is not applicable to Hawai‘i.
2G3	N_2O from Product Uses		NO: Activity is not applicable to Hawai‘i.
AFOLU			
3A1	Livestock Enteric Fermentation	✓	
3A2	Livestock Manure Management	✓	
3B1a	Forest Land Remaining Forest Land	✓	
3B1b	Land Converted to Forest Land		NE: Data on land conversion are not readily available.
3B2	Cropland	✓	
3B3	Grassland	✓	
3B4	Wetlands		NE: Data is not readily available and emissions are likely very small.
3B5a	Settlements Remaining Settlements	✓	
3B5b	Land Converted to Settlements		NE: Data on land conversion are not readily available.
3B6	Other Land		NE: Other Land is assumed to be unmanaged in Hawai‘i.
3C1a	Biomass Burning in Forest Lands	✓	
3C1b	Biomass Burning in Croplands	✓	
3C1c	Biomass Burning in Grassland		NE: Data is not readily available and emissions are likely very small.
3C1d	Biomass Burning in All Other Land		NO: Activity is not applicable to Hawai‘i.
3C2	Liming		NE: Activity data are either withheld or zero.
3C3	Urea Application	✓	
3C4	Direct N_2O Emissions from Managed Soils	✓	
3C5	Indirect N_2O Emissions from Managed Soils	✓	
3C6	Indirect N_2O Emissions from Manure Management	✓	
3C7	Rice Cultivation		NO: Activity is not applicable to Hawai‘i.
3D1	Harvested Wood Products		NE: Data is not readily available and sinks are likely very small.
Waste			
4A1	Managed Waste Disposal Sites	✓	

Category Code and Name		Included in Inventory	Notes
4A2	Unmanaged Waste Disposal Sites		NO: All waste disposal is assumed to occur in managed sites in Hawaiʻi.
4B	Biological Treatment of Solid Waste	✓	
4C	Incineration and Open Burning of Waste		In Hawaiʻi, incineration of MSW occurs at waste-to-energy facilities and thus emissions are accounted for under the Energy sector.
4D	Wastewater Treatment and Discharge	✓	

NO (emissions are Not Occurring); NE (emissions are Not Estimated).

Appendix B. Updates to the Historical Emission Estimates Presented in the 2022 Inventory Report

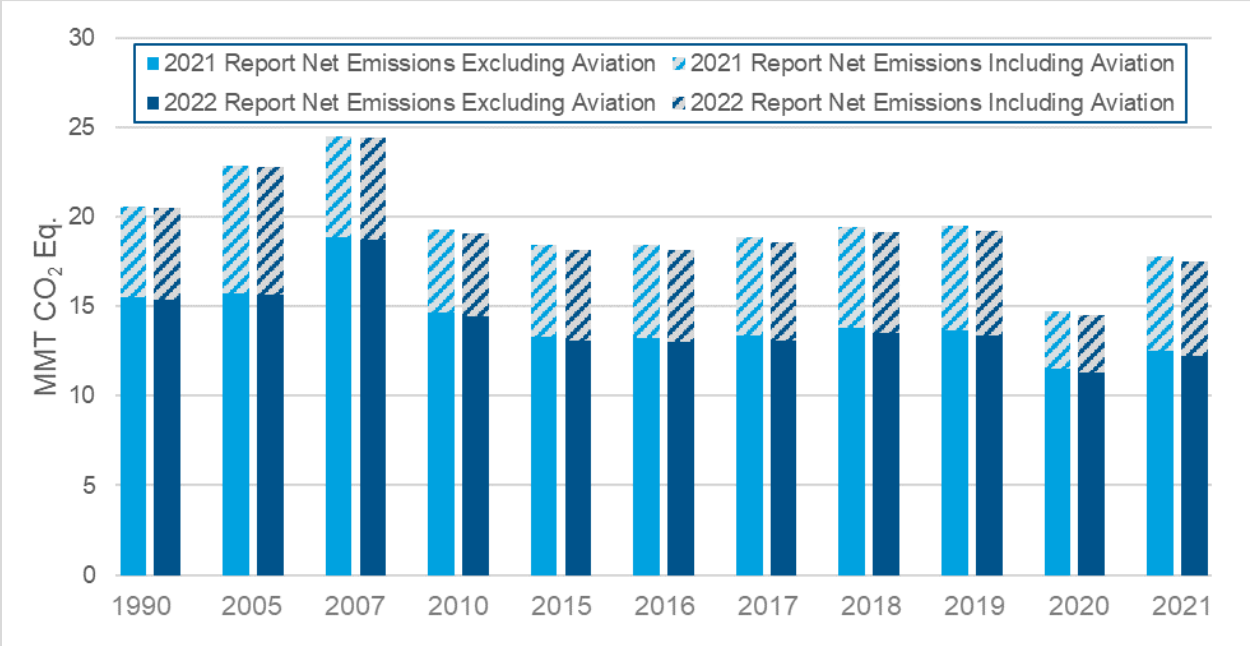
As it is best practice to review GHG emission estimates for prior years, this report includes revised estimates for 1990, 2005, 2007, 2010, 2015, 2016, 2017, 2018, 2019, 2020, and 2021 and newly developed estimates for 2022. The 1990, 2005, 2007, 2010, 2015, 2016, 2017, 2018, 2019, 2020, and 2021 estimates were updated to account for updated activity data and methods, and to ensure time-series consistency across all inventory years. Changes in emission estimates from the 2021 inventory report estimates are largely due to the following:

1. Updates to Hawai‘i specific data for wastewater treatment plants (WWTP) (e.g., flow rates and BOD_5 National Pollutant Discharge Elimination System [NPDES]).
2. Updates to Hawai‘i specific data for annual area burned in wildfires, soil emissions, urban tree cover, and the distribution of crop and grasslands by county.
3. Updates to Hawai‘i specific data (e.g., historical population numbers).
4. Incorporation of emissions from the consumption of renewable natural gas (RNG) produced by the Honouliuli Wastewater Treatment Plant.
5. A new State Energy Data System (SEDS) category for other petroleum products consumed by the transportation sector was added with biodiesel consumed by the transportation sector, as the new category was determined to only represent biodiesel consumption and is not duplicative of other biodiesel consumption already incorporated in the inventory.
6. The CH_4 emission factor for jet fuel was updated to match updates to the U.S. Greenhouse Gas Inventory. Across the timeseries, the Emission Factor is now zero.

Updates to the U.S. Inventory also resulted in some minor updates compared to the 2021 report for the sectors that utilize data from the U.S. Inventory, such as agricultural soil carbon, substitution of ozone depleting substances (ODS), and electric transmission and distribution. These and other updates that impacted emission estimates are discussed on a source-by-source basis in the subsequent sections of this report. Appendix B additionally summarizes the effort undertaken to investigate and implement areas for improvement that were identified in the 2017 inventory report.

Collectively, these changes resulted in an average annual decrease of 0.22 MMT CO_2 Eq. (1.2 percent) in net emissions and 0.21 MMT CO_2 Eq. (1.6 percent) in net emissions excluding aviation within the previous report’s timeseries. Figure B-1 compares the net emissions between the 2021 report and this report.

Figure B-1: Net Emissions Comparison Between 2021 Report and 2022 Report



Updates that impacted emission estimates are discussed by source in this report. A summary of the change in emission estimates relative to the 2021 inventory report is provided below in Table B-1.

Table B-1: Change in Emissions Relative to the 2021 Inventory Report

Sector	Energy	Energy (Excluding Aviation)	Energy (Aviation)	IPPU	AFOLU (Sources)	AFOLU (Sinks) [a]	Waste	Total Emissions (Excluding Sinks)	Net Emissions (Including Sinks)	Net Emissions (Including Sinks, Excluding Aviation)
1990										
2021 Report	20.26	15.14	5.11	0.18	1.58	(2.43)	1.01	23.02	20.59	15.48
2022 Report	20.25	15.14	5.11	0.18	1.47	(2.40)	1.01	22.90	20.51	15.40
Difference	(+)	(+)	(+)	+	(0.11)	0.03	(+)	(0.12)	(0.08)	(0.08)
Percent Change	(+%)	(+%)	(0.1%)	+%	(7.2%)	(1.4%)	(+%)	(0.5%)	(0.4%)	(0.5%)
2005										
2021 Report	22.72	15.56	7.16	0.50	1.25	(2.57)	0.98	25.45	22.87	15.71
2022 Report	22.72	15.56	7.16	0.50	1.10	(2.50)	0.98	25.29	22.78	15.62
Difference	(0.01)	+	(0.01)	+	(0.15)	0.07	(+)	(0.16)	(0.09)	(0.09)
Percent Change	+%	+%	(0.1%)	+%	(12.1%)	(2.6%)	(0.3%)	(0.6%)	(0.4%)	(0.6%)
2007										
2021 Report	24.35	18.68	5.67	0.55	1.31	(2.59)	0.88	27.09	24.50	18.83
2022 Report	24.34	18.68	5.66	0.55	1.18	(2.54)	0.88	26.95	24.41	18.75
Difference	(0.01)	(+)	(+)	+	(0.13)	0.04	(+)	(0.13)	(0.09)	(0.09)
Percent Change	(+%)	(+%)	(0.1%)	0.1%	(9.7%)	(1.6%)	(0.2%)	(0.5%)	(0.4%)	(0.5%)
2010										
2021 Report	19.38	14.73	4.65	0.67	1.25	(2.60)	0.59	21.90	19.30	14.65
2022 Report	19.38	14.73	4.64	0.67	1.08	(2.62)	0.60	21.71	19.09	14.45
Difference	(+)	(+)	(+)	(+)	(0.18)	(0.02)	+	(0.18)	(0.20)	(0.20)
Percent Change	(+%)	(+%)	(0.1%)	(0.7%)	(14.1%)	0.8%	0.4%	(0.8%)	(1.1%)	(1.4%)
2015										
2021 Report	18.50	13.41	5.10	0.79	1.29	(2.68)	0.51	21.09	18.40	13.30
2022 Report	18.50	13.41	5.09	0.79	1.09	(2.73)	0.51	20.88	18.16	13.06
Difference	(+)	(+)	(+)	(0.01)	(0.20)	(0.04)	0.00	(0.21)	(0.25)	(0.24)

Percent Change	(+%)	(+%)	(0.1%)	(0.6%)	(15.2%)	1.5%	0.0%	(1.0%)	(1.3%)	(1.8%)
2016										
2021 Report	18.53	13.35	5.18	0.80	1.29	(2.65)	0.46	21.08	18.43	13.25
2022 Report	18.52	13.34	5.17	0.79	1.08	(2.69)	0.46	20.85	18.16	12.99
Difference	(0.01)	(+)	(+)	(0.01)	(0.22)	(0.04)	0.00	(0.23)	(0.27)	(0.26)
Percent Change	+%	+%	(0.1%)	(0.7%)	(16.7%)	1.6%	0.0%	(1.1%)	(1.5%)	(2.0%)
2017										
2021 Report	18.97	13.51	5.46	0.80	1.28	(2.61)	0.42	21.48	18.86	13.40
2022 Report	18.97	13.51	5.46	0.80	1.01	(2.66)	0.42	21.20	18.54	13.08
Difference	+	0.01	(+)	(+)	(0.28)	(0.04)	0.00	(0.28)	(0.32)	(0.32)
Percent Change	+%	+%	(0.1%)	(0.5%)	(21.6%)	1.7%	0.0%	(1.3%)	(1.7%)	(2.4%)
2018										
2021 Report	19.23	13.59	5.64	0.81	1.48	(2.51)	0.41	21.92	19.41	13.77
2022 Report	19.23	13.60	5.64	0.80	1.25	(2.56)	0.41	21.69	19.14	13.50
Difference	+	0.01	(+)	(+)	(0.23)	(0.04)	0.00	(0.23)	(0.27)	(0.27)
Percent Change	+%	0.1%	(0.1%)	(0.4%)	(15.5%)	1.8%	0.0%	(1.0%)	(1.4%)	(2.0%)
2019										
2021 Report	19.45	13.61	5.84	0.83	1.30	(2.50)	0.44	22.02	19.52	13.68
2022 Report	19.45	13.62	5.84	0.82	1.06	(2.54)	0.44	21.77	19.23	13.39
Difference	+	0.01	(+)	(0.01)	(0.25)	(0.04)	0.00	(0.25)	(0.29)	(0.29)
Percent Change	+%	+%	(0.1%)	(0.8%)	(19.0%)	1.6%	0.0%	(1.2%)	(1.5%)	(2.1%)
2020										
2021 Report	14.65	11.48	3.18	0.77	1.28	(2.38)	0.41	17.10	14.72	11.54
2022 Report	14.66	11.48	3.17	0.76	1.10	(2.43)	0.41	16.93	14.50	11.33
Difference	+	0.01	(+)	(+)	(0.17)	(0.04)	+	(0.17)	(0.22)	(0.21)
Percent Change	+%	0.1%	(0.1%)	(0.4%)	(13.5%)	1.8%	+%	(1.0%)	(1.5%)	(1.8%)

2021										
2021 Report	17.50	12.25	5.25	0.82	1.45	(2.39)	0.41	20.18	17.79	12.53
2022 Report	17.47	12.22	5.25	0.82	1.22	(2.42)	0.41	19.92	17.50	12.25
Difference	(0.04)	(0.03)	(+)	0.01	(0.23)	(0.03)	+	(0.26)	(0.28)	(0.28)
Percent Change	(0.2%)	(0.2%)	(0.1%)	0.7%	(15.9%)	1.1%	+%	(1.3%)	(1.6%)	(2.2%)

+ Does not exceed 0.005 MMT CO_2 Eq. or 0.05 percent.

(+) Does not exceed -0.005 MMT CO_2 or -0.05 percent.

[a] Positive percent change in this column indicates an increase in carbon sinks.

Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Appendix C. Inventory Improvements

This appendix summarizes proposed areas for improvement to the Hawai‘i statewide greenhouse gas inventory for the next iteration of inventory development.

Energy

Area for Improvement #1

If data become available, naphtha and fuel gas consumption data for 2005 should be incorporated into stationary combustion emissions calculations.

Area for Improvement #2

All SEDS fuel consumption data should continue to be reviewed against other available datasets to verify its accuracy and completeness for use in the development of the Hawai‘i statewide inventory. Currently, SEDS does not report jet fuel kerosene consumption for stationary combustion separately, as this category is very small. Future research could be done to determine whether any jet fuel is consumed for this purpose and removed from transportation estimates. Alternative options for estimating military aviation fuel consumption across the relevant fuel types could be reviewed, as EIA no longer reports this data separately. Alternative options for estimating civil aviation fuel consumption could also be reviewed, such as the same BTS data that is used to estimate bunker fuels. Alternative options for estimating the fraction of transportation emissions that are from non-highway vehicles could be reviewed. Additionally, future research could be done into the potential to use GHGRP data in place of SEDS data to estimate stationary emissions.

Area for Improvement #3

Confirm with EIA that all stationary emissions from petroleum refining, including combustion activities supporting the refining of petroleum products and on-site combustion for own use electricity and heating, are included in SEDS fuel consumption data. Currently, refinery-related fuels from SEDS data are recategorized from the industrial sector to the energy industries sector, to remain aligned with IPCC guidance. Further information from EIA is needed to confirm that all refinery-related fuels have been identified and recategorized, and that the SEDS data includes all stationary emissions from petroleum refining. If it is determined that SEDS data does not include all stationary emissions from petroleum refining, future research should be conducted to identify supplemental or alternative data sources.

Area for Improvement #4

Review data sources and methodological options to further disaggregate data reported for the transportation source categories beyond the current end use sectors of ground, domestic marine, domestic aviation, military aviation, and military (non-aviation) transportation.

Area for Improvement #5

If data becomes available, marine bunker fuel consumption data for 1990 should be incorporated into emissions calculations.

Area for Improvement #6

Review emission factors that are updated annually and incorporate most up-to-date emission factors throughout emissions calculations. For example, review emission factors used to calculate fugitive emissions from natural gas distribution and transmission pipelines.

Area for Improvement #7

Research should be conducted into whether electricity was generated by the Waipahu Incinerator in 1990. Based on the findings of this research, emissions estimates may need to be adjusted.

Area for Improvement #8

The methodology used to project VMT and emissions from EVs should be revisited to incorporate additional data that may become available and to more closely align with the methodology used in emissions estimates. In addition, EV methodology should be reviewed to confirm assumptions about earliest instance of EV use in Hawai'i.

IPPU

Area for Improvement #9

ODS substitute emissions from refrigeration and AC Systems could be disaggregated by equipment size (i.e., systems above and below a 50 lbs. charge size). Further research would be required to establish assumptions and then incorporate them into the existing top-down estimation methodology. Similarly, national emissions for the AC sub-category could be disaggregated if metrics to do so are identified. For example, if available, information on the percentage of households with central or room air conditioning could be incorporated. Alternatively, a bottom-up approach to estimate emissions from this sector for which significant additional research would be required.

Area for Improvement #10

Homeland Infrastructure Foundation-Level Data (HIFLD) Open Data provides national geospatial data on electrical transmission and distribution systems. The methodology could be revised to incorporate Hawai'i-specific transmission line data to apportion U.S. emissions, rather than apportioning U.S. emissions using electricity sales. HIFLD is an open access source, and similar work has been done by the U.S. Inventory team.

AFOLU

Area for Improvement #11

If crop residue factors are updated and/or better data become available, future analyses should update the factors accordingly. Additional research was conducted on crop residue factors, but no new information was identified that could be used to inform emission estimates from agricultural soil management. Further research into updated crop residue factors may be considered in future analyses.

Area for Improvement #12

Further research into the accuracy of calendar year fertilizer consumption patterns may be considered in future analyses, as well as investigating new sources for urea consumption data. Additional research was conducted on urea consumption in Hawaiʻi, but no new information was identified that could be used to verify the accuracy of calendar year fertilizer consumption patterns.

Updated historical data was identified for urea application in 2015 and 2016 during the 2019 inventory from the American Association of Plant Food Control Officials Commercial Fertilizers Reports; however, no new data was available for 2017 to 2021 for the 2021 inventory. Additional research was conducted to identify other sources of more recent urea consumption data, but no new information was identified that could be used to inform emission estimates from urea application.

Area for Improvement #13

Research is being conducted to develop a soil carbon map for Hawaiʻi and new models are being explored to model GHG flux and soil carbon in Hawaiʻi. Outreach regarding this research will be conducted and further research into emission reductions from improved agricultural soil management practices may be considered in future analyses. This would contribute to agricultural soil management and, if data is sufficient, to a new forest soil carbon category.

Area for Improvement #14

Coordination with EPA to understand the cause for the discrepancy between emission estimates presented in this report and NEI prescribed fire emissions may be considered. Tesh Rao (EPA), the point of contact for data on agricultural fires and events (wildfires and prescribed burning) published in EPA's National Emissions Inventory (NEI), was contacted to inquire about the emission estimates from prescribed burning in Hawaiʻi. In the 2016 inventory report, it was assumed there were no emissions from prescribed fires based on input from Christian Giardina from the Institute of Pacific Islands Forestry that prescribed burning is not a common practice in Hawaiʻi; therefore, emissions from prescribed fires are likely very small. However, the NEI indicates that emissions from prescribed fires in Hawaiʻi were 0.13 MMT CO_2 Eq. in 2011, 2.07 MMT CO_2 Eq. in 2014, and 0.09 MMT CO_2 Eq. in 2017. According to Tesh, different models (e.g., the FINN model, NOAA's Hazard Mapping System) were used to identify acres-burned from prescribed fires for the NEI, which are the reason for the large variation in reported emissions from prescribed fires for Hawaiʻi.

Due to the inconsistency in methodology used to identify emissions for the NEI, a lack of data available for all inventory years, and expert guidance from Christian Giardina, this inventory continues to assume that emissions from prescribed fires in Hawaiʻi are negligible. Incorporating emissions from prescribed wildfires into the statewide inventory for Hawaiʻi if data becomes available was also identified as a potential improvement.

Area for Improvement #15

Further research into Hawaiʻi trends in diverting yard trimmings and food scraps from landfills, as well as yard trimmings and food scraps sequestration rates that incorporate Hawaiʻi's climate may be considered in future analyses. Additional research was conducted to identify Hawaiʻi-specific waste composition data and sequestration rates, but no new information was identified that could be used to inform emission estimates from landfilled yard trimmings and food scraps.

Future improvement could include further research into Hawaiʻi trends in diverting yard trimmings and food scraps from landfills, as well as yard trimmings and food scraps sequestration rates that incorporate Hawaiʻi's climate may be considered in future analyses.

Area for Improvement #16

Further investigation into whether estimated acreage of land use districts, by island, from the Hawaiʻi DBEDT Databook can be used for estimating urban areas should be conducted. The annual updating of the Hawaiʻi Databook and the changing definitions of urban area in every U.S. Census could make using the databook estimates a more consistent approach.

Area for Improvement #17

Additional land cover data and annually variable net sequestration rates should be incorporated into future analyses if they become available. Further research into the age of Hawaiʻi forests, improved forest management practices, and their emissions reduction potential may also be considered in future analyses.

The 2016 inventory report used carbon sequestration rates and land cover data by forest type for Hawaiʻi forests from the United States Geological Survey (USGS) paper titled "Baseline and Projected Future Carbon Storage and Carbon Fluxes in Ecosystems of Hawaiʻi" (Selmants et al. 2017). Paul Selmants (USGS) was contacted in 2019 to confirm that the 2017 study contained the latest available information on Hawaiʻi land-cover and sequestration rates. Paul indicated at that time that his team recently finished a new set of model runs that incorporate two new land use/land cover change scenarios and two new climate change scenarios. Based on that new information provided by Paul Selmants (USGS), new yearly carbon sequestration rates for forest and shrubland were calculated and incorporated into the 2017 – 2022 inventory reports. Further improvements can include incorporating additional data on forest land cover if they become available as additional models are run.

Area for Improvement #18

Identify data and estimate emissions for source and sink categories that are currently not estimated due to a lack of data. The affected source categories include land converted to forest land, wetlands, land converted to settlements, other land, biomass burning in grassland, liming, and harvested wood products. Research was conducted to identify additional data from sources and sinks that are not currently included in the Hawaiʻi Inventory but no new information was identified that could be used to

estimate emissions from these categories for the current inventory report. Data for harvested wood product could be requested through the Uniform Information Practices Act from the Department of Land and Natural Resources Forestry program. It is assumed that emissions from these categories, if estimated, would have an insignificant impact on the statewide total.

Further improvements could include identifying data and estimating emissions for source and sink categories that are currently not estimated due to a lack of data.

Waste

Area for Improvement #19

Further assessment can be done to ensure the accuracy of the back-casting method used to estimate emissions from landfills for years prior to 2010, when GHGRP reporting requirements began. The current back-casting method assumes that CH_4 generation increases exponentially over time. Confirming waste in place data by Hawaiʻi DOH or landfills themselves to either replace or confirm LMOP data would lead to more accurate scaling factors to account for landfills under the GHGRP reporting threshold.

Area for Improvement #20

Future improvement could be made by incorporating flow rate and BOD_5 data for non-NPDES WWTPs for 2022 and historical years in which no or little data were available. Should state-specific data on total number of households on septic systems and/or share of households in Hawaiʻi on septic systems become available, it can be incorporated. Additionally, more recent data on the percentage of biosolids from WWTPs used as fertilizer can be used to improve estimates.

Appendix D. County Emissions Methodology

This appendix summarizes the methodology used to quantify Hawai'i's GHG emissions by county. The methodology used varies by emissions source, depending on data availability. For some sources, county-level activity data were available to build bottom-up county level emissions estimates. For other sources, only state-level activity data were available, requiring emissions to be allocated to each county using proxy information such as population and VMT data.

County Emissions estimates were calculated using the best data available at the time of this report. GHG emissions estimates from inventories prepared at the county level by other organizations may differ from those in this report due to differences in data sources, boundaries, or other assumptions. Should additional data become available, the methodology described here will be revised for future inventories.

Energy

Stationary Combustion

County-level stationary combustion emissions estimates were calculated for each economic sector using a combination of disaggregated state-level emission estimates and/or county-level activity data, based on the availability and reliability of data for each source category and inventory year. Results for each economic sector were then summed to calculate total county-level stationary combustion emissions.

Emissions for the energy industries and industrial sectors for 2010 and 2015 to 2022 were calculated using the methodology described in Section 3.1 and allocated to each county based on county-level emission breakdowns calculated from GHGRP data (EPA 2024c). GHGRP facility level emissions data were unavailable for the years 1990, 2005, and 2007. Emissions for the energy industries and industrial sectors for 1990, 2005, and 2007 were calculated using the methodology described in Section 3.1 and allocated to each county by applying the 2010 county allocations derived from GHGRP facility level emissions data (EPA 2024c).

Residential and commercial sector emissions for all inventory years were calculated using the methodology described in Section 3.1 and allocated to each county by population data from DBEDT (2024a)**.**

Transportation

Ground transportation emissions for 2005, 2007, 2010, and 2015 to 2022 were calculated using the methodology described in Section 3.2 and allocated to each county based on motor vehicle registration data from DBEDT data book (DBEDT 2023). For 1990 ground transportation emissions, 1990 motor vehicle registration data were unavailable. Therefore, 1995 motor vehicle registration data were used to allocate 1990 ground transportation emission to each county.

Emissions from domestic marine, military aviation, and military non-aviation transportation were allocated solely to Honolulu based on available DBEDT data (DBEDT 2008a) which indicate that over 99 percent of fuel consumption in the military and water transportation sectors occur in Honolulu. Emissions from domestic aviation transportation were calculated using the methodology described in Section 3.2 and allocated to each county based on domestic BTS flight data (DOT 2022a).

Incineration of Waste for Energy Purposes

Hawaiʻi's two waste incineration facilities, Waipahu and HPOWER, are both in Honolulu County; therefore, total emissions from the incineration of waste for energy purposes were allocated to Honolulu County, calculated using the methodology described in Section 3.3.

Oil and Natural Gas Systems

Hawaiʻi's one oil and natural gas facility currently in operation, Par East, is in Honolulu County; Hawaiʻi's other oil and natural gas facility that fully closed in 2022 was also in Honolulu County. Therefore, total emissions from oil and natural gas systems were allocated to Honolulu County, calculated using the methodology described in Section 3.4.

Non-Energy Uses

Emissions for non-energy uses for 2010 and 2015 to 2022 were calculated using the methodology described in Section 3.5 and allocated to each county based on county-level emission breakdowns for the energy industries and industrial sector calculated from GHGRP data (EPA 2024c).

GHGRP facility level emissions data were unavailable for the years 1990, 2005, and 2007. Emissions for non-energy uses for 1990, 2005, and 2007 were calculated using the methodology described in Section 3.5 and allocated to each county by applying the 2010 county allocation for the energy industries and industrial sector derived from GHGRP facility level emissions data (EPA 2024c).

IPPU

Cement Production

All process emissions from cement production in 1990 occurred within Honolulu County.

Electrical Transmission and Distribution

Emissions were calculated by apportioning U.S. emissions from this source to each island based on the ratio of the island's electricity sales to U.S. electricity sales. Estimates of national SF_6 and CH_4 emissions data were taken from the U.S. Inventory (EPA 2024b). National electricity sales data come from the EIA (2023a). Hawaiʻi electricity sales data by island come from the State of Hawaiʻi Data Book (DBEDT 2023). Island-level data was aggregated by county to estimate county-level emissions.

Substitution of Ozone Depleting Substances

Emissions from mobile air-conditioning systems were estimated by apportioning national emissions from the U.S. Inventory (EPA 2024b) to each county based on the ratio of the county's vehicle registrations from the State of Hawai'i Data Book (DBEDT 2023) to U.S. vehicle registrations from the U.S. Department of Transportation, Federal Highway Administration (FHWA 2023). County emissions from other air-conditioning systems (i.e., air conditioning systems excluding mobile air conditioners) were estimated by apportioning national emissions from the U.S. Inventory (EPA 2024b) to each county based on the ratio of the number of houses with air conditioners in each county to the number of houses with air conditioners in the U.S. The number of houses in each county with air conditioners was estimated by apportioning the total number of houses with air conditioners in hot and humid climate regions in the United States using EIA's 2009, 2015, and 2020 RECS to each county based on population (EIA 2013; EIA 2018; EIA 2022). For the remaining sub-categories, national emissions from the U.S. Inventory (EPA 2024b) were apportioned to each county based on the ratio of the county's population from DBEDT (2024a) to U.S. population from the U.S. Census Bureau (2023).

AFOLU

Enteric Fermentation

County-level population data for total cattle, beef cattle, swine, and chickens were obtained from USDA NASS. County-level cattle population data were used to apportion state-level cattle population data from the U.S. Inventory (EPA 2024b) to each county, using the methodology described in Section 5.1. The years with county-level data available for these animal types varied based on the animal type and county, with 2022 being the most recent year that county-level data were available. Population estimates for years and animal types with no data were estimated based on state-level data. Emissions were calculated based on population data using the methodology described in Section 5.1.

County-level population data for sheep, goats, and horses were obtained from the USDA Census of Agriculture, which is compiled every five years. For years without population data, population data were extrapolated or interpolated based on available data. Emissions were calculated based on population data using the methodology described in Section 5.1.

Manure Management

County-level population data for total cattle, beef cattle and swine were obtained from USDA NASS. County-level cattle population data were used to apportion state-level cattle population data from U.S. Inventory (EPA 2024b) to each county, using the methodology described in Section 5.2. The years with county-level data available for these animal types varied widely based on the animal type and county, with 2022 being the most recent year that county-level data were available. Population estimates for years and animal types with no data were estimated based on state-level data. Emissions were calculated based on population data using the methodology described in Section 5.2.

County-level population data for sheep, goats and horses were obtained from the USDA Census of Agriculture, which is compiled every five years. For years without population data, population data extrapolated or interpolated based on available data. Emissions were calculated based on population data using the methodology described in Section 5.2.

Agricultural Soil Management

County-level annual sugarcane area and production estimates for the years 1990 to 2007, 2017, and 2022 were obtained directly from USDA NASS. Between 2007 and 2017, county-level acreages were estimated based on the average proportion of county-level area (or production) to state-level area (or production) for sugarcane over the full timeseries. Sugarcane area and production was zeroed out in 2018 and onward due to the closure of the last sugarcane mill in Hawaiʻi. For other crops (i.e., pineapples, sweet potatoes, ginger root, taro, and corn for grain), county-level data were obtained from the USDA Census of Agriculture, which is compiled every five years. For crops for which an average proportion was not available due to limited years of data, the ratio of county-level data to state-level data in 2022 (or the most recent year available) was used. Emissions from county-level crop data were estimated using the methodology described in Section 5.3.

State-level synthetic and organic fertilizer N application data were allocated to each county based on percent cropland by county by year. Agricultural land use by county was obtained from Agricultural Land Use Maps (Hawaiʻi State Office of Planning 2015) for the year 1992 and the University of Hawaiʻi (2016 and 2022) for 2015 and 2020. Agricultural land use by county for the years 1990 and 1991 were proxied to 1992, years 1993 through 2014 were interpolated based on 1992 and 2015 data, and years 2016 to 2019 were interpolated between 2015 and 2020. Agricultural land use by county for 2021 and beyond was proxied to 2020. Emissions were then estimated using the methodology described in Section 5.3.

Animal population data were used to calculate the N inputs to agricultural soils from pasture, range, and paddock manure from all animals. County-level population data for total cattle, beef cattle and swine were obtained from USDA NASS. County-level cattle population data were used to apportion state-level cattle population data from the U.S. Inventory (EPA 2024b) to each county, using the methodology described in Section 5.1. The years with county-level data available varied widely based on the animal type and county, with 2022 being the most recent year that county-level data were available. County-level population estimates for years and animal types with no data were estimated based on state-level data. County-level population data for sheep, goats and horses were obtained from the USDA Census of Agriculture, which is compiled every five years. For years without population data, population data were extrapolated or interpolated based on available data. Emissions were calculated based on population data using the methodology described in Section 5.3.

Field Burning of Agricultural Residues

County-level annual sugarcane area and production estimates for the years 1990 to 2007 were obtained directly from USDA NASS and for year 2017 from the USDA Census of Agriculture. Between 2007 and 2017, county-level data were estimated based on the average proportion of county-level area (or production) to state-level area (or production) for sugarcane over the full timeseries. Sugarcane area

and production was zeroed out in 2018 and onward due to the closure of the last sugarcane mill in Hawaiʻi. Emissions were then estimated using the methodology described in Section 5.4.

Urea Application

State-level urea fertilizer application data were allocated to each county based on the percent of cropland area by county by year. Agricultural land use by county was obtained from Agricultural Land Use Maps (Hawaiʻi State Office of Planning 2015) for 1992 and the University of Hawaiʻi (2016 and 2022) for 2015 and 2020. Agricultural land use by county for the years 1990 and 1991 were proxied to 1992, years 1993 through 2014 were interpolated based on 1992 and 2015 data, and years 2016 to 2019 were interpolated between 2015 and 2020. Agricultural land use by county for the 2021 and beyond was proxied to 2020. Emissions were then estimated using the methodology described in Section 5.5.

Agricultural Soil Carbon

Emissions from agricultural soil carbon were estimated using the methodology described in Section 5.6 and allocated to each county based on the percent area of cropland and percent area of grassland by county by year. Agricultural land use by county was obtained from NASS Census data for the years 2002, 2007, 2012, 2017, and 2022 (NASS 2024). The NASS data was then converted into a percent of state agricultural area by county which was then interpolated throughout the timeseries based on available data. Agricultural land use by county prior to 2002 and beyond was proxied to 2002.

Forest Fires

Emissions from forest fires were estimated using the methodology described in Section 5.7 and allocated to each county based on the share of forest and shrubland area in each county relative to total forest and shrubland area in the state (DBEDT 2024a, NOAA-CCAP 2000, Selmants et al. 2017).

Landfilled Yard Trimmings and Food Scraps

Carbon sequestration in landfilled yard trimmings and food scraps were estimated using the methodology described in Section 5.8 and allocated to each county based on the ratio of county population to state population (DBEDT 2024a).

Urban Trees

Urban tree cover by county was estimated based on urbanized area and cluster data in 1990, 2000, 2010, and 2020 from the U.S. Census and percent tree cover by county from the NLCD, as described in section 4.9. Census-defined urbanized areas were mapped to their respective county to establish county-level urban area estimates. Then, county-level urban area estimates and urban tree cover % were interpolated and extrapolated throughout the timeseries based on available data, as described in Urban Trees (IPCC Source Category 3B5a). CO_2 sinks were calculated based on urban tree cover and Hawaiʻi-specific sequestration rates, as described in Section 5.9Urban Trees (IPCC Source Category 3B5a).

Forest Carbon

Carbon sequestration in forests and shrubland were estimated using the methodology described in Forest Carbon (IPCC Source Category 3B1a) and allocated to each county based on forest and shrubland area data by island from DBEDT (2024a). County-level emissions estimates were then calculated as the sum of each island in the county. CO_2 sinks were calculated using Hawai‘i-specific forest and shrubland sequestration rates (Selmants et al. 2017), as described in Section 5.10.

Waste

Landfills

Landfill emissions were calculated for each county using the methodology described in Section 6.1.

Composting

Composting emissions were calculated based on per capita rates of composting per year by county, which were provided by Hawai‘i’s Department of Health (Hawai‘i DOH 2024).

Wastewater Treatment

Wastewater treatment emissions were calculated for each island using the methodology described in Section 6.3; county-level emissions estimates were calculated as the sum of each island in the county.

Appendix E. Hawai‘i Administrative Rule (HAR) Facility Data

Hawai‘i Administrative Rule (HAR) affected facilities refers to large existing stationary sources with potential GHG emissions at or above 100,000 tons of CO_2 Eq. per year.[65] These facilities are subject to an annual facility-wide GHG emissions cap of 16 percent below the facility's total 2010 baseline (or alternate approved baseline) GHG emission levels to be achieved by January 1, 2020 and maintained thereafter. Table D-1 summarizes reported GHG emissions for the HAR affected facilities from 2010 to 2022. 2020 reported emissions have been included for comparison purposes and are based on data from the EPA's GHGRP (EPA 2024c). The table also includes information on the facility-specific 2020 emissions cap and the calculated difference between the cap and reported emissions for 2020. This table includes stationary combustion emissions from electric power plants, petroleum refineries, and industrial facilities as well as fugitive emissions from petroleum refineries. Biogenic CO_2 emissions from HAR affected facilities are not presented, as these emissions are excluded from the annual facility-wide GHG emission cap. The Hawai‘i Administrative Rules dictate that estimates used for permitting be developed using the GWPs published in Table A-1 to subpart A of 40 CFR 98 which is in alignment with GHGRP reporting. These GWPs are AR4 GWPs and therefore HAR facility emissions totals are reported here using AR4 GWPs for consistency.

[65] Hawai‘i Administrative Rules, Chapter 11-60.1, available online at http://health.Hawaii.gov/cab/files/2014/07/HAR_11-60_1-typed.pdf, excludes municipal waste combustion operations and conditionally exempts municipal solid waste landfills.

Table D-1: Reported HAR Affected Facility Emissions (excluding biogenic CO_2 emissions) (MMT CO_2 Eq.)

HAR Affected Facility	Inventory Sector (IPCC) Source Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2020 Cap	Difference
AES Hawai'i, Inc.	Energy Industries (1A1ai)	1.53	1.68	1.82	1.69	1.77	1.64	1.93	1.47	1.29	1.31	1.19	1.07	0.64	1.28	0.09
Hāmākua Energy Partners	Energy Industries (1A1ai)	0.17	0.13	0.14	0.10	0.11	0.13	0.09	0.09	0.16	0.22	0.12	0.10	0.10	0.14	0.02
Hawaiian Commercial & Sugar Company[a]	Industrial (1A2)	0.14	0.13	0.12	0.15	0.14	0.12	0.04	+	+	NO	NO	NO	NO	NA	NA
HELCO Kanoelehua Hill Generation Station	Energy Industries (1A1ai)	0.20	0.19	0.17	0.17	0.17	0.18	0.23	0.18	0.16	0.18	0.18	0.15	0.18	0.16	(0.02)
HELCO Keahole Generating Station	Energy Industries (1A1ai)	0.17	0.18	0.15	0.19	0.21	0.21	0.21	0.22	0.24	0.22	0.27	0.21	0.21	0.22	(0.05)
HELCO Shipman Generating Station[b]	Energy Industries (1A1ai)	NE	NE	NE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA
HELCO Puna Generating Station	Energy Industries (1A1ai)	0.09	0.09	0.08	0.09	0.05	0.02	0.02	0.02	0.04	0.07	0.06	0.09	0.06	0.03	(0.03)
HECO Waiau Generating Station	Energy Industries (1A1ai)	0.97	0.88	0.86	0.86	0.88	1.01	0.80	0.81	0.85	0.86	0.63	0.75	0.79	0.80	0.17
HECO Kahe Generating Station	Energy Industries (1A1ai)	2.52	2.63	2.41	2.22	2.13	2.02	2.03	2.01	2.00	1.87	1.89	1.72	2.02	2.00	0.11
HECO Campbell Industrial Park Generating Station	Energy Industries (1A1ai)	NO	+	+	+	+	+	+	+	0.02	0.14	0.12	0.12	0.13	0.11	(0.01)
HECO Honolulu Generating Station[c]	Energy Industries (1A1ai)	0.12	0.10	0.05	0.06	+	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA
Hu Honua Bioenergy Pepeekeo Power Plant[d]	Energy Industries (1A1ai)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA

HAR Affected Facility	Inventory Sector (IPCC) Source Category	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2020 Cap	Difference
Kalaeloa Cogeneration Plant	Energy Industries (1A1ai)	0.95	0.99	0.91	0.96	0.92	0.95	0.85	0.86	0.88	0.90	0.79	0.84	0.88	1.06	0.27
Kaua'i Island Utility Co. Kapaia Power Station	Energy Industries (1A1ai)	0.13	0.12	0.13	0.12	0.13	0.12	0.11	0.11	0.12	0.11	0.09	0.09	0.11	0.14	0.05
Kaua'i Island Utility Co. Port Allen Generating Station	Energy Industries (1A1ai)	0.15	0.15	0.14	0.14	0.13	0.12	0.08	0.08	0.08	0.05	0.03	0.03	0.03	0.09	0.06
MECO Kahului Generating Station	Energy Industries (1A1ai)	0.21	0.19	0.18	0.13	0.14	0.11	0.14	0.18	0.17	0.18	0.15	0.15	0.18	0.14	(0.01)
MECO Maalaea Generating Station	Energy Industries (1A1ai)	0.56	0.55	0.52	0.49	0.46	0.49	0.48	0.48	0.47	0.49	0.38	0.43	0.46	0.42	0.04
MECO Palaau Generating Station	Energy Industries (1A1ai)	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	(0.00)
Par West Refinery[e,f]	Energy Industries (1A1ai)	0.34	0.35	0.34	0.30	0.32	0.33	0.31	0.31	0.34	0.21	0.09	+	+	0.29	0.20
	Oil and Natural Gas (1B2)	0.19	0.21	0.23	0.16	0.21	0.19	0.19	0.17	0.18	+	+	+	NO	NA	NA
Par East Refinery[f]	Energy Industries (1A1ai)	0.44	0.45	0.41	0.26	0.43	0.44	0.43	0.47	0.48	0.48	0.44	0.51	0.49	0.62	0.18
	Oil and Natural Gas (1B2)	0.12	0.13	0.12	0.07	0.13	0.11	0.09	0.13	0.12	0.11	0.09	0.10	0.09	NA	NA
Energy Industries Subtotal[g]		**8.58**	**8.72**	**8.35**	**7.81**	**7.87**	**7.81**	**7.74**	**7.32**	**7.31**	**7.29**	**6.45**	**6.30**	**6.31**	**7.52**	**1.07**
Industrial Subtotal[g]		**0.14**	**0.13**	**0.12**	**0.15**	**0.14**	**0.12**	**0.04**	**+**	**+**	**NO**	**NO**	**NO**	**NO**	**NA**	**NA**
Oil and Natural Gas Subtotal		**0.32**	**0.34**	**0.34**	**0.24**	**0.34**	**0.30**	**0.29**	**0.30**	**0.30**	**0.11**	**0.09**	**0.10**	**0.09**	**NA**	**NA**
Total		**9.04**	**9.19**	**8.82**	**8.19**	**8.36**	**8.23**	**8.06**	**7.62**	**7.61**	**7.40**	**6.54**	**6.39**	**6.41**	**7.52**	**0.98**

[a] The Hawaiian Commercial & Sugar Company plant closed in December 2016.
[b] The HELCO Shipman Generating Station was deactivated in 2012 and closed at the end of 2015.
[c] The HECO Honolulu Generating Station was deactivated in January 2014.
[d] The Hu Honua Bioenergy, LLC Pepeekeo Power Plant is currently under development. Once the plant becomes operational, emissions are still expected to not occur, based on the definitions set forth in administrative rules, because the plant will use biomass as its fuel source.

[e] Par West Refinery shut down in 2020, facility equipment remained running in 2021, but fully closed in 2022.
[f] Par West Refinery was previously known as Island Energy Services Refinery and prior to that, as the Chevron Products Company Hawaiʻi Refinery; the Par East Refinery was previously known as the Refinery Kapolei which previously was known as the Hawaiʻi Independent Energy Petroleum Refinery. In 2018, the Island Energy Services refinery ceased refinery operations and converted to an import terminal (Mai 2018).
[g] Sector subtotals presented in this table, which are based on facility-level data, differ from the estimates by end-use sector presented in this report, which are adjusted to ensure consistency with how SEDS allocates data by end-use sector. In addition, the data in this table only represent emissions from HAR facilities and may not represent total statewide emissions.
+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring); NA (emissions are Not Applicable).
Note: Totals may not sum due to independent rounding.

Additionally, HAR-affected facilities have the option to combine the emissions from multiple partnering facilities and be regulated by a combined cap. Hawaiʻi has three sets of partnering facilities, each graphically shown with their caps in Figures Figure E-1, Figure E-2, and Figure E-3.

Figure E-1: Independent Power Producers and Hawaiian Electric Partnering Facilities

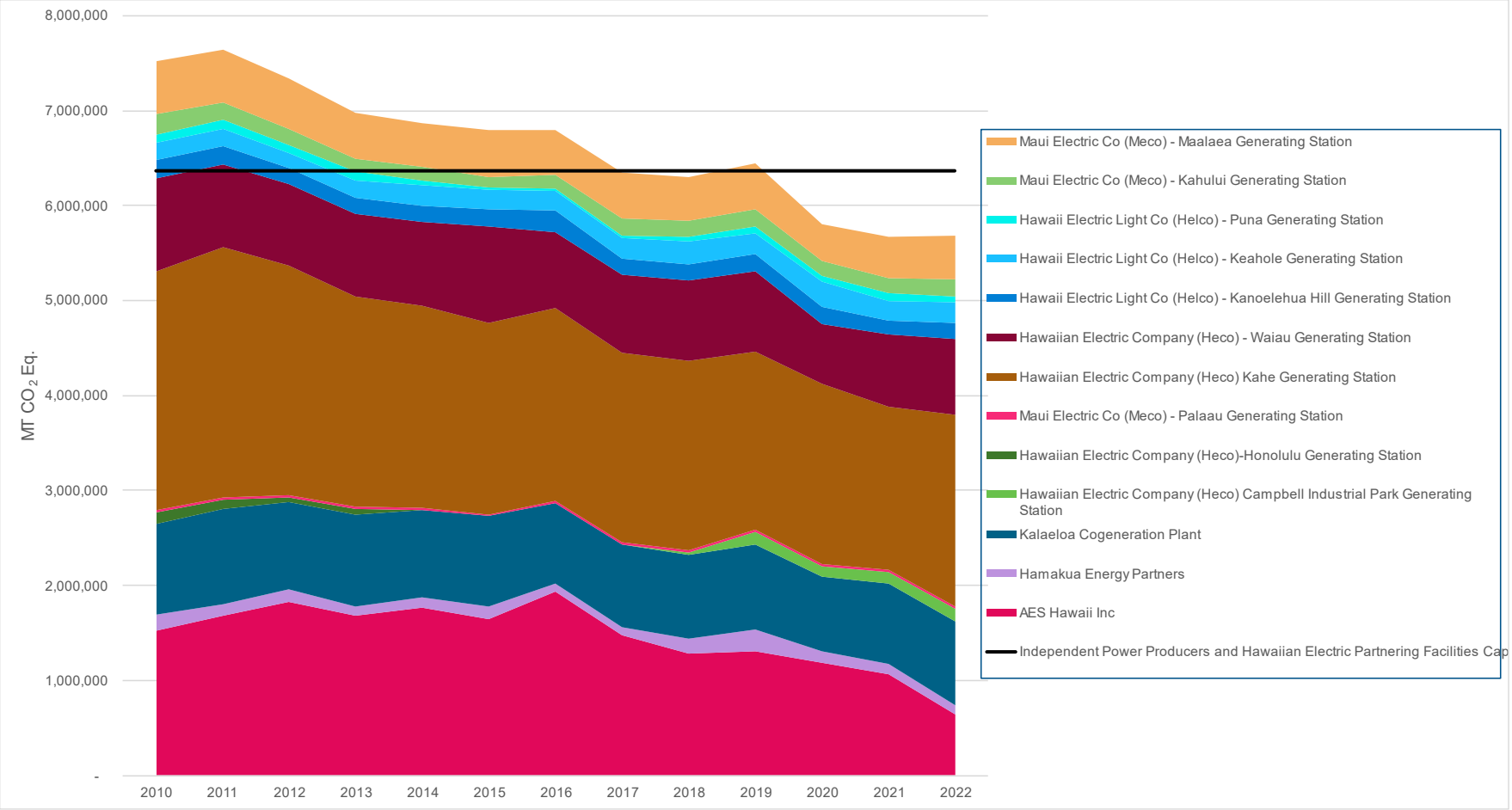
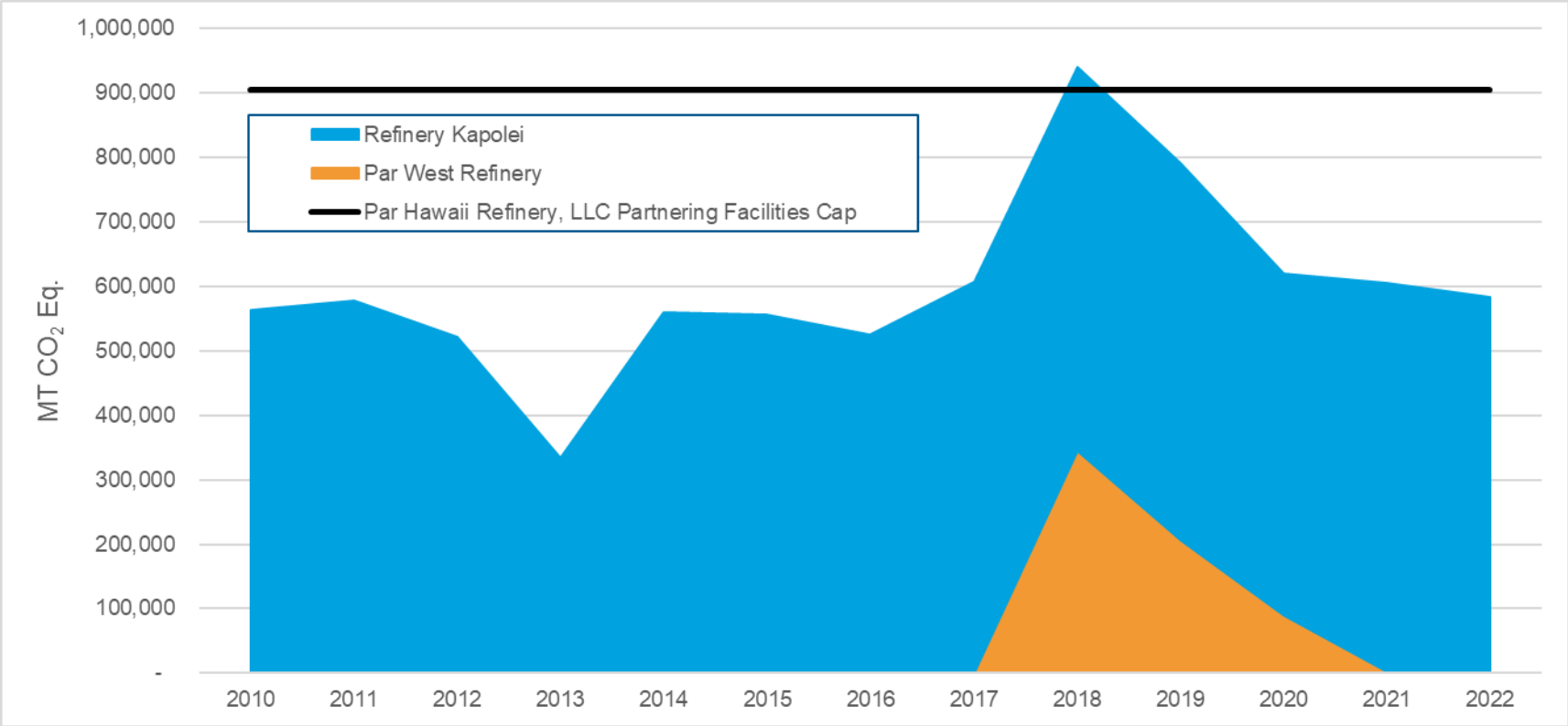
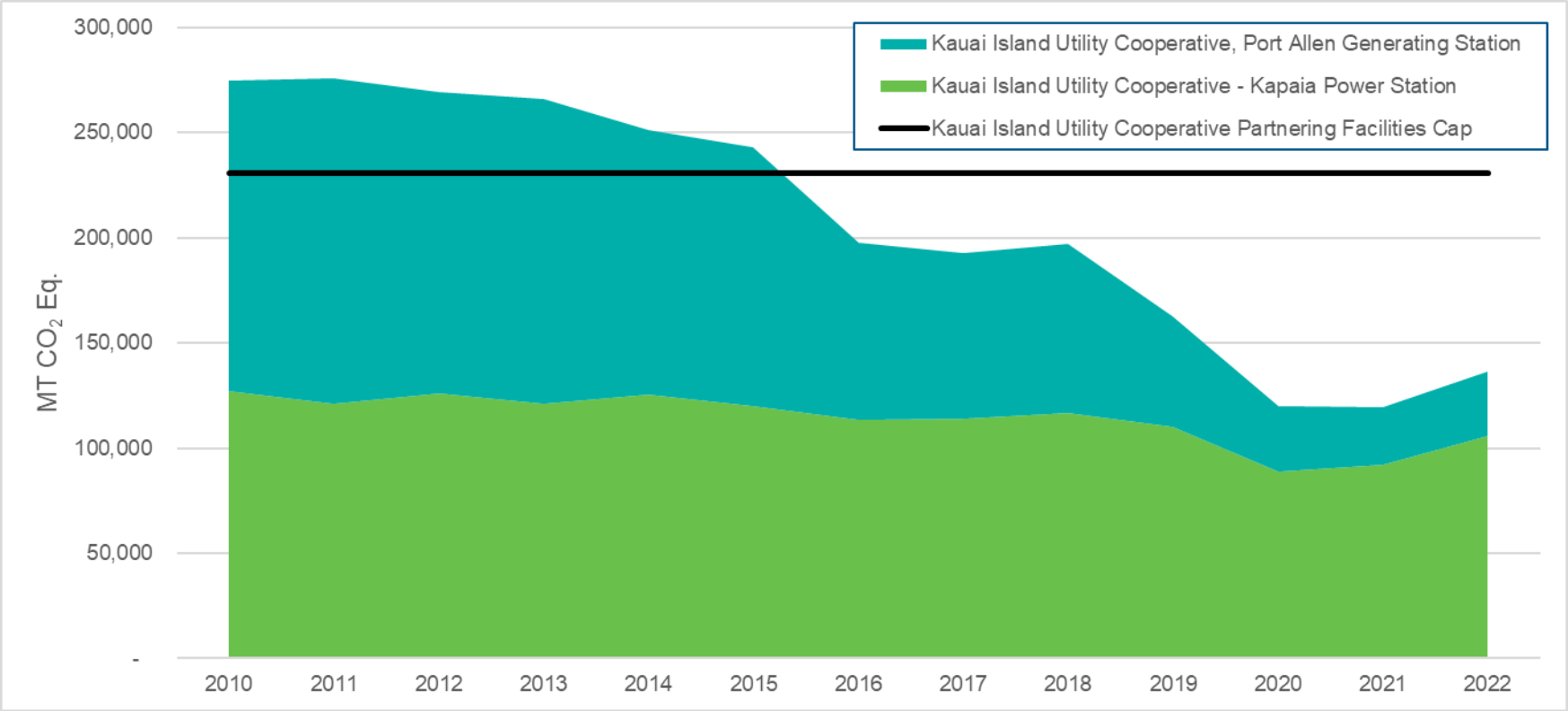


Figure E-2: Par Hawaii Refinery, LLC Partnering Facilities



Note: In this stacked area chart, emissions from Par West Refinery began in 2018 and ended in 2021.

Figure E-3: Kauai Island Utility Cooperative Partnering Facilities



Appendix F. Activity Data

This appendix summarizes activity data used to develop the inventory presented in this report.

Energy

Table F-1: Stationary Fuel Consumption by Fuel Type, Economic Sector, and Year (Bbtu)

Sector/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Residential												
Diesel Fuel	2	1	19	1	2	0	1	0	0	0	1	1
Propane	217	584	480	919	505	691	580	455	495	472	590	570
Natural Gas	605	535	528	529	562	560	558	567	529	553	551	535
Wood and Waste	0	32	172	367	14	10	32	23	23	18	17	17
Commercial												
Diesel Fuel	2,636	2,237	1,629	1,528	1,298	904	1,181	1,361	1,823	1,298	1,341	1,279
Motor Gasoline[a]	310	62	60	58	1,452	1,473	1,495	1,521	1,527	1,534	1,547	1,597
Propane	359	965	857	2,041	2,319	2,327	3,025	2,843	3,085	2,803	3,444	3,210
Residual Fuel	5,189	18	3	0	0	0	0	0	0	0	0	0
Natural Gas	2,379	1,905	1,904	1,848	1,874	2,339	2,385	2,501	2,464	1,626	1,874	2,099
Ethanol	0	1	2	3	111	112	115	117	119	121	123	127
Wood and Waste	0	3,553	2,350	2,945	3,185	3,734	3,553	3,805	3,517	3,275	3,183	3,183
Other Fuels[b]	1	0	0	0	0	0	0	0	0	0	0	0
Industrial[c]												
Coal	695	1,411	1,795	1,415	1,136	271	0	0	0	0	0	0
Diesel Fuel	4,222	2,977	2,606	1,882	1,851	939	1,789	1,515	2,191	1,988	1,641	1,658

Sector/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Motor Gasoline[a]	701	676	1,216	684	1,335	1,320	1,329	1,373	1,374	1,386	1,248	1,352
Propane	53	48	198	199	27	33	217	408	105	90	144	147
Residual Fuel	10,942	4,912	2,690	2,834	1,876	2,565	3,233	2,797	2,487	0	2,910	2,982
Natural Gas	0	455	521	353	434	81	83	87	89	76	95	83
Ethanol	0	14	37	40	102	100	103	105	107	109	99	108
Wood and Waste	18,159	68	5,447	4,392	3,169	3,360	68	68	68	68	68	68
Other Fuels[b]	2,653	1,425	169	5,349	4,404	2,917	2,791	2,310	1,994	1,889	2,328	2,332
Energy Industries												
Coal	26	15,095	15,313	15,702	14,495	16,160	14,948	14,367	14,179	13,281	12,566	7,680
Diesel Fuel	9,747	15,035	13,377	12,971	12,297	11,726	12,053	12,407	13,344	12,633	12,553	13,749
Residual Fuel	77,780	71,070	71,832	65,157	54,987	53,197	52,777	52,790	52,678	48,786	48,461	53,293
Fuel Gas[c]	0	1,763	1,763	2,503	3,793	3,160	3,991	5,599	4,391	3,324	3,953	3,957
Biodiesel[d]	0	1	25	130	867	643	907	703	469	255	223	156
Wood and Waste	7,765	1,762	0	40	853	1,076	1,762	1,456	1,297	1,062	1,368	1,368
Other Fuels[b]	(2,905)	100	573	241	(148)	67	605	231	1,060	1,127	259	(3)
Naphtha[e]	0	4,065	4,065	4,419	6,240	5,413	5,579	6,515	7,558	4,156	4,475	4,870

[a] The motor gasoline consumption totals by end-use sector, as provided by SEDS, include ethanol blended into motor gasoline. Ethanol was subtracted from the motor gasoline totals and is presented separately in the table.

[b] Other fuels include asphalt and road oil, kerosene, lubricants, waxes, aviation gasoline blending components, aviation gasoline blending components and unfinished oils.

[c].

[c] Fuel Gas data were obtained from EPA's GHGRP (EPA 2024c) for 2010, 2015, and 2016 and were only available in MMT CO_2 Eq. Fuel consumption in Bbtu was estimated by back-calculating emissions using the corresponding naphtha emissions factor from the U.S. Inventory (EPA 2024b).

[d] Biodiesel data were obtained from EPA's GHGRP (EPA 2024c) for 2015 and 2016 and were only available in MMT CO_2 Eq. Fuel consumption in Bbtu was estimated by back-calculating emissions using the corresponding biodiesel emissions factor from the U.S. Inventory (EPA 2024b).

[e] Naphtha data were obtained from EPA's GHGRP (EPA2024c) for 2010, 2015, and 2016 and were only available in MMT CO_2 Eq. Fuel consumption in Bbtu was estimated by back-calculating emissions using the corresponding naphtha emissions factor from the U.S. Inventory (EPA 2024b). Naphtha data were obtained from DBEDT (2008a) for 1990 and 2007 in Bbtu.

Sources: EIA (2024a); EPA (2024b); DBEDT (2008a).

Note: Parentheses indicate negative values.

Table F-2: Transportation Fuel Consumption by Fuel Type, Mode, and Year (Bbtu)

Mode/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Aviation												
Aviation Gasoline	1,375	224	206	188	47	35	50	109	158	119	55	57
Jet Fuel Kerosene[a]	70,406	103,698	80,796	67,057	78,891	80,535	85,820	87,073	88,949	45,174	67,252	77,684
Ground												
Diesel Fuel[b]	9,674	13,759	16,096	10,412	10,511	8,785	8,384	9,306	8,151	6,240	5,995	5,400
Motor Gasoline[c]	39,916	55,034	55,301	47,059	49,072	49,902	49,515	47,813	48,286	37,337	42,825	43,034
Propane	49	57	48	13	17	17	0	0	0	0	0	0
Natural Gas	0	3	3	2	2	2	2	2	0	1	2	0
Ethanol	0	1,176	1,699	2,742	3,765	3,787	3,821	3,717	3,804	2,942	3,401	3,430
Biodiesel[d]	0	58	204	38	0	584	576	699	558	566	984	1,017
Marine												
Diesel Fuel[b]	5,771	8,241	9,601	6,061	627	973	772	819	1,098	1,097	434	1,880
Motor Gasoline[c]	18	35	35	43	54	23	25	722	464	45	31	22
Residual Fuel[e]	15,897	7,049	28,069	6,756	4,394	5,091	7,215	6,443	8,299	4,796	7,505	7,690
Ethanol	0	0	0	3	4	1	1	2	2	1	1	1
Military Aviation												
Aviation Gasoline	0	0	0	+	+	+	+	+	+	+	+	+
Jet Fuel Kerosene[a]	1,969	14,102	10,987	9,119	11,043	10,952	11,671	11,841	12,096	6,143	9,146	10,564
Naphtha[f]	17,786	0	0	0	0	0	0	0	0	0	0	0
Military Non-Aviation												
Diesel Fuel[b]	4,929	205	10,428	6,738	669	2,202	2,632	4,199	2,181	4,255	4,255	4,255
Motor Gasoline	4,597	0	0	0	0	0	0	0	0	0	0	0
Residual Fuel[e]	806	0	0	0	0	0	0	0	0	0	0	0

+ Does not exceed 0.5 Bbtu.
[a] SEDS jet fuel consumption was apportioned between aviation and military aviation based on the breakout of the data collected by DBEDT (2008a) into military aviation and non-military aviation. For 1990, a portion of jet fuel consumption was allocated to military aviation naphtha consumption based on direct communication with EIA (2019).
[b] SEDS diesel consumption was apportioned between ground, marine, and military non-aviation based on the breakout of the data collected by DBEDT (2008a) by end-use sector. Biodiesel consumption data collected by DBEDT (2024a) was subtracted from the SEDS diesel total as the SEDS data includes biodiesel.
[c] The motor gasoline consumption totals by end-use sector, as provided by SEDS, include ethanol blended into motor gasoline. Ethanol was subtracted from the motor gasoline totals and is presented separately in the table.
[d] Biodiesel data was collected by DBEDT (2024a).
[e] 1990 residual fuel data from SEDS were apportioned between marine and military non-aviation based on military residual fuel data obtained from EIA Fuel Oil and Kerosene Sales (EIA 2019).
[f] Military aviation naphtha consumption was obtained from direct communication with EIA (2019).
Sources: EIA (2024a); EIA (2019); DBEDT (2024a).

Table F-3: Share of Consumption Used for Non-Energy Uses (%)

Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Industrial												
Coal	0.5%	0.9%	0.9%	1.0%	1.3%	1.4%	1.5%	1.6%	1.8%	2.1%	2.1%	2.1%
Asphalt and Road Oil	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Propane	74.2%	80.1%	79.5%	87.1%	88.8%	86.6%	86.9%	86.7%	84.6%	85.2%	85.6%	85.1%
Lubricants	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Diesel Fuel	0.6%	1.4%	1.2%	0.5%	0.6%	0.6%	0.6%	0.5%	0.5%	0.6%	0.6%	0.6%
Transportation												
Lubricants	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: EPA (2024c).

Table F-4: Non-Energy Use Consumption (Bbtu)

Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Industrial												
Coal	3	12	17	13	15	4	0	0	0	0	0	0
Diesel Fuel	27	42	32	10	10	6	11	8	12	12	10	9
Propane	39	38	157	173	24	29	189	354	89	77	123	125
Other Fuels[a]	2,652	1,424	169	5,349	4,404	2,917	2,791	2,310	1,994	1,889	2,328	2,332
Aviation												
Other Fuels[a]	214	184	185	14	45	51	44	60	105	63	97	89
Ground Transportation												
Other Fuels[a]	187	161	162	383	382	330	308	281	250	211	221	234
Marine Transportation												
Other Fuels[a]	61	53	53	66	27	22	22	20	16	8	3	13

[a] Other fuels include asphalt and road oil, lubricants, and waxes.
Sources: EIA (2024a), EPA (2024c).

Table F-5: Derived Consumption Data Used to Apportion Jet Fuel Data to International Bunker Fuels ('000 Gallons)

Aviation Miles	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
International	7,336	9,741	9,817	9,536	16,309	17,189	18,000	18,434	18,461	6,771	5,018	10,709
Domestic	18,137	41,485	45,938	41,106	47,903	50,474	50,472	55,849	59,688	32,123	72,321	69,358
International Share	28.8%	19.0%	17.6%	18.8%	25.4%	25.4%	26.3%	24.8%	23.6%	17.4%	6.5%	13.4%
Domestic Share	71.2%	81.0%	82.4%	81.2%	74.6%	74.6%	73.7%	75.2%	76.4%	82.6%	93.5%	86.6%

Notes: Consumption data are from flights originating in Hawai'i. Flights with a destination within Hawai'i or to the mainland U.S. are considered domestic while flights with an international destination are considered international.
Source: DOT (2022a).

Table F-6: International Bunker Fuel Consumption by Fuel Type, Mode, and Year (Bbtu)

Mode/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Aviation[a]												
Jet Fuel Kerosene	20,277	19,718	14,226	12,627	20,037	20,459	22,560	21,608	21,012	7,864	4,363	10,390
Marine[b]												
Diesel Fuel	944	1,263	251	2,398	1,084	461	1,191	2,095	1,095	1,350	1,043	1,038
Residual Fuel	465	9,190	425	2,826	247	323	405	590	435	166	26	3

[a] Calculated based on domestic and international flight mileage data from DOT (2022a).
[b] Obtained directly from the Census Bureau (DOC 2005, 2007, 2010, 2015 through 2022). Data are provided in barrels, then converted to gallons using a conversion factor of 42 gallons per barrel before being converted to Bbtu using a conversion factor of 0.000139 Bbtu per gallon. For 1990, marine bunker fuel consumption was estimated based on the ratio Hawai‘i consumption to total U.S. consumption in 2006 (the earliest year data is available for Hawai‘i marine bunker fuel). National marine bunker fuel consumption was obtained from the U.S. Inventory (EPA 2024b).
Source: EIA (2024a), DOT (2022a), DOC (2005, 2007, 2010, 2015 through 2022), EPA (2024b).

IPPU

Table F-7: Clinker production by Year (MT)

	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Clinker Production	195,044	0	0	0	0	0	0	0	0	0	0	0

Source: Wurlitzer (2008). Cement production ended in 2001.

Table F-8: Electricity Sales by Year (million MWh)

	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai‘i	8.3	10.5	10.6	10.0	9.4	9.3	9.1	9.1	9.2	8.5	8.7	8.8
U.S.	2,712.6	3,661.0	3,764.6	3,754.8	3,759.0	3,762.5	3,723.4	3,859.2	3,811.2	3,717.7	3,805.9	3,927.2

Sources: EIA (2023a) (U.S.); DBEDT (2023) (Hawai‘i).

Table F-9: Registered Vehicles by Year (thousands)

	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai‘i	870.7	1,091.3	1,103.8	1,086.2	1,193.9	1,194.7	1,213.1	1,219.6	1,232.9	1,190.5	1,188.4	1,207.8
U.S.	188,170.9	240,386.9	246,430.2	241,214.5	254,120.4	259,143.5	262,782.5	263,943.8	266,899.8	266,578.6	271,534.4	272,879.2

Sources: FHWA (2023) (U.S.); DBEDT (2023) (Hawai‘i).

Table F-10: U.S. GHG Emissions by Year (MMT CO_2 Eq.)

Source	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Cars and Trucks A/C ODS Substitutes	0.00	61.53	62.91	59.22	37.22	34.01	30.67	28.66	26.64	24.63	22.85	20.79
Other A/C ODS Substitutes	0.02	2.96	4.94	9.46	22.08	25.36	28.84	32.43	35.99	40.12	48.79	54.04
Other ODS Substitutes	0.24	34.98	45.24	69.12	94.79	96.48	96.69	96.79	99.47	101.48	101.03	103.30
Electrical Transmission and Distribution	24.70	11.90	10.20	7.80	5.30	5.40	5.30	5.00	6.10	5.90	6.00	5.10

Source: EPA (2024b).

AFOLU

Table F-11: Animal Population by Animal Type, Year (Thousand Head)

Animal Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Cattle	**198.8**	**157.8**	**159.3**	**149.1**	**128.9**	**136.2**	**138.1**	**139.5**	**139.7**	**135.7**	**132.9**	**143.9**
Dairy Cattle	**22.8**	**10.7**	**6.8**	**3.7**	**4.3**	**4.3**	**4.6**	**4.1**	**3.3**	**2.1**	**2.5**	**2.2**
Dairy Cows	11.0	5.7	3.8	1.8	2.2	2.2	2.4	2.0	1.5	0.7	0.7	0.8
Dairy Replacement Heifers	5.9	2.0	1.0	1.0	1.0	1.0	1.0	1.1	1.0	1.0	1.0	1.0
7-11 months	1.7	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
12-23 months	4.2	1.4	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.7	0.7

Animal Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Dairy Calves	5.9	2.9	2.0	0.9	1.1	1.1	1.2	1.0	0.8	0.4	0.8	0.4
Beef Cattle	**176.0**	**147.1**	**152.6**	**145.4**	**124.5**	**131.9**	**133.5**	**135.4**	**136.4**	**133.7**	**130.4**	**141.7**
Beef Cows	75.0	81.3	85.2	81.2	68.8	72.8	73.6	75.0	75.5	75.3	72.2	79.2
Beef Replacement Heifers	12.8	12.1	11.9	9.5	8.9	9.2	10.4	9.3	10.4	8.7	9.7	10.9
7-11 months	3.8	3.6	3.5	2.7	2.7	2.7	3.0	2.8	3.0	2.6	2.9	2.9
12-23 months	9.0	8.4	8.4	6.7	6.2	6.5	7.3	6.5	7.3	6.2	6.8	8.0
Other Beef Heifers	17.6	2.8	2.7	3.5	2.9	3.0	2.4	2.6	2.5	2.7	2.4	2.4
Heifer Stockers	13.0	2.6	2.5	3.1	2.6	2.7	2.1	2.2	2.1	2.3	2.1	2.0
Heifer Feedlot	4.7	0.2	0.2	0.4	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.4
Steers	26.5	3.9	4.3	4.7	4.8	5.3	5.5	5.9	5.6	5.3	5.9	4.8
Steer Stockers	17.3	3.5	3.9	4.0	4.3	4.7	4.8	5.1	4.9	4.6	5.2	4.1
Steer Feedlot	9.2	0.4	0.4	0.8	0.5	0.6	0.7	0.8	0.7	0.7	0.7	0.7
Beef Calves	39.1	42.1	43.4	41.5	35.2	37.5	37.6	38.7	38.5	37.6	36.7	40.3
Bulls	5.0	5.0	5.0	5.0	4.0	4.0	4.0	4.0	4.0	4.0	3.6	4.0
Sheep and Lambs	**22.5**	**21.4**	**22.4**	**22.1**	**25.1**	**26.1**	**27.2**	**25.4**	**25.7**	**26.0**	**26.3**	**21.5**
Goats	**3.3**	**7.6**	**9.2**	**11.5**	**14.9**	**15.6**	**16.2**	**17.0**	**17.8**	**18.5**	**19.2**	**12.3**
Swine	**36.0**	**19.0**	**15.0**	**12.5**	**9.0**	**10.0**	**8.0**	**9.0**	**11.0**	**10.0**	**9.0**	**7.0**
Horses and ponies	**3.8**	**5.8**	**6.5**	**5.7**	**4.8**	**4.7**	**4.5**	**5.2**	**5.2**	**5.2**	**5.2**	**4.3**
Chickens	**1,487.9**	**629.4**	**424.6**	**368.9**	**256.2**	**242.6**	**228.9**	**215.8**	**204.9**	**194.7**	**185.2**	**171.9**
Chickens (excluding broilers)	1,183.0	547.0	422.5	366.0	247.0	231.0	216.0	203.3	191.3	179.9	169.2	159.2
Broilers	304.9	82.4	2.1	2.9	9.0	10.9	12.8	12.5	13.6	14.8	16.0	12.8

Sources: (EPA 2024b) (cattle); (USDA 2024a) (swine); USDA (1989, 1994, 2009, 2014, 2019, and 2024b) [sheep, goats, horses, broilers, and chickens (for years 1990 – 2022)].

Table F-12: Crop Area by Crop Type, Year (Acres)

Crop Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Sugarcane for sugar	72,000	21,700	20,400	15,500	12,900	15,500	30	0	0	0	0	0
Pineapples	18,205	8,358	(D)	5,986	4,288	4,011	3,752	3,510	3,283	3,071	2,873	(D)
Sweet potatoes	193	296	297	648	878	877	876	976	1,019	1,063	1,106	539
Ginger root	300	122	80	64	115	136	157	132	132	132	132	175
Taro	462	548	535	503	489	492	495	463	457	450	444	557
Corn for grain	0	3,622	3,115	4,365	5,019	4,959	4,899	5,443	5,580	5,718	5,855	2,176
Seed production	900	3,680	4,260	6,500	4,260	3,980	4,090	3,030	2,790	2,360	2,240	2,235

Sources: USDA (2018b) (sugarcane); USDA (1989, 1994, 2009, 2014, 2019, and 2024b) (pineapples, sweet potatoes, ginger root, taro, and corn for grain); USDA (2004b, 2015, 2022) (seed production).
(D) data withheld by USDA to avoid disclosing information for individual operations.

Table F-13: Crop Production by Crop Type, Year (Thousand Tons)

Crop Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Sugarcane for sugar	6,538.0	1,753.0	(D)	1,195.0	1,139.0	1,336.0	0.4	0.0	0.0	0.0	0.0	(D)
Pineapples	607.3	257.9	(D)	185.2	133.0	124.5	116.5	109.1	102.1	95.5	89.4	123.8
Sweet potatoes	1.0	1.2	1.4	3.1	4.2	4.2	4.2	5.0	5.2	5.4	5.7	2.6
Ginger root	4.5	1.8	1.3	0.9	1.6	1.9	2.2	2.0	2.1	2.2	2.4	2.5
Taro	3.5	2.4	2.6	2.1	2.3	2.5	2.7	2.4	2.5	2.5	2.6	3.1
Corn for grain	0.0	4.4	3.5	7.6	12.9	13.7	14.6	16.1	17.2	18.3	19.4	4.3
Seed production	1.2	4.4	4.8	11.3	10.9	11.0	12.2	9.0	8.6	7.5	7.4	4.4

Sources: USDA (2018b) (sugarcane); USDA (1989, 1994, 2009, 2014, 2019, 2024b) (pineapples, sweet potatoes, ginger root, taro, and corn for grain); USDA (2004b, 2015, 2022) (seed production).
(D) data withheld by USDA to avoid disclosing information for individual operations.

Table F-14: Fertilizer Consumption by Fertilizer Type, Fertilizer Years

Year	Urea Fertilizer Consumption (short tons)	Synthetic Fertilizer Consumption (kg N)
1990	2,638	16,161,178
2005	2,038	12,550,066
2007	2,038	12,550,115
2010	2,002	12,519,269
2015	2,121	13,108,252
2016	2,150	13,277,305
2017	2,112	13,292,183
2018	2,093	13,140,022
2019	2,074	13,089,401
2020	2,055	13,038,780
2021	2,036	12,988,160
2022	2,018	12,988,160

Sources: TVA (1991 through 1994) (urea fertilizer); AAPFCO (1995 through 2019) (urea and synthetic fertilizer), EPA (2023a)

Table F-15: Wildfire Area Burned by Year (Hectares)

Area Burned	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Area Burned (Hectares)	1,705	18,753	15,586	7,987	5,546	9,225	3,427	13,107	9,292	7,997	18,634	7,325

Source: Pacific Fire Exchange (Trauernicht et al., 2015)

Table F-16: Forest and Shrubland Area (Hectares)

Forest and Shrubland Area	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Forest and Shrubland Area (Hectares)	494,360	485,107	483,029	482,769	484,121	484,830	485,301	453,349	453,349	441,726	441,221	453,608

Source: DBEDT (2024a).

Table F-17: Forest and Shrubland Area (%)

Forest and Shrubland Area	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Forest	52.0%	58.5%	60.9%	64.5%	68.4%	68.4%	68.4%	68.4%	68.4%	68.4%	68.4%	68.4%
Shrubland	48.0%	41.5%	39.1%	35.5%	31.6%	31.6%	31.6%	31.6%	31.6%	31.6%	31.6%	31.6%

Sources: NOAA-CCAP (2000); Selmants et al. (2017).

Table F-18: Hawai'i Landfilled Yard Trimmings and Food Scraps (thousand short tons, wet weight)

Material	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Landfilled Yard Trimmings	**126**	**48**	**45**	**55**	**54**	**48**	**43**	**53**	**46**	**40**	**41**	**40**
Grass	38	14	14	17	16	15	13	16	14	12	12	12
Leaves	51	19	18	22	22	19	17	21	18	16	16	16
Branches	37	14	13	16	16	14	13	16	14	12	12	12
Food Scraps	**85**	**115**	**119**	**136**	**151**	**153**	**153**	**265**	**197**	**185**	**202**	**214**

Source: EPA (2020).

Table F-19: Hawai'i Urban Area (km^2)

Hawai'i Urban Area	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Urban Area (km^2)	757.0	981.7	1,006.1	1,042.8	1,000.7	992.3	983.9	975.5	967.1	958.7	972.7	986.9

Sources: U.S. Census Bureau (1990a, 2002, 2012); Nowak et al. (2005).

Waste

Table F-20: Quantity of MSW Landfilled (MT) in Hawaii by Year

Year	Amount	Year	Amount	Year	Amount
1960	312,381	**1981**	852,137	**2002**	822,814

Year	Amount	Year	Amount	Year	Amount
1961	336,277	**1982**	868,330	**2003**	814,567
1962	360,910	**1983**	887,551	**2004**	881,034
1963	372,098	**1984**	903,600	**2005**	994,112
1964	394,914	**1985**	916,714	**2006**	924,488
1965	410,684	**1986**	930,154	**2007**	803,274
1966	428,276	**1987**	947,296	**2008**	692,983
1967	450,956	**1988**	960,756	**2009**	572,399
1968	473,394	**1989**	976,832	**2010**	546,656
1969	500,171	**1990**	996,000	**2011**	555,138
1970	530,921	**1991**	702,000	**2012**	517,978
1971	565,703	**1992**	702,000	**2013**	480,571
1972	598,176	**1993**	980,000	**2014**	500,888
1973	629,328	**1994**	1,040,000	**2015**	513,907
1974	656,404	**1995**	827,142	**2016**	536,847
1975	685,793	**1996**	889,342	**2017**	609,923
1976	716,076	**1997**	851,153	**2018**	628,535
1977	744,188	**1998**	763,193	**2019**	574,249
1978	772,606	**1999**	759,442	**2020**	595,765
1979	809,071	**2000**	780,692	**2021**	678,570
1980	837,840	**2001**	817,079	**2022**	666,930

Sources: Hawai‘i DOH (2024); Otsu (2008); EPA (2024c).

Table F-21: Weight of Composted MSW (MT) per County by Year

MSW Composted	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai‘i	22,564[a]	31,041	34,377	38,009	37,097	59,602	37,629	35,538	37,884	36,665	1,139	34,456
Maui	37,455[a]	50,067[a]	51,390[a]	52,705	46,637	46,255	51,112	46,087	51,157	51,768	7,267	10,872
Honolulu	60,190[a]	63,226	63,506[a]	75,163	65,233	90,465	98,608	100,745	86,412	95,628	95,544	83,030

MSW Composted	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Kaua‘i	12,812[a]	14,869[a]	15,565[a]	15,547	22,019	16,591	14,811	16,548	22,644	20,236	7,892	22,810

[a] Weight composted is calculated using a proxy to the nearest year with available data on per capita composting rate.
Source: Hawai‘i DOH (2024).

Table F-22: Per Capita Biological Oxygen Demand for Wastewater treatment (kg/person/day) by Island

Island	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai‘i	0.0615	0.0615	0.0615	0.0059	0.0052	0.0054	0.0052	0.0046	0.0042	0.0031	0.0026	0.0001
Kaua‘i	0.0615	0.0615	0.0615	0.0001	0.0002	0.0007	0.0007	0.0002	0.0002	0.0003	0.0003	0.0002
Lāna‘i	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0165	0.0109	0.0059	0.0062	0.0069	0.0070
Maui	0.0615	0.0615	0.0615	0.0003	0.0003	0.0005	0.0006	0.0007	0.0006	0.0007	0.0008	0.0009
Moloka‘i	0.0615	0.0615	0.0615	0.0615	0.0615	0.0008	0.0008	0.0010	0.0008	0.0011	0.0019	0.0024
Ni‘ihau	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615	0.0615
O‘ahu	0.0615	0.0615	0.0615	0.0289	0.0264	0.0262	0.0261	0.0247	0.0249	0.0175	0.0174	0.0129

Sources: Pruder (2008), Hawai‘i DOH (2017, 2018, 2022a, 2022b, 2022c, 2022d, and 2022e).

Table F-23: Fraction of Population not on Septic (percent)

Country	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
US	75.6%	78.8%	79.4%	79.9%	80.1%	81.1%	82.1%	82.9%	83.6%	84.2%	84.8%	83.6%

Source: EPA (2024b).

Table F-24: Hawai‘i Annual Protein Consumption (kg/person/year)

State	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai‘i	43.1	44.9	44.9	43.8	44.3	44.5	44.7	44.9	44.4	44.6	44.6	44.4

Source: EPA (2024d).

Appendix G. Emission Factors

This appendix summarizes emission factors used to develop the inventory presented in this report.

Energy

Table G-1: CO_2 Emission Factors Used to Estimate Emissions from Stationary Fuel Use by Fuel Type, Economic Sector, and Year (lb C/MMBtu)

Sector/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Residential												
Diesel Fuel	44.47	44.91	44.64	44.62	44.58	44.56	44.56	44.58	44.58	44.58	44.58	44.58
Propane	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81
Natural Gas	31.88	31.88	31.88	31.92	31.81	31.81	31.81	31.81	31.81	31.81	31.81	31.81
Commercial												
Diesel Fuel	44.47	44.91	44.64	44.62	44.58	44.56	44.56	44.58	44.58	44.58	44.58	44.58
Motor Gasoline	42.81	42.59	43.14	42.75	42.44	42.46	42.51	42.48	42.48	42.48	42.48	42.48
Propane	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81
Residual Fuel	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15
Natural Gas	31.88	31.88	31.88	31.92	31.81	31.81	31.81	31.81	31.81	31.81	31.81	31.81
Other Fuels												
Kerosene	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*
Industrial												
Coal	57.19	57.50	57.39	57.43	57.47	57.45	57.50	57.52	57.50	57.58	57.61	57.61
Diesel Fuel	44.47	44.91	44.64	44.62	44.58	44.56	44.56	44.58	44.58	44.58	44.58	44.58
Motor Gasoline	42.81	42.59	43.14	42.75	42.44	42.46	42.51	42.48	42.48	42.48	42.48	42.48
Propane	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81

Sector/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Residual Fuel	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15
Natural Gas	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88
Other Fuels												
Asphalt and Road Oil	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*	*45.30*
Kerosene	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*	*44.00*
Lubricants	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*	*44.53*
Waxes	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*	*43.64*
Energy Industries												
Coal	57.19	57.50	57.39	57.43	57.47	57.45	57.50	57.52	57.50	57.58	57.61	57.61
Diesel Fuel	44.47	44.47	44.47	44.47	44.47	44.47	44.47	44.47	44.47	44.47	44.47	44.47
Residual Fuel	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15
Fuel Gas	40.12	40.12	40.12	40.12	40.12	40.12	40.12	40.12	40.12	40.12	40.12	40.12
Other Fuels												
Aviation Gasoline Blending Components	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*	*41.60*
Motor Gasoline Blending Components	*42.81*	*42.68*	*43.12*	*42.90*	*42.90*	*42.90*	*42.90*	*42.90*	*42.90*	*42.90*	*42.90*	*42.90*
Unfinished Oils	*44.42*	*44.78*	*44.71*	*44.78*	*44.78*	*44.78*	*44.78*	*44.78*	*44.78*	*44.78*	*44.78*	*44.78*

Source: EPA (2024b).

Table G-2: CH_4 and N_2O Emission Factors Used to Estimate Emissions from Stationary Fossil Fuel Use by Fuel Type and End-Use Sector (g/GJ)

Fuel Type/Sector	CH_4	N_2O
Coal		
Industrial	10	1.5
Energy Industries	1	1.5
Petroleum		
Residential	10	0.6
Commercial	10	0.6
Industrial	3	0.6
Energy Industries	3	0.6
Natural Gas		
Residential	5	0.1
Commercial	5	0.1
Industrial	1	0.1
Wood		
Residential	300	4
Commercial	300	4
Industrial	30	4
Energy Industries	30	4

Source: IPCC (2006).

Table G-3: C, CH_4, and N_2O Emission Factors Used to Estimate Emissions from Biofuel Use by Fuel Type

Fuel Type	C (lb C/MMBtu)	CH_4 (kg/Bbtu)	N_2O (kg/Bbtu)
Ethanol	41	19	NA
Biodiesel	40	9.5	0.57
Wood[a]	94	NA	NA
Renewable Natural Gas	52	3.2	0.63

NA (emissions are Not Applicable).

[a] Methane and N_2O emission factors for Wood are reported in Source: EPA (2024b).

Table G-4: CO_2 Emission Factors Used to Estimate Emissions from Non-Highway Vehicles by Fuel Type and Year (lb C/MMBtu)

Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Aviation Gasoline	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58
Diesel Fuel	44.47	44.91	44.64	44.62	44.58	44.56	44.56	44.58	44.58	44.58	44.58	44.58
Jet Fuel Kerosene	42.77	43.43	43.43	43.43	43.43	43.43	43.43	43.43	43.43	43.43	43.43	43.43
Motor Gasoline	42.81	42.59	43.14	42.75	42.44	42.46	42.51	42.48	42.48	42.48	42.48	42.48
Propane	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81	37.81
Residual Fuel	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15	45.15
Natural Gas	31.88	31.88	31.88	31.92	31.81	31.81	31.81	31.81	31.81	31.81	31.81	31.81
Ethanol	41.16	41.16	41.16	41.16	41.16	41.16	41.16	41.16	41.16	41.16	41.16	41.16
Biodiesel	40.42	40.42	40.42	40.42	40.42	40.42	40.42	40.42	40.42	40.42	40.42	40.42
Lubricants	44.53	44.53	44.53	44.53	44.53	44.53	44.53	44.53	44.53	44.53	44.53	44.53

Source: EPA (2024b).

Table G-5: CH_4 and N_2O Emission Factors Used to Estimate Emissions from Highway Vehicles by Vehicle Type and Control Technology (g/mile)

Vehicle Type/Control Technology	CH_4	N_2O
Gasoline Passenger Cars		
EPA Tier 3 / CARB LEV III	0.0045	0.0012
EPA Tier 2	0.0072	0.0048
CARB LEV II	0.0070	0.0043
CARB LEV	0.0100	0.0205
EPA Tier 1a	0.0271	0.0429
EPA Tier 0 a	0.0704	0.0647
Oxidation Catalyst	0.1355	0.0504
Non-Catalyst Control	0.1696	0.0197
Uncontrolled	0.1780	0.0197
Gasoline Light-Duty Trucks		
EPA Tier 3 / CARB LEV III	0.0065	0.0012
EPA Tier 2	0.0100	0.0025
CARB LEV II	0.0084	0.0057
CARB LEV	0.0148	0.0223
EPA Tier 1a	0.0452	0.0871
EPA Tier 0a	0.0776	0.1056
Oxidation Catalyst	0.1516	0.0639
Non-Catalyst Control	0.1908	0.0218
Uncontrolled	0.2024	0.0220
Gasoline Heavy-Duty Vehicles		
EPA Tier 3 / CARB LEV III	0.0411	0.0136
EPA Tier 2	0.0297	0.0015
CARB LEV II	0.0391	0.0049
CARB LEV	0.0300	0.0466
EPA Tier 1a	0.0655	0.1750
EPA Tier 0a	0.2630	0.2135
Oxidation Catalyst	0.2356	0.1317
Non-Catalyst Control	0.4181	0.0473
Uncontrolled	0.4604	0.0497
Diesel Passenger Cars		
Advanced	0.0005	0.0010
Moderate	0.0005	0.0010
Uncontrolled	0.0006	0.0012
Diesel Light-Duty Trucks		
Advanced	0.0009	0.0014

Vehicle Type/Control Technology	CH_4	N_2O
Moderate	0.0009	0.0014
Uncontrolled	0.0011	0.0017
Diesel Medium- and Heavy-Duty Trucks		
Aftertreatment	0.0095	0.0431
Advanced	0.0051	0.0048
Moderate	0.0051	0.0048
Uncontrolled	0.0051	0.0048
Diesel Medium- and Heavy-Duty Buses		
Aftertreatment	0.0129	0.0741
Advanced	0.0070	0.0083
Moderate	0.0070	0.0083
Uncontrolled	0.0070	0.0083
Motorcycles		
Non-Catalyst Control	0.0672	0.0069
Uncontrolled	0.0899	0.0087

Source: EPA (2024b).

Table G-6: N_2O Emission Factors Used to Estimate Emissions from Off-Road Vehicles by Vehicle Type and Fuel Type (g/kg fuel)

Vehicle/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Ships and Boats												
Residual Fuel	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Aircraft												
Aviation Gasoline	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Industrial and Commercial Equipment												
Motor Gasoline	0.43	0.52	0.53	0.54	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.56
Diesel Fuel	0.18	0.18	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.20

Source: EPA (2024b).

Table G-7: CH_4 Emission Factors Used to Estimate Emissions from Off-Road Vehicles by Vehicle Type and Fuel Type (g/kg fuel)

Vehicle/Fuel Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Ships and Boats												
Residual Fuel	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
Aircraft												
Aviation Gasoline	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64	2.64
Industrial and Commercial Equipment												
Motor Gasoline	0.76	0.91	0.94	0.97	0.99	0.99	0.99	0.99	0.99	0.98	0.98	1.01
Diesel Fuel	0.12	0.11	0.12	0.13	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.14

Source: EPA (2024b).

Table G-8: CH_4 and N_2O Emission Factors Used to Estimate Emissions from Natural Gas Use for Off-Road Vehicles (kg/TJ fuel)

Fuel Type	CH_4	N_2O
Natural Gas	92	3

Source: IPCC (2006).

Table G-9: CH_4 and N_2O Emission Factors Used to Estimate Emissions from International Bunker Fuels by Fuel Type (g/kg fuel)

Fuel Type	CH_4	N_2O
Jet Fuel Kerosene	NA	0.10
Diesel Fuel	0.315	0.08
Residual Fuel	0.315	0.08

NA (emissions are Not Applicable).
Source: IPCC (2006).

IPPU

Table G-10: Clinker Production Emission Factors and Correction Factor by Year (Ton CO_2/Ton clinker produced)

	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Clinker Production (EF)	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51
Cement kiln dust correction factor	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02

Source: IPCC (2006).

AFOLU

Table G-11: CH_4 Cattle Emission Factors Used to Estimate Emissions from Enteric Fermentation by Cattle Type, and Year (kg CH_4 per head per year)

Cattle Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Dairy Cows	115.42	104.77	105.68	108.24	118.07	113.11	122.47	122.94	122.94	122.94	122.94	122.94
Dairy Replacements 7-11 months	47.94	44.59	46.24	45.92	45.64	45.62	45.58	45.54	45.51	45.47	45.47	45.47
Dairy Replacements 12-23 months	72.54	67.29	69.78	69.31	68.90	68.86	68.75	68.73	68.65	68.68	68.68	66.68
Other Dairy Heifers	60.24	55.94	58.01	57.62	57.27	57.24	57.39	57.48	57.48	57.45	57.45	57.45
Dairy Calves	11.54	11.74	12.23	12.16	12.20	12.17	12.18	12.18	12.27	12.27	12.27	57.45
Beef Cows	93.70	98.78	99.81	99.77	99.95	100.04	100.15	100.25	100.31	100.37	100.37	103.3
Beef Replacements 7-11 months	57.91	63.33	64.52	64.56	64.38	64.44	64.54	64.53	64.51	64.45	64.45	64.45
Beef Replacements 12-23 months	67.43	73.14	74.26	74.26	74.28	74.27	74.26	74.26	74.27	74.27	74.27	74.27
Heifer Stockers	36.36	33.32	36.63	31.20	37.19	35.19	36.36	36.64	34.11	35.73	35.73	35.73
Heifer Feedlot	33.15	31.48	34.49	29.01	36.67	34.55	35.16	35.03	31.97	34.62	34.62	34.62
Steer Stockers	34.10	32.85	35.81	30.85	36.74	34.07	34.79	35.32	33.32	34.95	34.95	34.95
Steer Feedlot	33.15	31.48	34.49	29.01	36.67	34.55	35.16	35.03	31.97	34.15	34.15	34.15
Beef Calves	11.57	11.35	11.29	11.27	11.31	11.30	11.30	11.30	11.32	11.33	11.33	11.33
Bulls	96.45	102.66	103.89	103.89	103.89	103.89	103.89	103.89	103.89	103.89	103.89	103.89

Source: EPA (2024b).

Table G-12: Typical Animal Mass (TAM) by Cattle Type and Year (kg)

Cattle Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Dairy Cows	680	680	680	680	680	680	680	680	680	680	680	680
Dairy Replacement Heifers	408	406	406	407	406	407	407	408	408	408	408	408
Other Dairy Heifers	408	406	406	407	406	407	407	408	408	408	408	408
Dairy Calves	122	123	123	122	123	123	123	123	123	123	123	123
Beef Cows	553	601	611	611	611	611	611	611	611	611	611	611
Beef Replacement Heifers	372	399	406	406	404	405	406	406	406	406	406	406
Heifer Stockers	295	320	320	323	324	326	322	322	322	322	322	318
Heifer Feedlot	383	416	421	425	445	449	444	444	444	444	444	448
Steer Stockers	314	325	327	329	325	327	324	324	324	324	324	325
Steer Feedlot	418	442	450	452	470	475	471	471	471	471	471	480
Beef Calves	122	123	123	122	123	123	123	123	123	123	123	123
Bulls	830	902	916	916	916	916	916	916	916	916	916	916

Source: EPA (2024b).

Table G-13: Volatile Solids (VS) by Animal Type and Year (kg VS/1000 kg animal mass/day)

Cattle Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Dairy Cows	7.8	7.6	8.0	8.3	9.1	8.7	9.4	9.5	4.4	4.4	4.4	4.4
Dairy Replacement Heifers	7.9	7.9	8.5	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Other Dairy Heifers	7.9	7.9	8.5	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Dairy Calves	6.4	7.4	7.6	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7

Cattle Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Beef Cows	8.7	8.5	8.4	8.4	8.4	8.4	8.5	8.5	8.5	8.5	8.5	8.5
Beef Replacement Heifers	8.0	8.5	8.5	8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Heifer Stockers	10.0	10.6	10.8	10.6	10.6	10.6	10.8	10.7	10.7	10.7	10.7	10.8
Heifer Feedlot	5.7	4.4	4.4	4.4	4.3	4.2	4.3	4.2	4.2	4.3	4.3	3.9
Steer Stockers	9.2	9.4	9.4	9.3	9.4	9.4	9.5	9.4	9.5	9.5	9.5	9.4
Steer Feedlot	5.2	4.0	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.5
Beef Calves	6.4	7.4	7.6	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
Bulls	6.0	5.9	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
Sheep	9.2	8.6	8.4	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Goats	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Horses	10.0	7.3	6.5	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
Chickens	10.8	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
Broilers	15.0	16.5	16.8	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Swine Breeding	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Swine < 50 lbs.	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Swine 50 - 119 lbs.	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Swine 120 - 179 lbs.	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Swine > 180 lbs.	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4

Source: EPA (2024b).

Table G-14: Nitrogen Excreted (Nex) Produced by Animal Type and Year (kg Nex per head per year)

Cattle Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Dairy Cows	143.8	129.5	125.9	124.4	133.0	129.1	136.8	137.3	83.8	83.8	83.8	83.8
Dairy Replacement Heifers	79.1	72.0	71.3	68.9	68.8	69.0	68.9	69.0	68.9	69.1	69.1	69.2
Other Dairy Heifers	79.1	72.0	71.3	68.9	68.8	69.0	68.9	69.0	68.9	69.1	69.1	69.1
Dairy Calves	13.4	18.5	19.6	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
Beef Cows	52.5	55.8	59.0	59.0	59.0	59.0	59.1	59.1	59.1	59.1	59.1	59.1
Beef Replacement Heifers	33.6	38.8	41.2	40.7	40.8	40.9	41.3	41.0	41.0	40.9	40.9	41.0
Heifer Stockers	33.6	38.8	41.2	40.7	40.8	40.9	41.3	41.0	41.0	40.9	40.9	41.0
Heifer Feedlot	57.4	53.1	53.1	54.6	57.7	59.0	58.1	57.7	58.2	58.5	58.5	59.1
Steer Stockers	30.8	31.9	33.4	33.5	33.4	33.6	33.4	33.3	33.4	33.3	33.3	33.5
Steer Feedlot	59.9	54.3	54.6	56.1	58.7	60.1	59.3	58.9	59.6	59.9	59.9	61.1
Beef Calves	13.4	18.5	19.6	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1	20.1
Bulls	61.1	65.1	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5	68.5
Sheep	10.5	11.0	11.2	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3
Goats	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.5	10.3
Horses	49.3	43.0	41.1	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2
Chickens	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Broilers	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Swine Breeding	17.0	15.2	14.8	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
Swine < 50 lbs	2.8	4.0	4.2	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Swine 50 - 119 lbs	6.0	7.3	7.5	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7

Cattle Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Swine 120 - 179 lbs	10.4	12.6	13.1	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4	13.4
Swine > 180 lbs	13.9	16.9	17.6	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9	17.9

Source: EPA (2024b).

Table G-15: Weighted Methane Conversion Factor (MCF) by Animal Type and Year (%)

Animal Type	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Dairy Cows	61.9%	53.6%	52.5%	51.2%	49.9%	49.3%	49.5%	49.7%	50.5%	49.7%	50%	50%
Dairy Replacement Heifers	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%
Other Dairy Heifers	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%	1.6%
Dairy Calves	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Beef Cows	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Beef Replacement Heifers	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Heifer Stockers	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Heifer Feedlot	2.2%	2.3%	2.3%	2.2%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%
Steer Stockers	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Steer Feedlot	2.2%	2.3%	2.3%	2.2%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%	2.3%
Beef Calves	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.0%	0.5%	0.5%	0.5%	0.4%	0.4%
Bulls	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Sheep	0.9%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Goats	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Swine	34.9%	47.2%	45.2%	42.0%	38.8%	38.2%	37.6%	37.7%	37.7%	37.7%	38.7%	38.7%
Horses	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%
Chickens & Broilers	60.4%	20.4%	20.3%	20.3%	20.5%	20.3%	20.4%	20.5%	20.5%	20.5%	20.4%	20.4%

Sources: EPA (2024b).

Table G-16: Non-Cattle Emission Factors for Enteric CH_4 and Typical Animal Mass by Animal Types

Animal Type	Enteric CH_4 (kg CH_4 per head per year)	Typical Animal Mass (kg)
Sheep	9.00	68.60
Goats	9.00	64.00
Swine	1.50	60.44
Swine Breeding	1.50	198.00
Swine < 50 lbs	1.50	15.88
Swine 50 - 119 lbs	1.50	40.60
Swine 120 - 179 lbs	1.50	67.82
Swine > 180 lbs	1.50	90.75
Horse	18.00	450.00
Chickens	NA	1.80
Broilers	NA	0.90

Sources: EPA (2024b).
NA (Not Applicable).

Table G-17: Maximum Potential Emissions for Estimating Emissions from Manure Management by Animal Type

Animal Type	Maximum Potential Emissions (B_0) (m^3 CH_4/kg VS)
Dairy Cows	0.24
Dairy Replacement Heifers	0.17
Other Dairy Heifers	0.17
Dairy Calves	0.17
Beef Cows	0.17
Beef Replacement Heifers	0.17
Heifer Stockers	0.17
Heifer Feedlot	0.33
Steer Stockers	0.17
Steer Feedlot	0.33
Beef Calves	0.17
Bulls	0.17
Sheep	0.34
Goats	0.17
Swine	0.48
Horses	0.33
Chickens	0.39
Broilers	0.24

Source: EPA (2024b)

Table G-18: Fraction Volatile Solids Distribution by Animal Type, Waste Management System (WMS), and Year (%)

Animal Type	WMS	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Dairy Cows	Pasture	0%	7%	7%	6%	4%	4%	4%	4%	4%	4%	4%	4%
Dairy Cows	Anaerobic Lagoon	68%	55%	55%	55%	54%	54%	54%	54%	54%	54%	54%	54%
Dairy Cows	Liquid/Slurry	21%	13%	11%	8%	3%	2%	2%	2%	2%	2%	2%	2%
Dairy Cows	Solid Storage	11%	19%	20%	22%	26%	27%	27%	27%	27%	27%	27%	27%
Dairy Cows	Deep Pit	0%	5%	6%	7%	9%	9%	9%	9%	9%	9%	9%	9%
Dairy Replacement Heifers	Liquid/Slurry	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Dairy Replacement Heifers	Dry Lot	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%
Other Dairy Heifers	Liquid/Slurry	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Other Dairy Heifers	Dry Lot	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	98%
Dairy Calves	Pasture	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Beef Cows	Pasture	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Beef Replacement Heifers	Pasture	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Heifer Feedlot	Liquid/Slurry	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%
Heifer Feedlot	Dry Lot	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	58%
Heifer Stockers	Pasture	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Animal Type	WMS	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Steer Feedlot	Liquid/Slurry	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%	0%
Steer Feedlot	Dry Lot	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	58%
Steer Stockers	Pasture	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Beef Calves	Pasture	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Bull	Pasture	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Sheep	Pasture	55%	69%	69%	69%	69%	69%	69%	69%	69%	69%	69%	69%
Sheep	Dry Lot	45%	31%	31%	31%	31%	31%	31%	31%	31%	31%	31%	31%
Goats	Pasture	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%
Goats	Dry Lot	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Swine	Pasture	36%	27%	30%	34%	41%	41%	42%	42%	42%	42%	42%	40%
Swine	Anaerobic Lagoon	13%	22%	21%	21%	18%	18%	18%	18%	18%	18%	18%	19%
Swine	Liquid/Slurry	18%	23%	24%	24%	22%	22%	22%	22%	22%	22%	22%	22%
Swine	Deep Pit	30%	20%	16%	13%	11%	11%	11%	11%	11%	11%	11%	11%
Swine	Solid Storage	3%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%
Horses	Pasture	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%
Horses	Dry Lot	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
Chickens	Anaerobic Lagoon	80%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	0%
Chickens	Poultry without bedding	10%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	0%
Chickens	Solid Storage	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	10%

Source: EPA (2024b).

Table G-19: Urea Emission Factor

Emissions Factor	Value
Urea Emission Factor (MT C/MT urea)	0.2

Source: IPCC (2006).

Table G-20: N_2O Emission Factors by Waste Management System Type (kg N_2O-N/kg N)

Waste Management System	Emission Factor
Anaerobic lagoons and liquid systems	0
Solid storage of manure	0.005
Deep pit manure	0.002
Drylot manure	0.02
Poultry without bedding	0.001

Source: IPCC (2006).

Table G-21: Crop Residue Factors by Crop for Estimating Emissions from Agricultural Soil Management

Crop	IPCC Crop Proxy	Dry matter fraction of harvested product (DRY)	Aboveground residue dry matter $AG_{DM(T)}$ (Mg/ha): $AG_{DM(T)} = Crop_{(T)} * slope_{(T)} + intercept_{(T)}$		N content of above-ground residues (N_{AG})	Ratio of below-ground residues to above-ground biomass (R_{BG-BIO})	N content of below-ground residues (N_{BG})
			Slope	Intercept			
Sugarcane	Perennial grasses	0.90	0.30	0.00	0.015	0.80	0.012
Pineapples	Perennial grasses	0.90	0.30	1.00	0.015	0.80	0.012
Sweet potatoes	Tubers	0.22	0.10	1.06	0.019	0.20	0.014
Ginger root	Tubers	0.22	0.10	2.06	0.019	0.20	0.014
Taro	Tubers	0.22	0.10	3.06	0.019	0.20	0.014
Corn for grain	Maize	0.87	1.03	0.61	0.006	0.22	0.007

Source: IPCC (2006).

Table G-22: Sugarcane Residue and Crop Factors for Estimating Emissions from Field Burning of Agricultural Residues

Crop	Res/Crop Ratio	Fraction Residue Burned	Dry Matter Fraction	Fraction Carbon	Fraction Nitrogen	Burning Efficiency	Combustion Efficiency
Sugarcane	0.2	0.95	0.62	0.424	0.004	0.81	0.68

Sources: Kinoshita (1988) (res/crop ratio and burning efficiency); Ashman (2008) (fraction residue burned); Turn et al. (1997) (dry matter fraction, fraction carbon, fraction nitrogen, and combustion efficiency).

Table G-23: Volatilization and Leaching/Runoff Fraction Lost and Emission Factors for Estimating Emissions from Agricultural Soil Management

Emission Factor	Value
Fraction lost to volatilization (used for synthetic nitrogen applied)	0.1
Fraction lost to volatilization (used for all non-Pasture, Range and Paddock manure deposited)	0.2
Fraction lost to leaching/runoff	0.3
Emission Factor for volatilization	0.01
Emission Factor for leaching/ runoff	0.0075

Source: IPCC (2006).

Table G-24: Emission Factors to Estimate Direct N2O Emissions from Agricultural Soil Management (kg N2O-N/kg N)

Emission Factor	Value
Emission factor for N additions from mineral fertilizers, organic amendments, and crop residues	0.01
Emission factor for cattle, poultry, and pigs	0.02
Emission factor for sheep and other animals	0.01

Source: IPCC (2006).

Table G-25: Fire Emission Factors, Forest and Shrubland (MT Carbon/ha)

Emission Factor	Value
Dry Forest	1.44
Mesic Forest	34.97
Wet Forest	15.05
Dry Shrubland	2.12
Mesic Shrubland	10.29

Source: Selmants et al. (2017).

Table G-26: Ratio of Hawai'i Forest Land to Wildland (Dimensionless)

Factor	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Ratio of Hawai'i forestland to wildland	0.37	0.36	0.36	0.36	0.36	0.36	0.36	0.34	0.34	0.33	0.33	0.34

Source: National Association of State Foresters (NASF) (1998, 2002); DLNR (2011, 2015, 2016, 2017, 2018, 2019, and 2020); Selmants et al. (2017).

Table G-27: Forest Fire Emission Factor (g/kg dry matter burnt)

Emission Factor	Value
CH_4	4.70
N_2O	0.26

Source: IPCC (2006).

Table G-28: Carbon Storage Factors for Landfilled Yard Trimmings and Food Scraps

Type of Waste	Content of Yard Trimmings (percent)	Moisture Content of Waste, MC_i (percent)	Proportion of Carbon Stored Permanently in Waste, CS_i (percent)	Initial Carbon Content of Waste, ICC_i (percent)	First Order Decay Rate, k
Grass	30.3	70.0	53.5	44.9	0.139
Leaves	40.1	30.0	84.6	45.5	0.035
Branches	29.6	10.0	76.9	49.4	0.030
Food Scraps	NA	70.0	15.7	50.8	0.156

Source: EPA (2024c).
NA (Not Applicable).

Table G-29: Urban Tree Sequestration Factor, S_c (MT C/km^2)

Factor	Value
Average net C sequestration per km^2 tree cover (MT C/km^2)	(464.0)

Source: EPA (2024b).

Table G-30: Forest Carbon Net Sequestration Factors

Year	Annual Net Forest C Sequestration Rate (MT C/ha/year)	Annual Net Shrubland C Sequestration Rate (MT C/ha/year)
2011	1.29	0.71
2012	1.36	0.70
2013	1.36	0.69
2014	1.37	0.67
2015	1.40	0.64
2016	1.38	0.61
2017	1.36	0.60
2018	1.39	0.57
2019	1.40	0.54
2020	1.37	0.52
2021	1.37	0.50
2022	1.38	0.49
2023	1.37	0.46
2024	1.39	0.44
2025	1.34	0.42

Source: Selmants (2020).

Waste

Table G-31: Landfilling CH_4 Emission Factors for Estimating Emissions from Waste Sector

Emission Factor	Value
Methane Generation Constant (yr^{-1})	0.04
Methane Generation Potential (m^3 CH_4/Mg of refuse)	100
Methane Oxidation Rate (percent)	10%

Source: EPA (2024b).

Table G-32: Composting CH_4 and N_2O Emission Factors for Estimating Emissions from Waste Sector

Emission Factor	CH_4	N_2O
Waste Treated on a Wet Weight Basis (g of gas/Kg waste)	4	0.24

Source: IPCC (2006).

Table G-33: Wastewater CH_4 and N_2O Emission Factors for Estimating Emissions from Waste Sector

Emission Factor	Value
Direct Emissions from Wet waste (MT CH_4/MT of waste)	0.6
Direct Emissions from Wet waste (g N_2O/person/year)	4.0
Indirect Emissions from Wet waste (kg N_2O-N/kg sewage N-produced)	0.005
Fraction of wastewater BOD anaerobically digested	12.78%
Fraction of Nitrogen in Protein (kg N/kg protein)	16%
Fraction of Nitrogen not Consumed	1.75
Percentage of Biosolids used as Fertilizer	0%

Source: EPA (2024c).

Appendix H. ODS Emissions

ODS—including chlorofluorocarbons (CFCs), halons, carbon tetrachloride, methyl chloroform, hydrochlorofluorocarbons (HCFCs), and other chlorine and bromine containing compounds—have been found to deplete the ozone levels in the stratosphere. In addition to contributing to ozone depletion, CFCs, halons, carbon tetrachloride, methyl chloroform, and HCFCs are also potent greenhouse gases. The GWP values for ODS are summarized in Table H-1.

The *Montreal Protocol on Substances that Deplete the Ozone Layer* is the international treaty that controls ODS; parties to the *Montreal Protocol* are required to provide statistical data about ODS to the Ozone Secretariat annually. In the United States, the Clean Air Act Amendments of 1990 implement the *Montreal Protocol* controls. IPCC (2006) guidelines exclude the reporting of ODS emissions because they are controlled under the *Montreal Protocol* controls.

For informational purposes, ODS emissions were estimated for the state of Hawaiʻi. To estimate ODS emissions for Hawaiʻi, national ODS emissions were apportioned based on the ratio of Hawaiʻi population to U.S. population. Estimates of national ODS emissions (in kilotons (kt) by gas) were obtained from the U.S. Inventory (EPA 2024b). National population numbers were obtained from the U.S. Census Bureau (2023) while Hawaiʻi population data were obtained from the State of Hawaiʻi Data Book (DBEDT 2023).

Table H-2 summarizes ODS emissions in Hawaiʻi by gas for 1990, 2005, 2007, 2010, 2015 to 2022.[66]

Table H-1: 100-year Direct Global Warming Potentials for Ozone Depleting Substances

Gas	GWP
CFC-11	4,660
CFC-12	10,200
CFC-113	5,820
CFC-114	8,590
CFC-115	7,670
Carbon Tetrachloride	1,730
Methyl Chloroform	160
Halon 1211	1,750
Halon 1301	6,290
HCFC-22	1,760
HCFC-123	79
HCFC-124	527
HCFC-141b	782
HCFC-142b	1980
HCFC-225ca	127
HCFC-225cb	525

Source: *IPCC Fifth Assessment Report* (AR5) (2013).

[66] The methodology and data sources used to estimate ODS emissions in Hawaiʻi are consistent with the methodology and data sources used to estimate emissions from ODS substitutes.

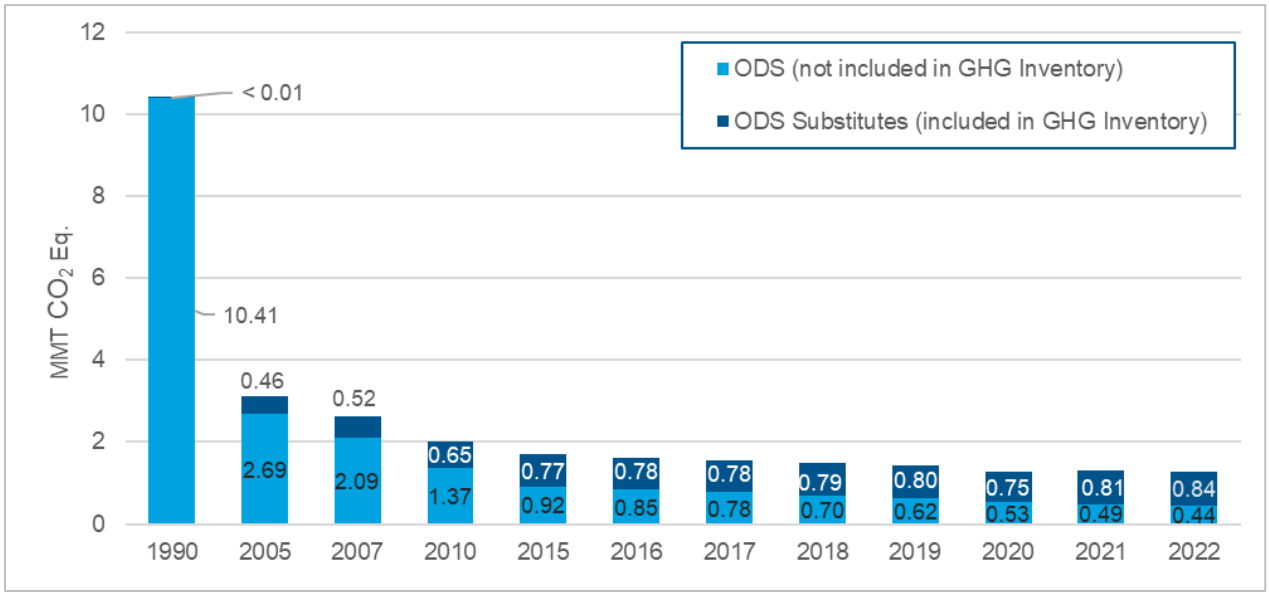
Table H-2: ODS Emissions by Gas (kt)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CFC-11	0.14	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
CFC-12	0.68	0.11	0.07	0.03	0.02	0.02	0.01	0.01	+	+	+	+
CFC-113	0.30	0.08	0.06	0.03	NO	NO	NO	NO	NO	NO	NO	NO
CFC-114	0.02	0.01	+	+	NO	NO	NO	NO	NO	NO	NO	NO
CFC-115	0.04	0.01	0.01	+	+	+	+	+	+	+	NO	NO
Carbon Tetrachloride	0.02	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Methyl Chloroform	1.12	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Halon 1211	0.01	+	+	+	+	+	+	+	+	+	+	+
Halon 1301	0.01	+	+	+	+	+	+	+	+	+	+	+
HCFC-22	0.15	0.35	0.36	0.34	0.29	0.27	0.25	0.23	0.21	0.18	0.16	0.14
HCFC-123	NO	+	+	+	+	+	+	+	+	+	+	+
HCFC-124	NO	0.01	0.01	+	+	+	+	+	+	+	+	+
HCFC-141b	+	0.02	0.02	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03
HCFC-142b	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02
HCFC-225ca/cb	NO	+	+	+	+	+	+	+	+	+	+	+
Total	**2.51**	**0.67**	**0.62**	**0.51**	**0.40**	**0.38**	**0.36**	**0.34**	**0.31**	**0.27**	**0.25**	**0.22**

+ Does not exceed 0.005 kt; NO (emissions are Not Occurring).
Note: Totals may not sum due to independent rounding.
Source: EPA (2024b).

Emissions from ODS in Hawai‘i have decreased significantly since 1990, following the implementation of the *Montreal Protocol*. Figure H-1 below presents combined emissions from ODS and ODS substitutes in Hawai‘i. Combined emissions have similarly decreased between 1990 and 2022, even though emissions from ODS substitutes increased during the same period.

Figure H-1: 2022 Emissions from ODS and ODS Substitutes (MMT CO_2 Eq.)



Appendix I. Uncertainty

This appendix provides a summary of the methodology used to develop the quantitative uncertainty results as well as a discussion on limitations of the analysis. Consistent with the U.S. Inventory and following the IPCC Chapter 3 Uncertainties guidelines (IPCC 2006), this inventory quantifies uncertainty for the current inventory year (i.e., 2022).

Methodology

Uncertainty analyses are conducted to qualitatively evaluate and quantify the uncertainty associated with GHG emission and sink estimates. Quantitative uncertainty analyses capture random errors based on the inherent variability of a system and finite sample sizes of available data, measurement error, and/or uncertainty from expert judgement (IPCC 2006). Systematic errors from models, measurement techniques, and data recording and interpretation are difficult to quantify and are therefore more commonly evaluated qualitatively (IPCC 2006). The results of an uncertainty analysis serve as guidance for identifying ways to improve the accuracy of future inventories, including changes to activity data sources, data collection methods, assumptions, and estimation methodologies.

The IPCC provides good practice guidance on two methods for estimating uncertainty for individual source categories (i.e., Approach 1 and Approach 2). Approach 1 is appropriate where emissions or sinks are estimated by applying an emission factor to activity data or by summing individual sub-source or sink category values to calculate an overall emissions estimation. Approach 2 is appropriate for more complex calculations and employs the Monte Carlo Stochastic Simulation technique and is more reliable than Approach 1. It is useful for input variables that are particularly large, have non-normal distributions, and are correlated with other input variables. Approach 2 is also appropriate if a sophisticated methodology or multiple input variables are used for the emissions estimation, as was the case for the sources estimated in this inventory.

For this inventory report, Approach 2 was applied to quantify uncertainty for all source categories in accordance with the *2019 Refinement to the 2006 IPCC Guidelines (IPCC 2019) and 2006 IPCC Guidelines (IPCC 2006)*. Under this method, GHG emissions (or sinks) for each source category are estimated by generating randomly-selected values according to the specified probability density function (PDF)[67] for each of the constituent input variables (e.g., activity data, emission factor) 10,000 times using @RISK, a commercially-available simulation software. The results of this methodology are presented as an overall emission (or sinks) PDF for each source category. The quantified uncertainties for each source category

[67] The PDF, which is dependent upon the quality and quantity of applicable data, describes the range and likelihood of possible values for constants and estimates that are not exactly known (IPCC 2006).

were then combined using Approach 2 to provide uncertainty estimates at the sector level as well as for the overall net and total emissions for the current inventory year.

Consistent with the U.S. Inventory, this inventory quantifies uncertainty for the current inventory year (i.e., 2022). Although uncertainty was not quantified for other inventory years, the uncertainty range relative to emission estimates across all inventory years are expected to be similar to those quantified for 2022. Similarities in quantitative uncertainties are expected because, in most cases, particularly for those that contribute the most to overall emissions, the same methodologies and data sources were used for all years. As a result of timeseries consistency, any future changes in the estimates will likely affect results similarly across all years.

Limitations of the Analysis

The uncertainty analysis results presented in this report reflect an IPCC Approach 2 Monte Carlo Uncertainty analysis that was completed for the third time for the Hawai‘i inventory. The IPCC publishes uncertainty information for most emission factors and some activity data (e.g., level of uncertainty associated with stationary combustion activity data), but most activity data uncertainty must be provided by the original data source.

Developing this analysis required a review of original data sources as well as outreach and collaboration with all data providers to establish uncertainty bounds for each of the input parameters. In cases where uncertainties have already been assessed for certain activity data, PDFs for these input parameters are derived using this information. If this information was not published, data providers were contacted. If data providers were unable to provide a quantitative measure of uncertainty for their data, PDFs were built around the input parameters using qualitative responses from data providers, default values provided by IPCC, and/or expert judgement based on ICF’s experience in developing uncertainty bounds for the U.S. inventory of GHG emissions and sinks in accordance with the *2019 Refinements to the 2006 IPCC Guidelines* (IPCC 2019) and *2006 IPCC Guidelines* (IPCC 2006).

While this uncertainty analysis quantified parameter uncertainty, which arises due to a lack of precision and/or accuracy in input data such as emission factors and activity data, it did not quantify model-based uncertainty, which arises when emission/sink estimation models do not fully or accurately characterize the emission/sink process due to a lack of technical details or other resources. Model based uncertainty is extremely difficult to quantify given, in most cases, only a single model has been developed to estimate emissions from any one source. Nonetheless, these uncertainties are discussed qualitatively, where appropriate, for each emission source and sink category in the subsequent sections of this report. Confidence in the uncertainty analysis results will improve over time as gaps in understanding and quantifying the uncertainty for additional data sources are addressed.

This uncertainty analysis is specific to the methods and data used for this report and is independent from those used in previous reports. These estimates consider the inherent uncertainty associated with these methodologies and data and their ability to accurately and precisely describe the activities within the scope of the inventory. While the uncertainty analysis is a useful tool for identifying areas for

improvement in an inventory, the uncertainty analysis should not be used to quantitatively compare changes observed between inventory reports where data sources and methods may have been revised.

Appendix J. Emission Projections Methodology

This appendix summarizes the methodology used to project statewide emissions for 2025, 2030, 2035, 2040, and 2045 by source and sink category under both the baseline and alternate scenarios. Projections utilize several key forecasts, including gross state/county product, visitor arrivals, future fossil fuel prices (residual oil, gasoline, diesel, and jet fuel), deployment of renewable energy technology, and the adoption of EVs in ground transportation. The study considers an additional uses alternate forecasts for the penetration of biofuels into air and marine travel and for electrification of air transport in the scenario for emissions from shipping and air transport.

This section also provides a discussion of key uncertainties and areas for improvement.

1. Macroeconomic and Fuel Price Forecasts

Energy usage and hence emissions associated with energy usage are tied tightly to economic growth, energy efficiency, fossil fuel usage, and energy prices. Therefore, forecasting macroeconomic growth and fossil fuel prices are key to constructing forecasts of emissions. The study relied on publicly available forecasts for state and county relevant economic variables, as provided by DBEDT. As for fuel price forecasts, the Energy Information Administration (EIA) is the best source for national energy prices and specifically oil prices upon which Hawai'i energy prices still largely rely.

The forecast for Gross County Product (GCP) in Table J-1 was developed using DBEDT short-run forecast of GSP through 2025 and the DBEDT long-run expected growth rate applied for years between 2025 and (DBEDT 2024d, DBEDT 2024e). To generate county level projections, a ratio of county specific personal income forecasts were applied to the projected GSP (DBEDT 2024e).

For simplicity, GCP and GSP are used interchangeably hereafter.

Table J-1: Gross County Product (Normalized to 2022=1)

Scenario	2025	2030	2035	2040	2045
Hawai'i	1.05	1.17	1.25	1.33	1.42
Honolulu	1.05	1.11	1.19	1.28	1.36
Kaua'i	1.05	1.17	1.26	1.36	1.46
Maui	1.05	1.17	1.27	1.38	1.49

The forecast for county level resident population, shown in Table J-2, used the DBEDT short-run forecast through 2025 and thereafter the long-run forecast (DBEDT 2024d, DBEDT 2024e).

Table J-2: Resident Population by County (Normalized to 2022=1)

Scenario	2025	2030	2035	2040	2045
Hawai'i	1.02	1.17	1.25	1.33	1.42
Honolulu	1.02	1.11	1.19	1.28	1.36
Kaua'i	1.02	1.17	1.26	1.36	1.46

Scenario	2025	2030	2035	2040	2045
Maui	1.02	1.17	1.27	1.38	1.49

The forecast for de facto population, shown in Table J-3 below, was developed analogously to the population forecasts.

Table J-3: De Facto Population for Each County (Normalized to 2022=1)

Scenario	2025	2030	2035	2040	2045
Hawai‘i	1.01	1.10	1.13	1.15	1.18
Honolulu	1.02	1.06	1.07	1.08	1.08
Kaua‘i	1.02	1.18	1.22	1.26	1.29
Maui	0.97	1.09	1.13	1.16	1.19

The forecast for visitor arrivals similarly used the DBEDT short-run forecast through 2025, and the DBEDT long-run forecast through 2045 (DBEDT 2024d, DBEDT 2024e). These forecasts are provided in Table J-4 below.

Table J-4: Visitor Arrivals by Air for Each County (Normalized to 2022=1)

Scenario	2025	2030	2035	2040	2045
Hawai‘i	1.01	1.08	1.16	1.23	1.30
Honolulu	1.01	1.04	1.08	1.10	1.14
Kaua‘i	1.01	1.06	1.12	1.17	1.22
Maui	1.01	1.07	1.13	1.19	1.25

EIA Annual Energy Outlook (AEO) 2023 was used to develop high and low fuel price forecasts (relative to the baseline) for four fuel types. These forecasts were used to determine outcomes in Scenarios 1A and 1B.[68] Table J-5 below presents these forecasts using the baseline AEO (EIA 2023) forecast was used to normalize the high and low price scenarios per fuel type. The AEO price forecast depends largely on world crude oil prices but is also influenced by refining and distribution costs as well as fuel taxes and other end-use markups.

Table J-5: Fuel Prices (Baseline=1)

Fuel Type	Scenario	2025	2030	2035	2040	2045
Residual Fuel Oil	High (1A)	1.45	1.64	1.65	1.65	1.69
	Low (1B)	0.63	0.65	0.57	0.63	0.62
Gasoline	High (1A)	1.60	1.55	1.46	1.53	1.47
	Low (1B)	0.73	0.72	0.75	0.73	0.73
Diesel	High (1A)	1.75	1.91	1.50	1.94	1.98
	Low (1B)	0.60	0.61	0.74	0.60	0.57

[68] There was no 2024 AEO release due to ongoing efforts by the EIA to overhaul their forecasting models.

Fuel Type	Scenario	2025	2030	2035	2040	2045
Jet Fuel	High (1A)	1.68	1.74	1.34	1.75	1.80
	Low (1B)	0.56	0.58	0.61	0.58	0.57

2. Energy

2.1. Stationary Combustion

2.1.a. Baseline Scenario Methodology

Emissions from stationary combustion were projected based on macroeconomic forecasts along with the following assumptions for each sub-sector:

- The *energy industries* subsector was further divided into *petroleum refinery* emissions and *electric power sector* emissions to develop long-run projections.
    - *Petroleum Refinery:* Emissions were projected from 2022 based on the projected growth in aviation emissions (see the *Transportation* section for the method used to project aviation emissions).
    - *Electric Power:* The baseline emissions forecast for the electric sector was driven by electricity demand forecasts, renewable energy deployment, and the projected demand from EVs.
- For the *residential, commercial, and industrial sectors*, statewide emissions were assumed to grow at the rate of forecasted gross county products.

2.1.a.i Energy Industries Subsector

Petroleum Refinery Emissions Projections

Petroleum refineries in Hawai‘i produce jet fuel used in aviation and therefore emissions projections between the two categories have a causal relationship. Given the additional data on projected aviation emissions, petroleum refinery emissions projections are scaled to align with growth in that sector.

Details on domestic aviation emissions projections methodologies can be found within the transportation section.

Electric Power Sector Emissions Projections

The baseline emissions forecast for the electric power sector was developed by projecting electricity demand forecasts, renewable energy deployment, and the projected demand for EVs. Annual GHG emissions from the electric power sector by county were developed by integrating these factors along with fuel price adjustments and heart rate calculations.

Emissions were calculated based on the demand for each type of fossil fuel-fired generation in each county for each year based on detailed unit level generation data developed for the IGP (Lau 2023).. The weighted average heart rate for fossil-fuel generation was determined for each county and fuel type,

considering the planned retirements of certain plants. The emission factor was then applied to estimate total emissions.

As the deployment of renewable energy increases, the demand for fossil-fuel based generation decreases, subsequently reducing the electric sector emissions.

The calculation method is as follows:

$$E_{c,t} = \sum_f (D_{f,c,t} \times HR_{f,c,t} \times EF_f)$$

where,

$E_{c,t}$	= Emissions of GHGs for year *t* (MMT CO_2 Eq.) and county *c* (MMT CO_2 Eq.)
$D_{f,c,t}$	= Demand (GWh) for each type of fossil fuel fired generation *f* (diesel, RFO, etc.) in county *c* in year *t*
$HR_{f,c,t}$	= Weighted average heat rate for fossil fuel fired generation *f in county* c within the PSIP[69] or KIUC[70] production plan for year *t.*
EF_f	= GHG CO_2 Eq. emission factor for fuel in county *c* for year *t* (Mt CO_2 Eq. per MMBtu)

Underlying Electricity Demand Forecast

Electricity use across the state is expected to grow by 17% percent between 2022 and 2045 primarily driven by EV demand. For Kaua‘i County, predictions for future electricity demand started with actual 2023 sales data (PUC 2024). The projections applied Maui’s growth rate from Hawaiian Electric’s Integrated Grid Plan (IGP) (Hawaiian Electric 2023). EV adoption on Kaua‘i was assumed to follow Maui’s rate (Hawaiian Electric 2023), as detailed in the Ground Transportation section.

For the Hawaiian Electric service area, the demand forecasts were based on the IGP “Base” scenario for Maui and Hawai‘i Counties and the “Land Constrained” scenario for Honolulu County (Hawaiian Electric 2023). The base scenario represents the middle-ground projection for future energy demand and infrastructure development under moderate growth scenarios and is often used as the benchmark scenario. Honolulu county uses the “land constrained” scenario as it reflects the limitations of renewable energy infrastructure in urbanized areas. This scenario reflects greater reliance on distributed

[69] The PSIP (Power Supply Improvement Plan) is a strategic planning document developed by Hawaiian Electric to outline how the utility will meet future electricity needs while achieving renewable energy goals. It includes forecasts of electricity demand, generation capacity, and plans for integrating renewable energy sources, enhancing grid reliability, and managing costs.

[70] KIUC production refers to the energy generation and operational activities of the Kaua‘i Island Utility Cooperative. As a member-owned utility, KIUC focuses on generating electricity for Kaua‘i, with an emphasis on renewable energy sources like solar, hydropower, and biomass to reduce reliance on fossil fuels and align with Hawai‘i's clean energy targets.

energy solutions and reflects slower progress towards renewable energy goals due to these constraints. Since the IGP used AEO 2021 fuel price data, adjustments were made using the differences between AEO 2021 and AEO 2023 forecasts (EIA 2021, EIA 2023). The updated AEO forecast assumes that prices are higher in 2023 and that prices will decline towards the year 2045. To better reflect realized electricity demand, the projections were further scaled using actual 2023 sales data, which turned out to be higher than previous forecasts for every county (PUC 2023).

Figure J-1 reports the adoption of EVs in the light-duty vehicle fleet for each county and for the state as a whole. Figure J-2 and Table J-6 and show Hawai‘i statewide and county-level electricity demand for 2022 and forecasts for 2025, 2030, 2035, 2040, and 2045 (including EVs). Figure J-3 shows renewable energy generation as a percentage of total electricity generation by county for the same years.

Figure J-1: Hawai‘i Statewide and County-level Electric Vehicle Adoption for 2022 and 2023 and Forecasts for 2024-2045 (EVs as % of light-duty vehicle fleet)

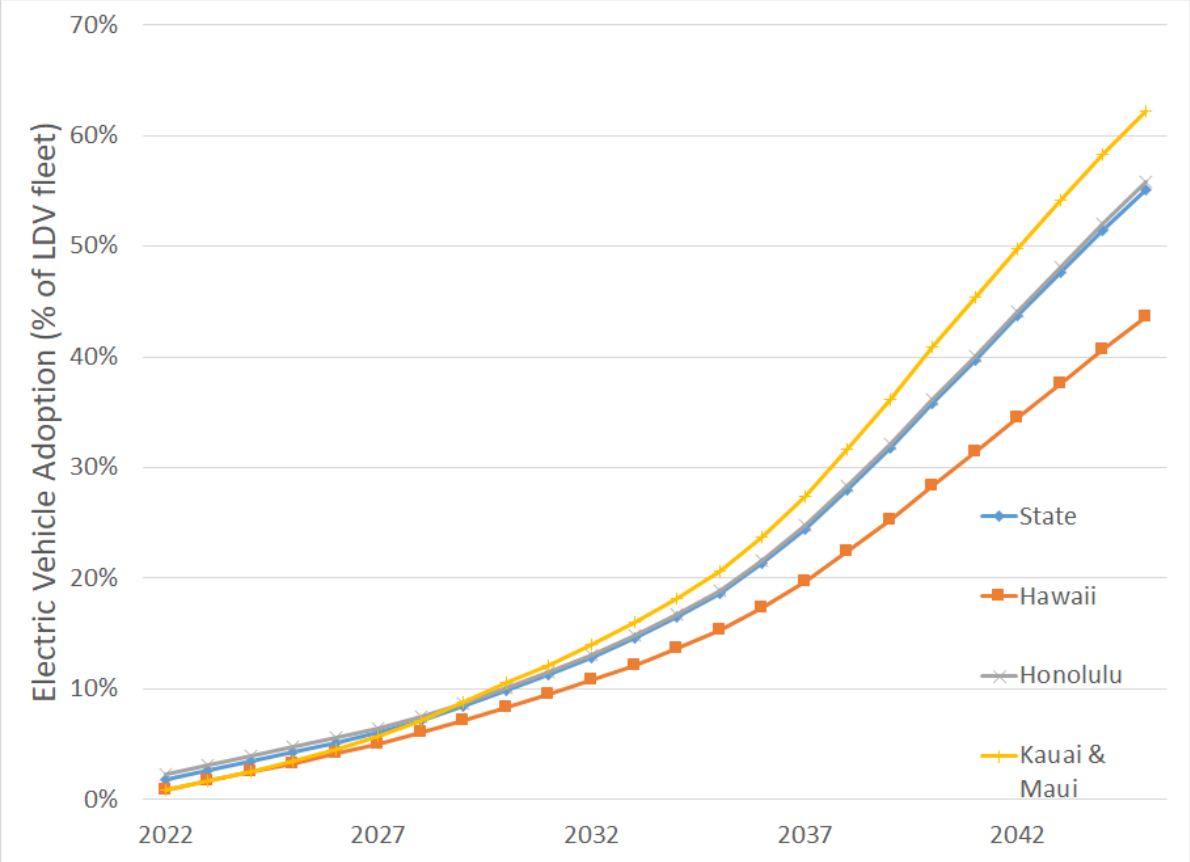


Figure J-2: Hawai‘i Statewide and County-level Electricity Demand for 2022 and Forecasts for 2025, 2030, 2035, 2040, and 2045 (GWh) (Including EVs)

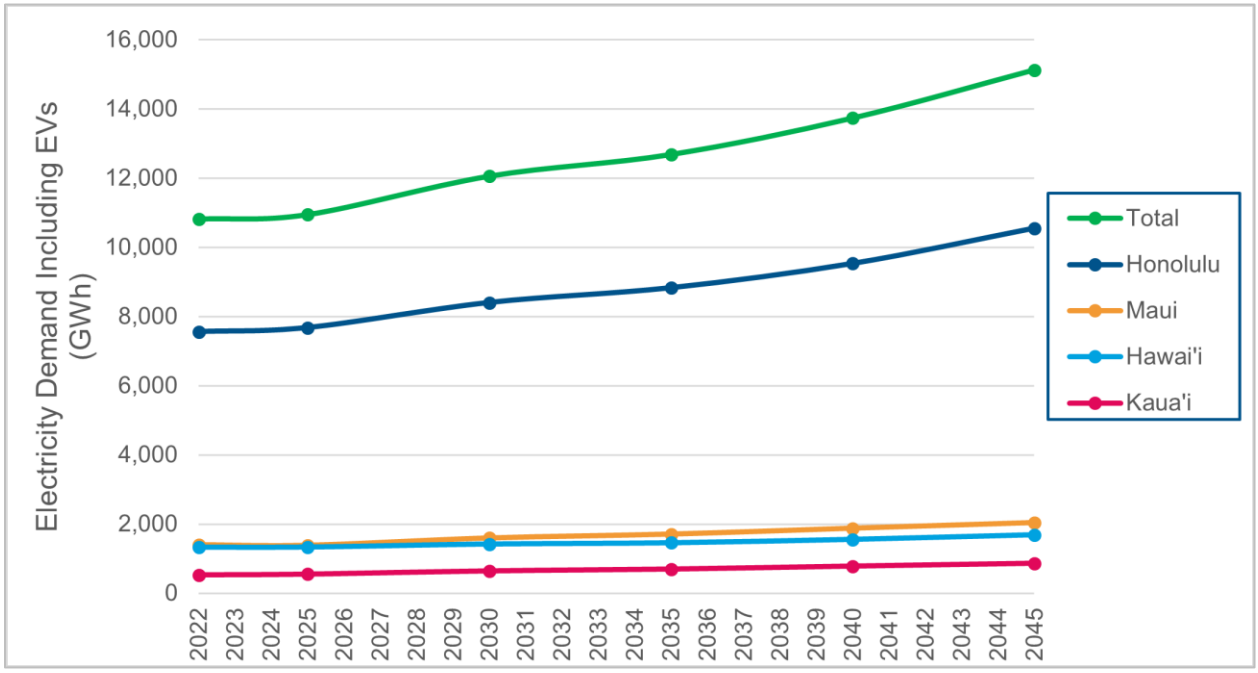
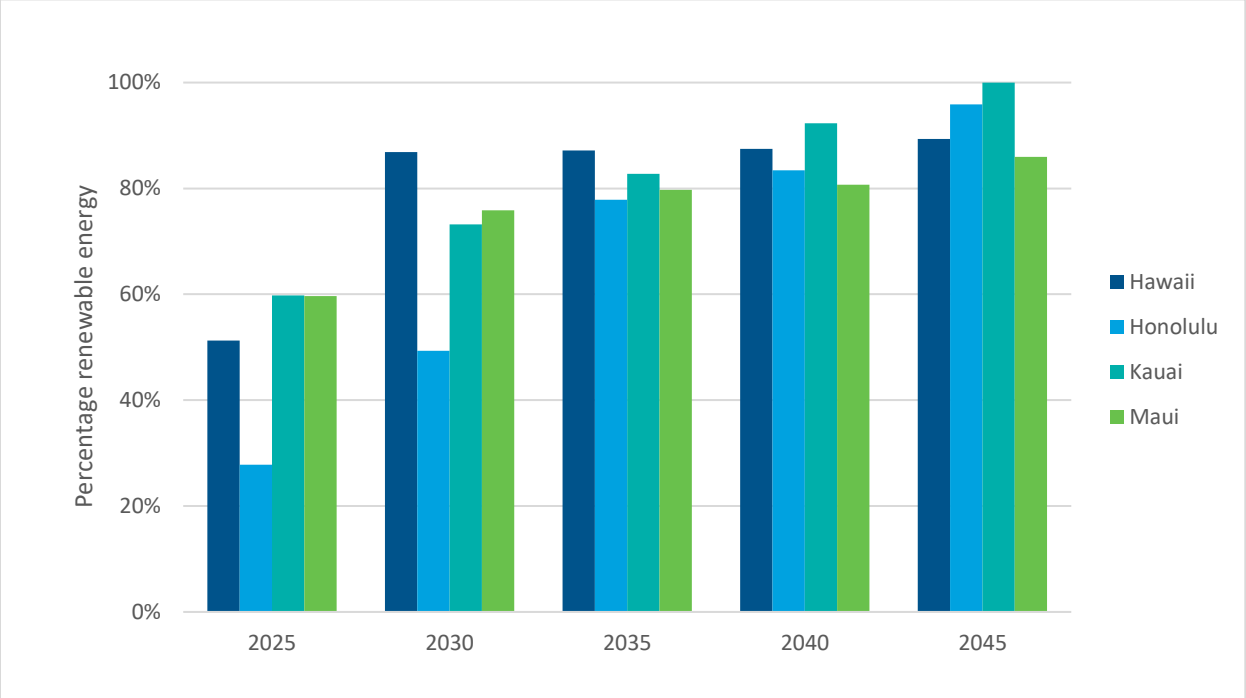


Table J-6: Hawai‘i Statewide and County-level Electricity Demand for 2022 and Forecasts for 2025, 2030, 2035, 2040, and 2045 (GWh) (Including EVs)

County	2022	2025	2030	2035	2040	2045
Honolulu	7,560	7,677	8,401	8,828	9,529	10,548
Maui	1,395	1,380	1,591	1,703	1,874	2,036
Hawai‘i	1,331	1,335	1,421	1,456	1,554	1,685
Kaua‘i	528	551	641	694	779	859
Total	**10,813**	**10,943**	**12,054**	**12,681**	**13,736**	**15,129**

Figure J-3: County-Level Renewable Energy Generation as Percentage of Generation



Renewable Energy Deployment

The deployment of renewable energy is expected to grow substantially to 2045 but slower than projected by the utilities. Using the 2023 PUC RPS report (PUC 2023) as a baseline, the renewable share for 2025 was determined by adding new projects from the Hawaiʻi State Energy Office (HSEO 2024). For Honolulu and Maui counties, this translated to an additional 121 GWh and 167 GWh of renewable generation, respectively, by 2025. No new projects were identified for Hawaiʻi County. The West Kauai Energy Project, currently in the permitting phase, is assumed to be operational by 2030, contributing an additional 127 GWh of renewable generation by that year. Until then, Kauaʻi's renewable generation capacity in 2025 is assumed to remain at 2023 levels. This slower expansion of renewable energy means Hawaiʻi and Kauaʻi Counties are expected to have a slightly lower RPS in 2025 compared to 2023, as rising electricity demand outpaces the growth in renewable generation. This higher demand is also the primary factor behind the projected increase in emissions for these counties in 2025.

Between 2030 and 2045, renewable energy expansion for Honolulu county used the IGP's "land constrained" scenario, Hawaiʻi and Maui counties used the "base" scenario. Given current delays in grid-scale renewable energy deployment, it is assumed that planned projects will become operational five years later than initially planned. From 2030 onward, renewable energy generation in Kauaʻi is expected to increase linearly to meet the state's 100 percent Renewable Portfolio Standard (RPS) target by 2045 (Act 240 of 2022). Projected RPS by county and year are detailed in Table J-7.

Table J-7: RPS by County and Year

County	2025	2030	2035	2040	2045
Honolulu	28%	49%	78%	83%	96%
Maui	60%	76%	80%	81%	86%
Hawai‘i	51%	87%	87%	87%	89%
Kaua‘i	60%	73%	83%	92%	100%

Heat Rate Calculations

To project fossil fuel emissions, heat rates for power plants were calculated based on generation (GWh) and heat output (MMBtu) data from EIA Form 923 (EIA 2023). Heart rate calculations measure the efficiency of a fossil fuel power plant by determining how much fuel energy is required to produce one unit of electricity. A lower heart rate indicates a more efficient plan as they use less fuel to generate the same amount of electricity. A weighted average heat rate was calculated for each county, fuel type, and projection year, considering the planned retirements of certain plants, as outlined in the IGP (Lau 2023). Fossil fuel generation was distributed across fuel types—DFO, RFO, Naphtha, and biodiesel—using the share of generation for each county and fuel type, corresponding to the in the IGP (Lau 2023).

2.1.a.ii Commercial, Residential, and Industrial Subsectors

Emissions from the residential, commercial, and industrial sectors are projected based on the growth in gross county products (GCP). Aligning emissions projections with GCP growth captures the impact of economic development on energy consumption and emissions ensuring projections reflect the dynamic nature of the economy and its influence on energy demand. It also allows for a more accurate estimation of future emissions, considering the interplay between economic activity and energy use.

2.1.b. Alternate Scenario 1A and 1B

Future energy prices, especially oil prices, are one of the greatest sources of uncertainty that will affect future GHG emissions. Hawai‘i’s demand for refined petroleum products depends on the price of refined petroleum products. The EIA Annual Energy Outlook price forecast for refined petroleum products was used to understand the potential effect of oil prices on Hawai‘i’s future emissions from the electric sector (EIA 2023).[71] Both a *high* (Alternate Scenario 1A) and *low* (Alternate Scenario 1B) future oil price pathway based on the EIA’s Annual Energy Outlook (AEO) 2023 for refined petroleum products (EIA 2023) were considered. Additionally, prices could be affected by external market forces not considered in the AEO, changes in existing fuel taxes, or by state or national policy regarding GHG pricing.[72]

[71] There was no 2024 AEO release due to ongoing efforts by the EIA to overhaul their forecasting models.

[72] An economy-wide carbon pricing scheme would also affect the price of coal and natural gas, which is not accounted for as part of this analysis. Given that coal phased out in 2022, and natural gas currently represents a small portion of total fuel consumption in Hawai‘i, the impact of a carbon-pricing scheme on future coal and natural gas emissions is expected to be small.

As shown, in Table J-5 under the *high* oil price forecast, the price of residual fuel oil was expected to be roughly 45 percent greater than in the baseline case in 2025 and roughly 70 percent greater in 2045, while in the low oil price forecast, the price of residual fuel oil was expected to be roughly 40 percent of the baseline case in all years.[73] The price of diesel was expected to be between 75 percent higher in 2025 and about 100 percent higher in 2045 under the *high* oil price forecast and roughly 40 percent lower in all years under the *low* oil price forecast.

To estimate the percent change in electricity demand due to higher and lower residual oil and diesel prices, the underlying electricity demand which was met with fossil generation in the baseline case was multiplied by the percentage change in price for each scenario and each year, the price elasticity of demand, the share of fossil fuel generation, and the contribution of fuel price ($/kWh) to the total electricity price ($/kWh) for each county (DBEDT 2023). The price increase for each fuel was weighted by the ratio of electricity demand that was met with diesel versus residual fuel oil for each county based on unit level fuel consumption data provided by HEI corresponding to the IGP base case scenario (Lau 2023). Based on empirical studies, electricity demand is relatively inelastic, meaning that a one percent increase in price is expected to result in much less than a one percent decrease in demand (Coffman et al. 2016). For this analysis, an elasticity parameter equal to -0.1 was selected based on the Electric Power Research Institute (2010). This means that a one percent increase in electricity price results in a 0.1 percent decrease in electricity demand. This elasticity parameter was similar to findings published by Nakajima and Hamori (2010), Paul et al. (2009), and Metcalf (2008). Using this parameter, the change in demand for fossil fuel-based electricity under each scenario was calculated based on the following equation:

$$DS_{c,t} = DB_{c,t} \times \left(1 + \left(\sum(\%\Delta ElePrice_{\,t,f} \times FuelShare_{\,f,c,t}\right) \times \sigma \times RPS_{c,t} \times FuelPriceRatio_{c,t}\,)\right)$$

where,

$DS_{c,t}$	= Demand (GWh) in county *c* in Scenario 1A or 1B
$DB_{c,t}$	= Baseline demand (GWh) in county *c* in year *t*
$\%\Delta ElePrice_{t,f}$ for fuel f	= The percentage change from the baseline in electricity price in year *t*
$FuelShare_{\,f,c,t}$	= The share of fossil fuel f in county c and year t
σ	= Price elasticity of demand for electricity
$RPS_{c,t}$	*= Total fossil fuel generation as a share of total generation in year t and county c*

[73] For context, a $25/MT CO_2 Eq. tax equates to approximately an additional $10/bbl of crude oil.

$FuelPriceRatio_{c,t}$ = The share of the total electricity price ($/kWh) attributable to fuel costs for each county

This new demand for fossil fuel generation was then used to determine GHG emissions.

2.1.c. Alternate Scenario 2A and 2B

There is considerable uncertainty associated with the energy technologies that will ultimately be used to meet future electricity demand. For the purposes of this alternate scenario, two additional renewable energy deployment pathways were considered. Scenario 2A and 2B assume lower and higher renewable energy deployment than the baseline, respectively. Table J-8 shows the renewable energy shares assumed in the scenarios for each county.

Scenario 2A assumed that renewable energy deployment largely follows the IGP "base" scenario for Maui and Hawai'i counties and the "land constrained" for Honolulu county, as presented in the final IGP report (Hawaiian Electric 2023). The share of renewables is slightly lower in the years 2025 to 2040 because of the assumed underlying demand. In 2045 it is assumed that the higher demand will be met with biofuels. Kaua'i will reach the goal of 100 percent renewables by 2033 according to the goal set by KIUC's board of directors (Rockwell 2024).

Table J-8: Shares of Renewable Energy Assumed in Scenario 2A and 2B

Scenario 2A	2025	2030	2035	2040	2045
Hawai'i	51%	95%	95%	95%	100%
Honolulu	24%	52%	80%	86%	100%
Kaua'i	60%	74%	84%	93%	100%
Maui	46%	85%	89%	89%	100%
Scenario 2B	**2025**	**2030**	**2035**	**2040**	**2045**
Hawai'i	51%	57%	80%	78%	77%
Honolulu	24%	29%	48%	76%	82%
Kaua'i[a]	58%	69%	78%	87%	100%
Maui	46%	52%	70%	72%	73%

[a] For Kaua'i we assumed the same rate of deployment of renewable energy as in the Baseline.

For Scenario 2A, Kaua'i's renewable energy deployment pathway follows KIUC board of directors newly established goal of reaching 100 percent renewable energy by 2033 (Rockwell 2023). No "low" renewable energy scenario was developed for Kaua'i as it is highly likely that Kaua'i will reach 100 percent renewables by 2045.

Scenario 2B assumed that delays in grid-scale renewable energy deployment follow the average annual capacity (MW) delay that has occurred between 2016 and 2023 for the Hawaiian Electric service area including both grid-scale projects and distributed resources. This delay was estimated by taking the difference between proposed renewable energy generation in the PSIP (PUC 2016) and the amount of renewable energy generation presented in Hawai'i Public Utilities Commission (HECO) RPS reports submitted to the Public Utilities Commission (PUC) in 2016 and 2024 (for calendar year 2023) (PUC

2024). This delay is then subtracted from the renewable energy generation assumed in the baseline. Delays in renewable energy projects can occur for a number of reasons – from concerns about siting to changes in prices due to changes in the global market for supplies. The average annual delay in renewable energy capacity expansion was calculated using the following equation:

$$RE_Delay_c = \frac{(RE_{PSIP,c,2016-2023} - RE_{HIST,c,2016-2023})}{(2023 - 2016)}$$

Where,

RE_Delay_c	= Average annual delay in renewable energy capacity expansion (GWh) for county c
$RE_{IGP,c,2016-2023}$	= Increase in renewable energy generation (GWh) between 2016 and 2023 proposed in the PSIP.
$RE_{HIST,c,2016-2023}$	= Historical increase in renewable energy generation (GWh) between 2016 and 2023.

2.1.d. Uncertainties and Areas for Improvement

As highlighted by the alternate scenarios described above, there is uncertainty associated with fluctuating electricity demand due to changes in world oil prices and the future build out of renewable energy capacity. Additional uncertainties exist in the future of renewable energy technology costs, particularly due to inflation and supply chain constraints, further land use constraints, and the viability of the remaining refinery. This analysis also did not account for future policies or programs that could impact fuel consumption by the Residential, Commercial, and Industrial sectors.

2.2. Transportation

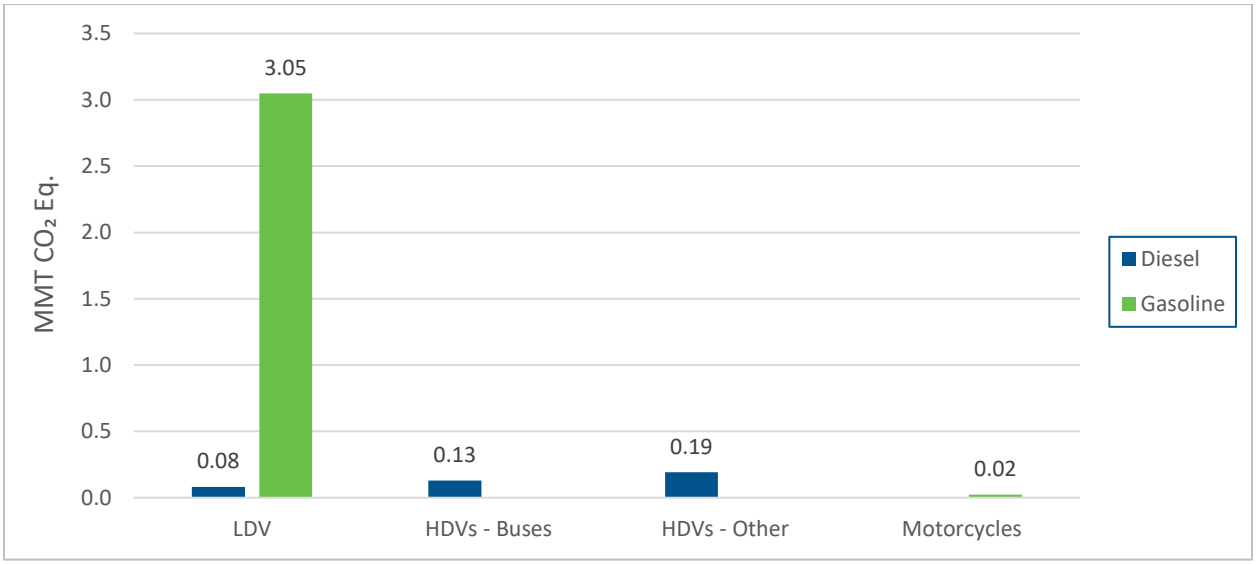
2.2.a. Baseline Scenario Methodology

Under the baseline scenario, differing methods are used to project emissions from ground transportation, domestic marine transportation, military transportation, and non-military air transportation. Where applicable, macroeconomic projections are applied for alignment with stationary combustion projections.

2.2.a.i Ground Transportation

Statewide emissions projections from ground transportation use 2022 fossil fuel consumption by fuel and vehicle type which is summarized in Figure J-4. HDVs have been split between buses and other vehicles, which includes large trucks and cranes.

Figure J-4: Statewide Emissions from Ground Transportation in 2022 (MMT CO_2 Eq.)



Note: Other HDVs includes large trucks and cranes, and motorcycles contribute 0.0220 MMTCO_2 Eq., or 0.70 percent, of LDV emissions.

Light Duty Vehicles

LDVs are defined as cars, light trucks, minivans, and sports utility vehicles and generally represent the dominating majority of statewide usage of on-road gasoline consumption, which comprise 88 percent of 2022 emissions in ground transportation.[74] An LDV turnover model was used to forecast the consumption of gasoline and its associated emissions from passenger cars and trucks. Vehicle turnover models estimate the rate at which older vehicles retire and new ones enter the road. This makes them useful tools to understand future compositions of vehicle types, and therefore GHG emissions from vehicles. The LDV model was calibrated to 2022 and tracks the miles, fuel efficiency, and fuel use of the existing stock of vehicles as well as all post-2022 vintages. Major changes to GHG emissions result from changing assumptions about the adoption of EVs and fuel prices.

To forecast future emissions from LDVs, the properties of the 2022 vehicle fleet were defined. Fleet characteristics were used to calculate the fleet's VMT by internal combustion engine vehicles (ICEVs) and EVs, as well as the average fuel efficiency of each. DBEDT (2023) and the FHWA (2022) provided data on the total number of LDVs by county and the average VMT per LDV by county; however, ICEVs and EVs were not distinguished. To compute the number of ICEVs, the number of EVs was subtracted from the total number of LDVs using 2022 EV sales and registrations (DBEDT 2024c). EVs include BEVs and PHEVs while ICEVs include conventional ICEVs and hybrid vehicles. Using FHWA (2022) for VMT per vehicle by county and assuming that average travel by EVs and ICEVs is the same, the total VMT by each vehicle type was computed as follows:

[74] It is assumed that all gasoline in Hawai'i is used by LDVs.

$$ICEV_{VMT\,c,2022} = (ICEV_{LDV\,c,2022} - EV_{c,2022}) \times VMTperVeh_{c,2022}$$

where,

$ICEV_{VMT\,c,2022}$	= The distance (miles) driven by ICEVs by county *c* in 2022
$ICEV_{LDV\,c,2022}$	= The number of ICEVs by county *c* in 2022 (DBEDT 2023, Table 18.08)
$EV_{c,2022}$	= The number of EVs by county *c* in 2022
$VMTperVeh_{c,2022}$	= the distance (miles) driven per vehicle by county *c* in 2022 (DBEDT 2023, Table 18.17)

To account for the ethanol content of gasoline, an adjustment was made to account for the Federal Renewable Fuel Standard that mandates blended gasoline contains 10 percent ethanol. The fuel efficiency of ICEVs was then given as follows:

$$ICEV_{FE\,c,2022} = ICEV_{VMT\,c,2022} \div \left(\frac{Gasoline_{c,2022}}{(1 - shE)}\right)$$

where,

$ICEV_{FE\,c,2022}$	= Fuel efficiency of the stock of ICEVs by county *c* in 2022
$Gasoline_{c,2022}$	= Petroleum gasoline (E0) consumption in county *c* in 2022
shE	= Share of ethanol in gasoline pool (10 percent)

To forecast future LDV GHG emissions, the 2022 calibration was projected into the future based on the assumptions about the following additional elements:

- A forecast for LDV VMT. For Honolulu, this forecast accounted for the proposed impact of the Honolulu rail transit project.
- An assumption of the relative contribution to the overall change in VMT from the change in VMT per vehicle or the change in the number of vehicles.
- Assumptions about new vehicle characteristics such as fuel efficiency, and the rate of additional EV adoption.
- Lastly, new vehicles enter the fleet based on assumptions on the scrappage rate of vehicles by vintage.

Future LDV VMT

To estimate future LDV VMT, the analysis used an Ordinary Least Squares regression between historical county level de facto population (DBEDT 2024e) and county VMT from 1979 to 2022. Using the state's most current long range-forecast for the growth rate of de facto population to the year 2045 (DBEDT 2018), total future VMT for passenger cars and trucks was projected to 2045 for each county using the following equation:

$$VMT_{c,t} = Intercept\ (c) + Slope\ (c)\ \times DefactoP_{c,t}$$

where,

$VMT_{c,t}$	= Total county level VMT from all LDVs in year
$Intercept\ (c)$	= Intercept term in the least squares fit by county
$Slope\ (c)$	= Slope term in the least squares fit by county
$DefactoP_{c,t}$	= Forecast for de facto population by county in year *t*

The resulting value for VMT served as an effective demand for travel. For Honolulu county, this demand could also be satisfied by future rail trips. To isolate future energy used for LDVs in Honolulu county, the LDV VMT was adjusted such that future VMT met through rail transit was subtracted. The Honolulu Area Rapid Transit (HART) initially estimated the maximum VMT that could be displaced from passenger cars and trucks, once the rail is fully operational and running at full capacity, to be 566 million miles (HART 2010). However, given the planned truncated service to the system and actual 2023 and 2024 ridership (HART 2019, DTS 2024), this original forecast was adjusted downward. Actual ridership for the first year of operation has averaged about 3,500 passengers on a weekday (Cruz 2024). This translates to a reduction in VMT of about 7 million miles, which is used for 2024. Using HART (2019) estimates for expected passenger trips, the current plans for the completion of segments two and three of Skyline, and making assumptions for peak and off-peak utilization, a new estimate for VMT reduction was made, reaching 456 million miles in 2045.

Because the project has experienced numerous delays in construction and difficulties estimating ridership, there is great uncertainty around this forecast. The effect of the rail project on VMT, however, is rather small and thus its effect on emissions from LDVs is small. For example, if the forecast were adjusted up by 50 percent from 2030 onward, forecasted VMT from LDVs would decline by about 1 percent in 2030 and 3 percent in 2045.

VMT per LDV

The next step was to further define LDV VMT per vehicle, which was determined based on the number of vehicles and the average VMT per vehicle. A multiplier of 0.5 is used as a simplifying assumption to attribute the total growth in aggregate VMT equally between two contributing factors. First, an increase in the number of LDVs, and second, an increase in the average VMT per LDV. The multiplier reflects an equal contribution to the total VMT growth in proportional terms. Assuming that the growth in number of vehicles and average VMT per vehicle are weighted equally, the VMT per LDV was given by the following:

$$VMTperLDV_{c,t} = (1 + 0.5\ \times VMTGrow_{c,t}) \times VMTperLDV_{c,t-1}$$

where,

$VMTperLDV_{c,t}$	= Average VMT per Vehicle (miles) in county *c* in year *t*
$VMTGrow_{c,t}$	= Annual growth in VMT in county *c* in year *t*
$VMTperLDV_{c,t-1}$	= Average VMT per Vehicle (miles) in county *c* in year *t-1*

Composition of the Vehicle Fleet

The LDV turnover model introduced new vehicles and retired older vehicles based on the assumed survival rate for cars and trucks by vehicle age (EPA 2016b). Vehicle sales by type in the current year was the difference between the total number of vehicles by type in the current year less the total number of vehicles in the previous year that remain on the road in the current year. The following standard vehicle turnover equation was used to compute the number of vehicles of each vintage, except the current year vintage.

$$Veh_{c,type,v,t} = (1 - Decay_{age}) \times New_{c,type,v,t-1}$$

where,

v	= all vintages except the current year vintage
type	= ICEV car, ICEV truck, EV car, or EV truck, for all post-2022 vintages
$Veh_{c,type,v,t}$	= Existing vehicles on the road in county *c*, by *type*, vintage *v*, and year *t*
$Decay_{age}$	= One year decay rate of vehicles of age (*t*-*v*)

The total number of vehicles was estimated by the ratio of total VMT and average VMT per vehicle. The number of new vehicles was the difference between the total number of all vehicles and the total number of existing vehicles:

$$NewVeh_{c,t} = TtlVeh_{c,t} - \Sigma_{type,v} Veh_{c,type,v,t}$$

for *v*=2022, ..., *t*-1

where,

$NewVeh_{c,t}$	= New vehicles in county *c* and year *t*
$TtlVeh_{c,t}$	= Total vehicles in county *c* and year *t*

New vehicles were then disaggregated into the four *types* of LDVs, first by splitting EVs and ICEVs. The share of new vehicles that are EVs came from HECO's IGP (Hawaiian Electric 2021):

$$TtlNewEV_{c,t} = EVSh_{c,t} \times NewVeh_{c,t}$$

where,

$TtlNewEV_{c,t}$	= New EVs in county *c* and year *t*
$EVSh_{c,t}$	= Share of new vehicle sales that are EVs

The difference between total new vehicles and total new EVs gave total new ICEVs. Next, new EVs were split into those that were cars and trucks. The share of new vehicles that were cars was set equal to the share of 2022 vehicle sales that were cars. So, the number of new car sales that were ICEVs was the difference of total car sales of all types and sales of EV cars, which then left the number of new LDVs that were ICEV trucks as the remainder of new vehicle sales after accounting for all EV sales and ICEV cars.

Fuel Efficiency of New Passenger Cars and Trucks

Fuel efficiency of new passenger cars and trucks was estimated using the U.S. Environmental Protection Agency's (EPA) corporate average fuel economy (CAFE) standards for passenger cars and light trucks. CAFE standards require light duty vehicles to have an EPA rated efficiency of 165 g CO_2 Eq./mile and 240 g CO_2 Eq./mile, respectively, by 2026. These standards can be met through a combination of improving vehicle efficiency and/or reducing emissions of hydrofluorocarbons (HFCs) from vehicle air conditioning. For this analysis, it was assumed based on Davis and Boundy (2019) that a portion of improvements was made through reductions in leakage of refrigerants from vehicle air conditioning systems. Specifically, this method of compliance meant that fleet average fuel economy standards in 2025 declined from 54.5 to 45.4 mpg (Lattanzio et al. 2018; Davis and Boundy 2019). These fleet average fuel efficiency standards translated into effective tailpipe fuel efficiency standards for light duty cars and trucks, respectively, of 60.9 and 40.7 mpg in 2026 (EPA 2022a). The fuel economy for 2027 to2032 is based on the National Highway Traffic Safety Administration proposed rulemaking (DOT 2023). The resulting 2032 fuel economy standards are 72.3 and 47.3 mpg, respectively, for light duty cars and trucks. This level of CAFE standard was assumed to remain constant from 2032 through 2045. National Highway Traffic Safety Administration (NHTSA) is developing new CAFE standards and does so at least every five years. The current numbers differ by only one or two mpg from the previous estimate for the last year modeled by NHTSA.

New vehicle fuel efficiency was adjusted to account for the difference between federal fuel standards and true on-road fuel efficiency as estimated by new car window labels. EPA estimated this difference to range from 20 to 25 percent (EPA 2014). It was assumed that the actual fuel efficiency of new vehicles would be 22.5 percent lower than the CAFE standards. This efficiency standard was an average across ICEVs and EVs.

To compute emissions from light duty ICEVs, the implied on-road fuel efficiency standard for ICEVs needed to be determined. Using the AEO (EIA 2023) forecast for EV sales, the Electric Vehicle's Database (2023) for EV efficiency, and the overall fleet efficiency, the effective efficiency standard for new ICEVs over the model horizon was computed. The efficiency of the existing stock of EVs was taken as the average across all 2023 EVs (EIA 2023). The 2045 value was taken to be the efficiency of the Lightyear 0 concept car (Electric Vehicle's Database 2022). The efficiency from 2023 to 2045 was assumed to increase exponentially between the 2023 and 2045 value.

In addition to EVs embedded in the fuel efficiency achieved through CAFE, the model assumed different EV adoption rates for each county. For the baseline, annual statewide sales shares for EVs were based on the International Council on Clean Transportation 2023 report on EV adoption for 2025-2035 (Slowik et al. 2023). For 2045, a boundary condition for EV sales share of 95 percent is assumed. For the intervening years, the statewide sales shares are computed by fitting an S-shaped curve between the 2035 and 2045 values. The sales share for Honolulu County was assumed to match that of the state, and the shares for the Hawai'i and Maui Counties were based on the ratio of the penetration shares of these counties to that of Honolulu County, based on HECO's IGP (Hawaiian Electric 2021). Since Kaua'i is not a part of HECO's service territory, EV penetration in this county was assumed to mirror that of Maui. By 2045, the baseline forecast projected the share of LDV sales to be EVs: 73 percent, 95 percent, 100 percent, and 100 percent for Hawai'i, Honolulu, Kaua'i, and Maui counties, respectively. These values

are a marked increase from the 2023 forecast because recent EV sales have far exceeded previous near-term forecasts.

Total Energy Consumption

With the number of ICEVs, EVs, VMT per vehicle, and fuel efficiency, the amount of gasoline and electricity used to power the fleet of LDVs throughout the model time horizon was calculated as follows:

$Gasoline_{c,t} = \Sigma_v(VMTperLDV_{c,t} \times (Veh_{c,type,v,t} \div FE_{type,v}))$ for type = ICEV car and ICEV truck

$Electricity_{c,t} = \Sigma_v(VMTperLDV_{c,t} \times (Veh_{c,type,v,t} \div FE_{type,v}))$ for type = EV car and EV truck

where,

$FE_{type,v}$ = Fuel efficiency of vehicles by type (in miles per gallon of gasoline for ICEVs and miles per kWh for EVs)

$Veh_{c,type,v,t}$ = Number of vehicles (including new and used) by county, type, and vintage in year t.

$Gasoline_{c,t}$ = Blended gasoline consumption (E10) in county *c* and year *t*

$Electricity_{c,t}$ = Electricity demand in county *c* and year *t*

LDV GHG Emissions

Lastly, tailpipe GHG emissions for ICEVs were computed as the product of the fossil gasoline (E0) consumed and GHG emissions factor for fossil gasoline plus the product of ethanol (E100) consumed and GHG emissions factor for ethanol.[75] GHG emissions from ICEVs were given by:

$$EmissionsICEV_{c,t} = Gasoline_{c,t} \times (1 - shE) \times EF_Gasoline + Gasoline_{c,t} \times shE \times EF_Ethanol$$

where,

$EmissionsICEV_{c,t}$ = Emissions (MMT CO_2 Eq.) in county *c* and year *t*

$EF_Gasoline$ = Emissions factor for gasoline (MT CO_2 Eq./gal of gasoline)

$EF_Ethanol$ = Emissions factor for ethanol (MT CO_2 Eq./gal of ethanol)

Total statewide emissions from gasoline for each year are the sum of emissions over all counties. GHG emissions resulting from the consumption of electricity used by both EVs and future rail transit were accounted for through emissions from power generation.[76]

Heavy Duty Vehicles

[75] Consistent with standard emissions accounting practices, the CO_2 emission factor for ethanol is assumed to be zero. CH_4 and N_2O emissions from biofuels are included in the overall CO_2 -equivalent GHG emission factor.
[76] Assuming that rail transit takes 15 MW to operate the entire line (Honore 2019), and its current planned level of service will be fully operational by 2035.

The existing stock of diesel-powered vehicles were categorized as HDVs, including buses, other HDVs, and medium HDVs (MHDVs). Other HDVs included large trucks and cranes. MHDVs included all diesel-powered vehicles that were not HDVs. This breakout was used because of the large difference among these vehicle types in their characteristics, usage, and forecasts for electrification.

As with the forecast of GHG emissions for gasoline powered LDVs, the characteristics of HDVs into the future were identified using a fleet turnover model where 2022 diesel fuel consumption was used for data calibration. FHWA (2022) data were used to disaggregate the country totals into these vehicle types. To forecast future emissions from HDVs, the properties of the 2022 stock of HDVs needed to be defined, specifically, the three fleet's VMT, fuel use, and average fuel efficiency.

For buses, fuel use equaled the product of the number of buses, annual mileage per bus, and average fuel economy of buses. The FHWA provided data on the number of buses by county; DBEDT (2021) provided data on the annual mileage of buses on O'ahu, which was assumed to hold for the other counties; and the average fuel efficiency for the fleet of buses was taken to be 7.3 mpg (EPA 2016a). Thus, total fuel use for buses by county was given by the following:

$$HDV_Fuel_{c,bus,2022} = HDV_VMT_{c,bus,2022} / FE_{c,bus,2022}$$

where,

$HDV_Fuel_{c,bus,2022}$ = Fuel consumed by buses in county in 2022 (millions of gallons of B5 diesel)

$HDV_VMT_{c,bus,2022}$ = VMT for buses in county in 2022 (millions of miles)

$FE_{c,bus,2022}$ = Average fuel efficiency for buses in county in 2022 (mpg)

For MHDVs, fuel consumption was computed in a similar manner to buses. The number of these vehicles in the state is 15,500 (AFDC 2022). The number per county was assumed to equal the product of the state total and the county's share of all LDV vehicles. The annual mileage for these vehicles was given by FHWA, and the average fuel economy of these vehicles was taken to be 18.1 (FHWA 2022). Thus, total fuel use for these vehicles by county was given by the following:

$$HDV_Fuel_{c,MHDV,2022} = HDV_VMT_{c,MHDV,2022} / FE_{c,MHDV,2022}$$

where,

$HDV_Fuel_{c,MHDV,2022}$ = Fuel consumed by MHDVs in county in 2022 (millions of gallons of B5 diesel)

$HDV_VMT_{c,nHDV,2022}$ = VMT for MHDVs in county in 2022 (millions of miles)

$FE_{c,nHDV,2022}$ = Average fuel efficiency for MHDVs in county in 2022 (mpg)

Fuel consumption for all other diesel-powered vehicles (other HDVs) was then taken to be the remainder of diesel fuel used in ground transportation. That is, diesel fuel consumed by other HDVs equaled the total diesel used in ground transportation less the diesel used for buses and MHDVs. The VMT for other HDVs was set equal to the total fuel use times the average fuel efficiency of other HDVs.

The average fuel efficiency was taken to be 6.0 mpg (FHWA 2022; based on the fuel economy for combination trucks).

$$HDV_VMT_{c,HDV,2022} = HDV_Fuel_{c,HDV,2022} \times FE_{c,HDV,2022}$$

where,

$HDV_Fuel_{c,HDV,2022}$	= Fuel consumed by other HDVs (millions of gallons of B5 diesel) in county *c* in the year 2022
$HDV_VMT_{c,HDV,2022}$	= VMT for other HDVs (millions of miles) in county *c* in the year 2022
$FE_{c,HDV,2022}$	= Average fuel efficiency for other HDVs (mpg) in county *c* in the year 2022

It was assumed that diesel used in ground transportation was comprised of five percent biodiesel and 95 percent petroleum diesel. Therefore, gallons of fossil diesel and biodiesel consumed equaled 95 and five percent of total diesel, respectively. Thus, GHG emissions from each vehicle type equaled 95 percent of the product of the amount of diesel consumed by each vehicle type and the emissions factor for fossil diesel plus 5 percent of the product of the amount of diesel consumed by each vehicle and emissions factor for biodiesel.[77]

To estimate future GHG emissions from HDVs, the 2022 calibration year was projected into the future based on the assumptions about the following additional elements:

- Forecasted VMT by type of vehicle.
- Change in fleet average fuel efficiency.
- The rate of electrification.

Specifically, future GHG emissions for each diesel vehicle type equaled the product of the diesel consumed by each vehicle type and the emissions factor for diesel. The level of diesel consumption was found by dividing VMT from diesel powered vehicles by the average fuel efficiency of these vehicles. Emissions associated with future electric buses, HDVs, and MHDVs were found in a similar manner where the average fuel efficiency was measured in miles per kWh and emissions factor depended on the generation mix in the county of interest.

The projections methodology and detailed assumptions are described below.

VMT Forecast for HDVs

Unlike LDVs, where VMT was projected based on the historic relationship to de facto population, county level VMT from all types of diesel powered vehicles were assumed to grow at the rate of GCP. This

[77] Consistent with standard emissions accounting practices, the CO_2 emission factor for ethanol is assumed to be zero. CH_4 and N_2O emissions from biofuels are included in the overall CO_2-equivalent GHG emission factor.

relationship is based on the fact that diesel powered vehicles are more closely aligned with economic activity than population as they are used for freight transport, public transit, and industrial purposes.

$$HDV_VMT_{c,tpe,t} = HDV_VMT_{c,type,2022} \times GCP_{c,t}/GCP_{c,2022}$$

where,

$HDV_VMT_{c,type,t}$	= Total VMT by HDVs by type and county in year t (millions of miles)
$HDV_VMT_{c,type,2022}$	= Total VMT by HDVs by type and county in 2022 (millions of miles)
$GCP_{c,t}$	= Forecast for real gross county product in year t
$GCP_{c,2022}$	= Gross county product in 2022
$type$	= Bus, HDV, MHDV

The VMT for each vehicle type was divided into travel by diesel powered (ICEV) and electric powered (EV) vehicles. For buses, the share of VMT by EVs was based on each county's projections for purchases of new buses that are electric. Based on a Federal grant, Kaua'i's and Maui's counties are planning to entirely electrify their bus fleets by 2035 (Maui Now 2022). Honolulu's was based on the City and County's Zero-Emission Fleet Transition Plan, which forecasted all buses to be electric by 2040 (City & County of Honolulu 2022). For Hawai'i county, the transition to electric buses was assumed to slower than that of Kaua'i and Maui counties because of the longer travel distances. Thus, the conversion to an all electric fleet on Hawai'i county is assumed to match that of Honolulu.

For MHDVs, given this is a much slower vehicle class to transition to EVs, the share of new vehicle sales that are EVs was taken to equal the low penetration forecast for LDVs (see Scenario 3B). For large HDVs, the penetration of these vehicles is based on the EPA's Final Rule regarding greenhouse gas standards for heavy duty vehicles (DOT 2023). The EPA forecasts that for manufacturers to comply with the Final Rule, 1 percent of the on-road fleet will be EVs in 2027, seven percent in 2032, and 22 percent in 2040. The model assumes constant growth rates in the share of on-road fleet between 2025 and 2027, 2028 and 2032, and 2032 to 2045.

VMT by diesel powered and EVs was given by the following:

$$HDV_ICE_VMT_{c,type,t} = HDV_VMT_{c,type,t} \times (1 - EV_Share_{c,type,t})$$

$$HDV_EV_VMT_{c,type,t} = HDV_VMT_{c,type,t} \times EV_Share_{c,type,t}$$

where,

$HDV_ICE_VMT_{c,type,t}$	= HDV ICE VMT (millions of miles) by county *c* and *type* in year *t*
$HDV_EV_VMT_{c,type,t}$	= HDV EV VMT (millions of miles) by county *c* and *type* in year *t*
$EV_Share_{c,type,t}$	= Share of travel by EVs (percent) by county *c* and *type* in year *t*

Fuel Efficiency and Fuel Consumption

The fleet average fuel efficiency of each type of ICEV HDV was based on the harmonic average fuel efficiency of the prior year's fleet and the fuel efficiency of new vehicles.

$$FE_HDV_ICEfleet_{c,type,t} = 1 \Big/ \left(\frac{1 - ShrVMT_HDV_ICEnew_{c,type,t}}{FE_HDV_ICEfleet_{c,type,t-1}} + \frac{ShrVMT_HDV_ICEnew_{c,type,t}}{FE_HDV_ICEnew_{c,type,t}} \right)$$

where,

$FE_HDV_ICEfleet_{c,type,t}$	= Fleet average HDV ICE fuel efficiency (mpg) by county *c* and *type* in year *t*
$ShrVMT_HDV_ICEnew_{c,type,t}$	= Share (percent) of miles driven by new ICE HDVs by county *c* and *type* in year *t*
$FE_HDV_ICEnew_{c,type,t}$	= Average fuel efficiency for new ICE HDVs (mpg) by county *c* and *type* in year *t*

A similar calculation was made for each type of fleet of HDVs that are EVs.

$$FE_HDV_EVfleet_{c,type,t} = 1 \Big/ \left(\frac{1 - ShrVMT_HDV_EVnew_{c,type,t}}{FE_HDV_EVfleet_{c,type,t-1}} + \frac{ShrVMT_HDV_EVnew_{c,type,t}}{FE_HDV_EVnew_{c,type,t}} \right)$$

where,

$FE_HDV_EVfleet_{c,type,t}$	= Fleet average EV fuel efficiency (mpg) by county *c* and *type* in year *t*
$ShrVMT_HDV_EVnew_{c,type,t}$	= Share (percent) of miles driven by new EV HDVs by county *c* and *type* in year *t*
$FE_HDV_EVnew_{c,type,t}$	= Average fuel efficiency (mpg) for new EV HDVs by county *c* and *type* in year *t*

The fuel efficiency for each fleet was solved recursively starting with the year 2023. In each year, the fuel economy for new vehicles and the share of the fleet that was comprised of new vehicles need to be determined. The improvement in fuel efficiency for buses over time was assumed to follow the EPA's Phase II standards (EPA 2016a), which imply about 10 percent improvement over 2016 efficiencies by 2025 or 8.9 mpg. From 2026 onward, fuel efficiency was forecasted to improve by the same absolute annual mpg fuel efficiency improvement from 2024 to 2025 of 0.15 mpg. The fuel efficiency of new types of other diesel (internal combustion) engines was assumed to increase over time in proportion with the increase in EPA's fuel efficiency standards for HDVs (EPA 2016a). Averaging across the different engine classes for HDVs yielded an average increase in fuel efficiency from 2016 to 2025 of about 11 percent, or 1.2 percent per year. This rate of annual improvement in fuel efficiency was assumed to persist through 2045. The rates of improvement in EV bus and EV HDV fuel efficiency followed the same

rate of improvement as their ICEV counterparts. The fuel efficiency of new electric 2021 buses and new 2021 HDVs was assumed to be 3 times that of their diesel counterparts on a diesel gallon equivalent.[78]

The fuel efficiency for new ICEV MHDVs was assumed to match the EPA CAFE standards combined for cars and trucks through 2029. Fuel efficiency for ICEVs was assumed to remain constant after 2029 because of the increased penetration of EVs, which eases compliance with the CAFE standards. The efficiency for the electric MHDVs was assumed to follow that of the LDVs.

As for the share of miles traveled by new vehicles, this analysis assumed that approximately nine percent of VMT for HDVs and MHDVs was undertaken by new vehicles of the respective type each year. This figure was derived from estimates of HDV VMT by model year as obtained from the U.S. Inventory (EPA 2024b).[79] For bus fleets, the model assumed four percent of travel by diesel powered buses was conducted by new buses. Note that the overall share of VMT by new buses was larger because more of the new buses were expected to be electric.

The share of travel by EVs that was made by new HDV EVs was represented by the following equation:

$$HDV_New_EV_VMT_{c,tpe,t0} = Shr_VMT_EV_{c,type,t0} \times HDV_VMT_{c,type,t0}$$

$$HDV_EV_VMT_{c,tpe,t} = Shr_VMT_EV_{c,type,t} \times HDV_VMT_{c,type,t}$$

$$HDV_New_EV_VMT_{c,tpe,t} = HDV_VMT_EV_{c,type,t} - Sum(tt, HDV_New_EV_VMT_{c,type,tt})$$

where,

$HDV_New_EV_VMT_{c,tpe,t}$	= VMT covered by new EVs sold in county *c* and *type* in year *t*
$HDV_EV_VMT_{c,tpe,t}$	= Total VMT covered by EVs sold through year *t* by *type* and in county *c*
t0	= First year EVs appear in the fleet for the *type* (buses, other HDVs, and MHDVs) in county *c*
tt	= *t0, … ,t-1*

The share of travel by new HDV EVs for a given *type* and county in year *t* is the ratio of the travel conducted by new EVs sold to the total travel conducted by EVs.

Knowing the VMT for each type of vehicle and its fleet average fuel efficiency, the fuel consumption by each type of HDV was computed as the ratio of VMT to fuel efficiency. The first equation computed the amount of diesel consumed, and the second equation computed the amount of electricity consumed:

$$Diesel_{c,type,t} = {HDV_ICE_VMT_{c,type,t}}/{FE_HDV_ICEfleet_{c,type,t}}$$

[78] The ratio of three was taken from the GREET model's ratio of fuel efficiency of electric buses to that of diesel buses (2019).

[79] The share of miles driven by new vehicles was estimated based on new vehicle data for 2007 because 2007 is believed to be a representative year in terms of typical vehicle sales.

where,

$Diesel_{c,type,t}$ = Consumption of B5 (gallons), which contains 95 percent fossil and five percent bio diesel, in county *c* by *type* and in year *t*

$$Electricity_HDV_{c,type,t} = {HDV_EV_VMT_{c,type,t}}/{FE_HDV_EleFleet_{c,type,t}}$$

where,

$Electricity_HDV_{c,type,t}$= Electricity consumption (GWh) in county *c* by *type* and in year *t*

HDV GHG Emissions

Lastly, tailpipe GHG emissions for diesel powered vehicles were computed as the product of the fossil diesel consumed and GHG emissions factor for fossil diesel. Total statewide emissions for each year were the sum of emissions over all counties. It was assumed that the share of biodiesel in the diesel pool remained constant at 2022 levels of five percent over time.

$$\begin{aligned} HDV_ICE_Emissions_{c,type,t} \\ &= ((1 - ShrBiodiesel(t)) \times Diesel_{c,type,t} \times EF_fDiesel) \\ &+ (ShrBiodiesel(t) \times Diesel_{c,type,t} \times EF_bDiesel) \end{aligned}$$

where,

$HDV_ICE_Emissions_{c,type,t}$ = Emissions (MM MT CO_2 Eq.) from diesel HDVs in county *c* by *type* and in year *t*

$ShrBiodiesel_t$ = Share of biodiesel in the diesel pool (five percent)

$EF_fDiesel$ = Emissions factor for fossil diesel (MT CO_2 Eq./gallon)

$EF_bDiesel$ = Emissions factor for biodiesel (MT CO_2 Eq./gallon)[80]

Total statewide emissions from transportation diesel for each year were the sum of emissions over all counties and vehicle types. GHG emissions resulting from the consumption of electricity used by HDV EVs were accounted for through emissions from power generation.

Motorcycles

Annual county level GHG emissions from motorcycles were calculated based on the average fuel efficiency of motorcycles and the total county level annual VMT for motorcycles. Historic data for county level gasoline consumption and emissions associated with motorcycles were based on county level data on the number of motorcycles (DBEDT 2023), VMT per motorcycle (FHWA 2022), and the average fuel efficiency of motorcycles (FHWA 2022).

$$Mot_VMT_{c,2022} = VMTperMot_{c,2022} \times NMot_{c,2022}$$

[80] The emissions factor for biodiesel includes methane and nitrous oxide but not CO_2.

where,

$Mot_VMT_{c,2022}$ = Motorcycle VMT in county *c* in the year 2022
$VMTperMot_{c,2022}$ = Average VMT per motorcycle in county *c* in the year 2022
$NMot_{c,2022}$ = Number of motorcycles in county *c* in the year 2022

Total VMT for motorcycles was assumed to grow at the same rate as total VMT for LDVs.

$$Mot_VMT_{c.t} = VMT_Growth_Index_{c,t} \times VMT_Mot_{c,2022}$$

where,

$Mot_VMT_{c.t}$ = Motorcycle VMT in county *c* and year *t*

$VMT_Growth_Index_{c,t}$ = Growth rate of VMT, based on LDV VMT, in county *c* and year *t*

$VMT_Mot_{c,t}$ = Motorcycle VMT in county *c* and the year 2022

Motorcycle gasoline consumption was calculated by dividing total VMT for motorcycles by their average annual fuel efficiency, which was assumed to be 44 mpg (FHWA 2022) (and assumed to remain constant over time).

$$Mot_Gasoline_{c.t} = Mot_FE \times VMT_Mot_{c,t}$$

where,

$Mot_Gasolinec_{c,t}$ = Motorcycle gasoline consumption (gallons) in county *c* and year *t*

Mot_FE = Fuel efficiency for motorcycles (mpg)
$VMT_Mot_{c,t}$ = Motorcycle VMT in county *c* and year *t*

GHG emissions from motorcycles were then calculated by multiplying gasoline consumption by the GHG emissions factor for gasoline. As with gasoline consumed by LDVs, this analysis assumed that gasoline consumed was E10, which contains 10 percent ethanol by volume.

$$Mot_Emissions_{c.t} = EF_Gasoline \times (1 - shE) \times Mot_Gasoline_{c.t}$$

where,

$EF_Gasoline$ = Emissions factor for gasoline (MM MT CO_2 Eq./gal.)
shE = Share of ethanol in gasoline
$Motorcycle_Emissions_{c,t}$ = GHG emissions (MM MT CO_2 Eq.) from motorcycles in county *c* and year *t*

Statewide GHG emissions from motorcycles were aggregated from county emissions for each year.

2.2.a.ii Domestic Aviation

GHG emissions from domestic aviation include emissions from passenger and cargo travel between Hawai‘i and other domestic locations (including within Hawai‘i). Passenger travel represents both residents and visitors. The inventory convention for attributing air travel emissions is to assign half the emissions to the location of the flight’s origin and the other half to the flight’s destination.

To forecast emissions for domestic aviation, the characteristics in these three categories – visitors, residents, and cargo traveling to and from domestic locations needed to be calibrated. Total jet fuel consumption by county in 2022 was broken into these three categories based on data for visitor arrivals and cargo shipments. First, all air travel was disaggregated into passenger overseas travel, passenger interisland travel, and cargo. This followed the methods presented in the City & County of Honolulu Climate Action Plan, Technical Appendix, for domestic aviation (City & County of Honolulu 2021).

In brief, air travel was split between that used to move passengers and cargo based on a share parameter from data on the number of passengers and tons of cargo, where tons of cargo were converted to passengers based on the assumed constraints of a Boeing 767. Overseas and interisland travel were combined in such a way that accounts for the difference in energy used for the two different types of trips. To do so, it was then assumed that an overseas trip required five times the amount of energy than an interisland trip (see City & County of Honolulu 2021). Next, passenger travel was further disaggregated into visitor overseas travel, visitor within Hawaiʻi travel, and residential travel. The share of overseas visitor travel was estimated based on the ratio of visitor arrivals to Hawaiʻi to total arrivals to Hawaiʻi, at 86 percent (City & County of Honolulu 2021). Interisland travel was assumed to be split evenly between visitors and residents.

Visitor and residential travel, as well as cargo were further disaggregated into international and domestic sources. Based on City & County of Honolulu (2021), two-thirds of visitor travel were found to come from the US. The share of air cargo traveling between Hawaiʻi and US destinations was taken to equal the ration of domestic jet fuel consumption to the sum of domestic jet fuel and international bunker jet fuel consumption.

Last, these categories were combined to make the following categories that accounted for all domestic aviation:

- Domestic visitor travel = Overseas visitor travel from domestic locations + Interisland visitor travel
- Domestic Residential travel = Overseas residential travel from domestic locations + Interisland residential travel
- Cargo = Cargo flown between domestic locations + Interisland cargo shipments

Since residential travel and cargo were assumed to increase with each county's GCP, domestic air travel was divided into visitor air travel and everything else. Thus, the share of travel by visitors was given by the following:

$$VisShr = DomVisTravel_{2022} / (DomVisTravel_{2022} + DomCargo_{2022} + ResTravel_{2022})$$

where,

$DomVisTravel_{2022}$	= Total 2022 travel by visitors between Hawaiʻi and domestic locations (including Hawaiʻi) (miles)
$DomCargo_{2022}$	= Total 2022 travel by cargo between Hawaiʻi and domestic locations (including Hawaiʻi) (miles)

$DomResTravel_{2022}$ = Total 2022 travel by residents between Hawai'i and domestic locations (including Hawai'i) (miles)

With the base year, 2022, value for jet fuel consumed in domestic activities by county and the share of jet fuel due to visitors, the model then forecasted the jet fuel consumed by visitors and all other domestic sources. To forecast jet fuel consumption due to visitor travel, the value of county level emissions from jet fuel was used as a starting point. The base year value was then multiplied by the growth index in visitor travel and the share of 2022 jet fuel due to visitor travel. This product was then multiplied by an efficiency index for air travel to account for the increase in efficiency of air travel over time.[81] The growth in domestic visitor travel was based on DBEDT's short- and long-range county level forecasts for visitor arrivals.

$$JetFuel_Visitors_{c,t} = VisNdx_{c,t} \times Eff_t \times VisShr \times JetFuel_{c,2022}$$

where,

$JetFuel_Visitors_{c,t}$ = Jet fuel consumed by visitors traveling between domestic locations and county, c, in year t (gallons)

$VisNdx_{c,t}$ = Visitor index for county, c, in year t (2022 = 1)

Eff_t = Efficiency index for air travel in year t (2022 = 1)

The growth in resident travel and cargo was based on DBEDT's short- and long-range county level forecasts for GCP.

$$JetFuel_Cargo\&Res_{c,t} = GCPNdx_{c,t} \times Eff_t \times (1 - VisShr) \times JetFuel_{c,2022}$$

where,

$JetFuel_Cargo\&Res_{c,t} =$ Jet fuel consumed by residents and cargo traveling between domestic locations and county, c, in year t (gallons)

$GCPNdx_{c,t}$ = Gross product index for county, c, in year t (2022 = 1)

Emissions from domestic aviation were then calculated by multiplying total jet fuel consumption by ICF's emission factors.

$$DomAir_Emissions_{c.t} = EF_JetFuel \times (JetFuel_{Visitors_{c,t}} + JetFuel_Cargo\&Res_{c,t})$$

where,

$DomAir_Emissions_{c,t} =$ County level emissions from domestic air in year t (MM MT CO_2 Eq.)

$EF_JetFuel =$ Emission's factor for jet fuel (MT CO_2 Eq./gallon)

[81] Efficiency index was based on EIA's AEO 2022 air travel efficiency metric.

2.2.a.iii Domestic Marine

Due to variations in historic emissions, projections use an average of 2015 through 2022 to generate a baseline instead of a single jumping off year. Then emissions are projected from this year by taking the product of this average, the State's GSP index relative to 2022, and the efficiency index for commercial shipping (EIA 2023).

$$MarineEmissions_t = GSPNdx_t \times EffNdx_t \times MarineEmissions_{avg}$$

where,

$MarineEmissions_t$	= State level emissions from commercial marine in year t (MMT CO_2 Eq.)
$MarineEmissions_{avg}$	= Average of State level emissions from commercial marine over the years 2015 through 2022 (MMT CO_2 Eq.)
$GSPNdx_{c,t}$	= GSP index in year t (2022 = 1)
$EffNdx_t$	= Efficiency index for commercial shipping in year t (2022 = 1)

2.2.a.iv Military Aviation and Military Non-Aviation

Emission projections were not developed for the military. Instead, future emissions were assumed to equal the average of the 2015 through 2022 emissions from this sector and remain constant for all projection years. Future military operations are based on decisions that are not made at the state-level; therefore, emissions from military operations are highly uncertain and are not accurately forecastable. Therefore, growing emissions based on GSP or other Hawai'i specific economic indicators was determined to be inappropriate. Further discussion of data uncertainties for these sources is provided in the section below.

2.2.b. Alternate Scenario 1A and 1B

To understand the potential effect of oil prices on Hawai'i's future emissions from the transportation sector, *high* (Alternate Scenario 1A) and *low* (Alternate Scenario 1B) future oil price pathway based on the EIA's Annual Energy Outlook (AEO) 2022 for gasoline, diesel and jet fuel were assessed.

2.2.b.i Ground Transportation

Light Duty Vehicles

To estimate the impact of a price change on LDV fossil fuel demand, the percent change in gasoline price between each oil price scenario and the baseline case was multiplied by the price elasticity of demand for gasoline. This analysis assumed that the elasticity started at -0.24 in 2023 and linearly increased in magnitude to -0.47 in the long run in 2035 (Hössinger et al. 2017). The change in demand for LDV gasoline for each scenario was then calculated based on the following equation:

$$\%\Delta LDV_{t,c,s} = \sigma_t \times \%\Delta GP_{t,s}$$

where,

$\%\Delta LDV_{t,c,s}$ = The percent change in LDV gasoline demand in county *c* and year *t* and under scenario *s*

σ_t = The price elasticity of LDV gasoline demand in year *t*

$\%\Delta GP_{t,s}$ = The percent change in gasoline price in year *t* under scenario *s*

As a last step, the percent change in gasoline demand under each alternate scenario was multiplied by emissions estimated under the baseline scenario and then added to the baseline emission estimates to adjust emissions accordingly.

Heavy Duty Vehicles

To estimate the sensitivity of HDV fuel demand to changing diesel prices, the same technique as that for LDVs was used. The percent change in diesel price between each oil price scenario and the baseline case was multiplied by the price elasticity of demand for diesel. Based on recent literature, this analysis assumed that the elasticity started at -0.07 in 2025 and linearly increased in magnitude to -0.27 in the long-run in 2035 (Dahl 2012; Washington Department of Commerce 2015). The change in demand for HDV diesel for each scenario was then calculated based on the following equation:

$$\%\Delta HDV_{t,c,s} = \sigma_t \times \%\Delta DP_{t,s}$$

where,

$\%\Delta HDV_{t,c,s}$ = The percent change in HDV diesel demand in county *c* and year *t* and under scenario *s*

σ_t = The price elasticity of HDV diesel demand in year *t*

$\%\Delta DP_{t,s}$ = The percent change in diesel price in year *t* under scenario *s*

As a last step, the percent change in diesel demand under each alternate scenario was multiplied by emissions estimated under the baseline scenario and then added to the baseline emission estimates to adjust emissions accordingly.

2.2.b.ii Domestic Aviation

To estimate the sensitivity of aviation fuel demand to changing fuel prices, the same methodology used to calculate the sensitivity of LDV and HDV fuel demand to changing fuel prices was applied to jet fuel. The percent change in the jet fuel price between each oil price scenario and the baseline case was multiplied by the price elasticity of demand for jet fuel for domestic aviation. Based on recent literature, this analysis assumed that the elasticity started at -0.19 in 2025 and linearly increased in magnitude to -0.24 in the long run in 2035 (Fukui 2017; Sobieralski 2012). The change in demand for HDV diesel for each scenario was then calculated based on the following equation:

$$\%Air_{t,c,s} = \sigma_t \times \%\Delta JFP_{t,s}$$

where,

$\%\Delta Air_{t,c,s}$ = The percent change in jet fuel demand in county *c* and year *t* under scenario *s*

σ_t = The price elasticity of jet fuel demand in year *t*

$\%\Delta JFP_{t,s}$ = The percent change in jet fuel price in year *t* under scenario *s*

As a last step, the percent change in aviation fuel demand under each alternate scenario was multiplied by emissions estimated under the baseline scenario and then added to the baseline emission estimates to adjust emissions accordingly.

2.2.c. Alternate Scenario 3A and 3B

In addition to the uncertainties around oil prices caused by global events and macroeconomic forces, there is great uncertainty over the future penetration of EV. To quantify these uncertainties, Alternate Scenario 3A and 3B accounted for potential variations in the sale of EVs. Alternate Scenarios 3A and 3B assumed higher and lower sales of EVs, respectively, than the baseline scenario.

For Alternate Scenario 3A, the share of LDV sales that are EVs were assumed to match that of the California Air Resources Board's Advanced Clean Cars II (CARB 2022). For Alternate Scenario 3B, the share of new LDV sales that are EVs were based on the growth rate of the AEO (EIA 2023) "Reference" scenario for national EV adoption. An additional constraint is added that EV adoption in Alternate Scenario 3B cannot exceed the baseline. This is only relevant through 2026, given differences in near- and long-term forecasts.

The electric sector demand forecasts (by county) were adjusted to account for the difference in the penetration of EVs from the baseline for each of these alternate scenarios Electricity demand from EVs in each scenario was calculated using the following formula:

$$Electricity_{c,t} = \Sigma_{type,v}(VMTperLDV_{c,t} \times (nEV_{c,type,v,t} \div FE_{type,v})$$

where,

$Electricity_{c,t}$ = Electricity demand from EVs in county *c* and year *t*

$VMTperLDV_{c,t}$ = Average vehicle miles travelled by a light duty vehicle.[82]

$nEV_{c,type,v,t}$ = Number of EVs by type and vintage in county *c* and year *t* as defined in the different EV sales' forecasts.

$FE_{type,v}$ = Fuel efficiency of EVs by type (car or truck) and vintage (miles per kWh)[83]

[82] The starting point (t=2022) is taken from DBEDT's data on average VMT per vehicle (DBEDT 2023). Over time, this value increases at half the rate that VMT does; thus, assuming that half of VMT growth is from more vehicles and the other half is because vehicles travel farther per year.

[83] The efficiency of the existing stock of EVs was taken as the average across all 2023 EVs (EIA 2023). The 2045 value was taken to be the efficiency of the Lightyear 0 concept car (Electric Vehicle's Database 2022). The efficiency from 2023 to 2045 was assumed to increase exponentially between the 2023 and 2045 value.

2.2.d. Uncertainties and Areas for Improvement

As highlighted by the alternate scenarios described above, there is uncertainty associated with fossil fuel prices and EV adoption. There is also uncertainty from other economic forces, including changes in VMT. Though this study accounted for LDV VMT reduction from the Honolulu Rail Project, there is uncertainty in future ridership estimates and thus potentially offset LDV VMT. Lastly, emission projections were not developed for the military because decisions around military activities are not economic in nature.

2.3. Incineration of Waste for Energy Purposes

2.3.a. Methodology

Emissions from incineration of waste for energy purposes represent the waste-to-power plant operating on Oʻahu. For future years, the relationship between emissions and electricity generation is assumed to remain constant at the level observed in the 2022 inventory year. This means that generating 1 kWh of electricity from waste incineration at H-Power is projected to produce the same amount of emissions in future years as it did in 2022, and that, as with inventory calculations, only non-biogenic emissions are counted. To estimate emissions for future years, the percentage change in electricity generation is calculated for the H-Power plant, as projected in the IGP, from 2022 to each target year (Hawaiian Electric 2023). That percentage change is then applied to project the corresponding emissions.

2.3.b. Uncertainties and Areas for Improvement

Projecting emissions from waste incineration for electricity generation involves uncertainties such as changes in waste composition, operational efficiency, future policies and technological advancements. Though emissions might change if electricity demand changes, it is likely that Hawaiian Electric will prioritize ramping up or down other power plants over H-Power because waste-to-energy plants need to operate continuously for waste disposal, are less flexible to adjust output, and are often less cost-effective or efficient for load balancing compared to alternatives.

2.4. Oil and Natural Gas Systems

2.4.a. Methodology

According to the IPCC methodology, oil and natural gas emissions include GHGs released during the production, processing, transportation, and storage of oil and natural gas. This covers fugitive emissions from leaks, venting, flaring, and other unintentional releases across the supply chain. In Hawaiʻi this relates to activities associated with the Par East petroleum refinery and Hawaiʻi Gas. Oil and natural gas emissions were therefore projected forward from 2022 based on a weighted average between projected growth in refinery emissions and emissions from gas in the residential and commercial sectors where gas is predominately consumed. This methodology combines sector-specific trends (growth in refinery emissions) with broader energy demand trends (residential and commercial gas use), to provide a balanced projection that accounts for both.

2.4.b. Uncertainties and Areas for Improvement

There are significant uncertainties associated with projecting fugitive emissions from the oil and gas sector, as these emissions can vary considerably due to stochastic events, technological and operational changes, regulatory shifts, and fluctuations in production levels. How the refinery continues to respond to the planned decline in demand for fossil fuel products is an area of uncertainty. The methodology used to project emissions from oil and natural gas systems assumed that at least one oil refinery will remain in operation in the state of Hawaiʻi. Emissions from transmission pipelines are another area of uncertainty and will change based on the overall amount of gas and petroleum, as well as the changing ratio of refined versus imported products.

2.5. Non-Energy Uses

2.5.a. Methodology

Emissions from non-energy uses were projected by applying the projected rate of change in GSP to historic emissions estimates, meaning that when GSP increases by 1% so will emissions from non-energy uses. In Hawaiʻi , non-energy uses of fossil fuels primarily include their use in the petrochemical industry for producing chemicals, plastics, and fertilizers. Additionally, oil is processed at refineries for petroleum products like gasoline and diesel, which are used in transportation and other sectors. These fuels are also used in industrial processes, such as the production of asphalt and other materials, where they serve as raw materials rather than being burned for energy. Because non-energy uses is related to a variety of economic activity, this methodology assumes that emissions from this sector correlate with overall economic activity in the State.

2.5.b. Uncertainties and Areas for Improvement

This analysis did not account for policies or programs that could impact fuel consumption for non-energy uses.

3. IPPU

3.1. Cement Production

3.1.a. Methodology

Consistent with the 2022 inventory, emissions from cement production in Hawaiʻi were projected to be zero through 2045.

3.1.b. Uncertainties and Areas for Improvement

There are no notable uncertainties or areas for improvement.

3.2. Electrical Transmission and Distribution

3.2.a. Methodology

Electrical transmission and distribution emissions were projected forward from 2022 based on the electricity sales forecast for 2022 to 2045 for each county, as described under the Stationary Combustion methodology section above. Due to the relatively small magnitude of emissions values presented in Table 7-6 appear constant across the timeseries despite small increases.

3.2.b. Uncertainties and Areas for Improvement

The methodology used to project electrical transmission and distribution emissions was based on the historical trend of emissions from this source being correlated with the trend in electricity sales. Because emissions from this source are small, future improvements to electrical transmission and distribution systems that could reduce the intensity of emissions (kg SF_6 per kWh sold), which has decreased over time, were not considered for the projections.

3.3. Substitution of Ozone Depleting Substances

3.3.a. Methodology

Statewide emissions from the substitution of ozone depleting substances (ODS) were assumed to depend on the implementation of the American Innovation and Manufacturing Act (AIM Act), the rate of turnover of existing air conditioning systems, and the share of new air conditioning systems that use hydrofluorocarbons (HFCs) and other ODS substitutes. The AIM Act mandates EPA to phase down production and consumption of HFCs in the US by 85 percent in a stepwise manner by 2036. Specifically, the effective targets were to achieve a 40 percent reduction in production and consumption of HFCs by 2028, 70 percent by 2033, 80 percent by 2035, and 85 percent by 2036 and thereafter (EPA 2021b).

There were four steps to compute the emissions from ODS substitutes. First, the expected emissions from ODS substitutes, assuming that there is no policy in place to eliminate HFCs or other ODS substitute chemicals, is determined based on growing county level 2022 emissions by each county's

GCP, accounting for the change in energy consumption intensity for the commercial sector (EIA 2023).[84] The emissions assuming no regulation were given by the following equation:

$$TtlUnregE_{c,t} = TtlUnregE_{c,2022} \times GSPIndex_{c,t} \times Eff_t$$

where,

$TtlUnregE_{c,t}$ = Estimated ODS substitute emissions if unregulated in county *c* and year *t*

$TtlUnregE_{c,t}$ = ODS substitute emissions in county *c* and in the year 2022

$GSPIndex_{c,t}$ = Forecast for GSP in county *c* and year *t*

Eff_t = Energy efficiency improvements in year *t*

Estimated unregulated emissions were then shared between existing units (i.e., appliances and air conditioning systems) and the vintages of new units. Emissions from the latest vintage were computed by taking the difference between the estimated unregulated emissions and the sum of emissions from prior vintages:

$$NewODSE_{c,t} = TtlUnregE_{c,t} - \Sigma_v UnregVintageE_{v,c,t}$$

where,

$NewODSE_{c,t}$ = New emissions from ODS substitutes in county *c* and year *t*

$UnregVintageE_{v,c,t}$ = Emissions from prior vintages *v* in county *c* and year *t*

To reflect the retirement of each vintage, it was assumed that the emissions of pre-2024 vintages decayed by 6.7 percent and 9.2 percent for stationary and mobile sources, respectively. Emissions from post-2023 sources were assumed to decay at a rate of five percent for stationary sources (based on the typical life of an air conditioning system) (DOE 2022) and seven percent for mobiles sources (based on the typical life of an automobile). So, the equation above was solved recursively for emissions from new sources for a given year after computing the emissions from all prior year vintages as shown below:

$$UnregVintageE_{v,c,t} = \frac{14}{15} \times UnregVintageE_{v,c,t-1}\text{, for } t<2024$$

$$UnregVintageE_{v,c,t} = 0.95 \times UnregVintageE_{v,c,t-1}\text{, for } t>2023$$

Last, to find the emissions under the AIM Act (i.e., regulated emissions), the AIM Act's reduction schedule was applied to the values for unregulated emissions for each county:

$$ODSE_{c,t} = \Sigma_v UnregVintageE_{v,c,t} \times (1 - AIM_{t-v})$$

where,

$ODSE_{c,t}$ = Emissions from ODS substitutes in county *c* and year *t*

AIM_{t-v} = AIM Act targets applied to new vintages

[84] Commercial sector energy consumption intensity in thousand Btus per square foot.

Statewide emissions from ODS substitutes were determined based on aggregating county level emissions.

3.3.b. Uncertainties and Areas for Improvement

This analysis considered the implementation of the AIM Act; however, the level to which sources of GHG emissions from ODS substitutes will be reduced also depends on the continued use of existing appliances and air conditioning systems. There is uncertainty in the usable life of these goods, as well as any future policy that might speed up their retirement.

4. Agriculture, Forestry and Other Land Uses (AFOLU)

4.1. Enteric Fermentation

4.1.a. Methodology

Emissions from enteric fermentation were projected by linearly extrapolating animal populations and animal-specific emission factors, and applying the same methodology used to estimate 2022 emissions. Animal population data were projected based on the trends in data, as obtained from the U.S. Inventory (EPA 2024b), the U.S. Department of Agriculture's (USDA) National Agricultural Statistics Service (NASS) (USDA 2024), and the USDA Census of Agriculture (USDA 2009, 2014, 2019, and 2024) except for Dairy Cattle, which were proxied to 2022 populations as the population are expected to remain constant. The span of data, which serves as a basis for the extrapolation, varied based on notable historic trends for each animal type. Swine populations were linearly projected and used a twenty-year baseline to capture the decline in swine husbandry. Within beef cattle, steers and bulls were linearly projected using different baselines years, twenty year and five-year baselines, respectively. This methodology was chosen to capture the significant drop in steer stockers between 1990 and 2005. Where necessary, animal population trends were set with a minimum value to ensure that projections remain greater than or equal to zero.

Annually variable enteric fermentation emission factors were projected using the ten-year average by cattle type from the U.S. Inventory (EPA 2024b). Emission factors for sheep, goats, horses, and swine, which come from IPCC (2006), were assumed to remain constant.

4.1.b. Uncertainties and Areas for Improvement

The methodology used to project emissions from enteric fermentation assumed that animal populations will follow a trend consistent with the past. However, there is potential for future animal populations to deviate from the historical trend. In addition, historical population estimates for sheep, goats, and horses are reported every five years in the USDA Census of Agriculture, with the latest data available from the 2022 Census of Agriculture (USDA 2024b). Because data is not available for every year in the timeseries, historical estimates for these animals were linearly interpolated between years. Further research into the accuracy and drivers of historical trends may be considered in future analyses.

4.2. Manure Management

4.2.a. Methodology

Emissions from manure management were projected by projecting activity data and emission factors, and applying the same methodology used to estimate 2022 emissions. Animal population data were projected using the same methodology as the enteric fermentation sector. For chicken populations, which have been historically decreasing over time, an annualized percent change method was applied instead to maintain projections greater than zero.

For non-cattle animal types, typical animal mass (TAM) and maximum potential emissions were assumed to remain constant relative to 2022 values (EPA 2024b). Volatile solids (VS) excretion rates, nitrogen excretion (Nex) rates, weighted methane conversion factors (MCF), and the percent distribution of waste to animal waste management systems for non-cattle types were projected using the ten-year average by factor from the U.S. Inventory (EPA 2024b). For cattle, TAM, maximum potential emissions, VS excretion rates, Nex rates, MCF, and percent distribution of waste-to-waste management systems, which are all from the U.S. Inventory (EPA 2024b), were projected using the ten-year average by factor.

4.2.b. Uncertainties and Areas for Improvement

The methodology used to project emissions from manure management assumed that animal populations will follow a trend consistent with the past. However, there is potential for future animal populations to deviate from the historical trend. In addition, historical population estimates for sheep, goats, horses, and chickens are reported every five years in the USDA Census of Agriculture. As a result, historical estimates for these animals were interpolated between years up to 2022, the most recent year of reported data. Further research into the accuracy and drivers of historical trends may be considered in future analyses.

4.3. Agricultural Soil Management

4.3.a. Methodology

Emissions from agricultural soil management were projected by projecting animal populations, crop area, crop production, as well as emission factors and other inputs, and applying the same methodology used to estimate 2022 emissions. Animal population data were projected using the same methodology as the enteric fermentation and manure management sectors.

Sugarcane crop area and production were projected to be zero in all years after 2018 due to the closing of the last sugar mill in Hawaiʻi (Honolulu Magazine 2016, USDA 2020). For other crops, crop area and production data were projected based on the twenty-year trend of historical data obtained from the USDA Census of Agriculture (USDA 2009, 2014, 2019, 2024). For pineapple production, which has been historically decreasing over time, an annualized percent change method was applied instead to maintain projections greater than zero. Seed crop production data were projected based on the average of the last five years of data, as obtained from the USDA NASS (USDA 2022).

The percent distribution of waste to animal waste management systems was projected based on the ten-year average of data from the U.S. Inventory (EPA 2024b). Synthetic fertilizer consumption was projected based on the five-year historical trend from 2010 to 2014 (AAPFCO 1995 through 2019) while commercial organic fertilizer consumption was assumed to remain at zero. Crop residue factors from IPCC (2006) were also assumed to remain constant. Baseline years used in projections were determined by reviewing trends, trend cycles, and known information about the future of agriculture in Hawaiʻi to most accurately reflect future expectations.

4.3.b. Uncertainties and Areas for Improvement

The methodology used to project emissions from agricultural soil management assumed that animal populations, crop area, crop production, fertilizer consumption, and seed production will follow a trend consistent with the past. However, there is potential for future animal populations and agricultural activity data to deviate from the historical trend. In addition, historical animal populations, crop area, and crop production are reported every five years in the USDA Census of Agriculture. As a result, historical estimates for these data were interpolated between years up to 2022, the latest year of reported data. Historical fertilizer consumption data were also extrapolated out to 2022 based on data available through 2017. Further research into the accuracy and drivers of historical trends may be considered in future analyses.

4.4. Field Burning of Agricultural Residues

4.4.a. Methodology

Sugarcane crop area and production was projected to be zero starting in 2018 due to the closing of the last sugar mill in Hawaiʻi (Honolulu Magazine 2016, USDA 2020). Historically, sugarcane was the only major crop in Hawaiʻi whose residues were regularly burned (Hudson 2008). As a result, no emissions from field burning of agricultural residues were projected in 2025, 2030, 2035, 2040, and 2045.

4.4.b. Uncertainties and Areas for Improvement

It is uncertain whether sugarcane production will return to Hawaiʻi as markets and trade regulations evolve. In addition, it is possible that other crop residues will be burned in the future. Further research into field burning practices in Hawaiʻi may be considered in future analyses.

4.5. Urea Application

4.5.a. Methodology

Emissions from urea application were projected by projecting fertilizer consumption and applying the same methodology used to estimate 2022 emissions. Fertilizer consumption data were projected based on the five-year historical trend (AAPFCO 1995 – 2019).

4.5.b. Uncertainties and Areas for Improvement

The methodology used to project urea application assumed that urea consumption will follow a trend consistent with the past. However, there is potential for urea application activity to deviate from the historical trend, specifically as crop acreage changes. Further research into the drivers of historical trends may be considered in future analyses.

4.6. Agricultural Soil Carbon

4.6.a. Methodology

Emissions from agricultural soils—both grassland and cropland—were projected based on projected changes in land cover and carbon stock from 2011 to 2061 by the U.S. Geological Survey (USGS) (Selmants et al. 2017). Specifically, the estimated percent change in grassland and cropland area from 2011 to 2061 were annualized and applied to the 2022 emission estimates for grassland and cropland, respectively, to obtain 2025, 2030, 2035, 2040, and 2045 estimates.

4.6.b. Uncertainties and Areas for Improvement

The methodology used to project emissions from agricultural soil carbon in grassland and cropland was based on USGS projections of emissions and area that are specific to Hawaiʻi and consider land transitions, impacts of climate change, and other factors under a business-as-usual (BAU) scenario (Selmants et al. 2017). There is potential for these projections to change as the impacts of climate change are realized and policies evolve. The projections were also based on the assumption that emissions from grassland and cropland will decrease at constant rates annually from 2011 to 2061. This methodology did not consider inter-annual variability in emissions from grassland or cropland.

In addition, the methodology assumed that emissions from cropland will decrease at the same rate as cropland area. However, emissions may not align with trends in cropland area if carbon sequestration rates in cropland improve over time, such as through improved management practices (e.g., no tilling). The Hawaiʻi Greenhouse Gas Sequestration Task Force established by Act 15 of 2018 will work to identify practices in agriculture to improve soil health, which may also reduce future emissions from cropland. Further research into emission reductions from improved agricultural soil management practices may be considered in future analyses.

4.7. Forest Fires

4.7.a. Methodology

Emissions from forest fires were projected by projecting activity data and emission factors, and applying the same methodology used to estimate 2022 emissions. Wildfire acres burned were projected based on the projected average area of land burned annually from 2012 to 2061, as obtained from USGS (Selmants et al. 2017). Forest and shrubland areas were projected based on projected changes in forest and shrubland area from 2011 to 2061 by the USGS (Selmants et al. 2017). Specifically, the percent change in forest and shrubland area from 2011 to 2061 was annualized and applied to the 2022

estimates of forest and shrubland area from the State of Hawaiʻi Data Book to obtain 2025, 2030, 2035, 2040, and 2045 estimates (DBEDT 2023). The impacts of climate change on extreme weather events increases uncertainty around projected acres burned.

The annual percent of area burned for each vegetation class were based on estimates from 1999 through 2019, which were obtained from USGS (Selmants 2020). The averages across the timeseries were used to project the percent of area burned for each vegetation class. Emission factors for CO_2 for each vegetation class were based on estimates from USGS and were assumed to remain constant (Selmants et al. 2017). Emission factors for CH_4 and N_2O as obtained from IPCC (2006) were also assumed to remain constant.

4.7.b. Uncertainties and Areas for Improvement

The methodology used to project emissions from forest fires was based on USGS projections of area that are specific to Hawaiʻi and consider land transitions, impacts of climate change, and other factors under a BAU scenario (Selmants et al. 2017). There is potential for these projections to change as the impacts of climate change are realized and policies evolve. The projections were also based on the assumption that forest and shrubland area will change at constant rates annually from 2011 to 2061. This methodology does not consider inter-annual variability in forest and shrubland area. Further research into the annual changes in composition of forest and shrubland in Hawaiʻi may be considered in future analyses.

4.8. Landfilled Yard Trimmings and Food Scraps

4.8.a. Methodology

Carbon sequestration in landfilled yard trimmings and food scraps were estimated by projecting activity data, emission factors, and other inputs, and applying the same methodology used to estimate 2022 emissions.

Estimates of the amount of yard trimmings and food scraps discarded in landfills in the United States were projected using the five-year historical trend, based on data obtained from EPA's State Inventory Tool (EPA 2024d). Hawaiʻi and U.S. population estimates were projected based on five-year growth rates in Hawaiʻi's population from the State of Hawaiʻi Data Book (DBEDT 2023) and annual growth rates in national population from the U.S. Census Bureau (2017).

The estimated carbon conversion factors and decomposition rates obtained from the State Inventory Tool (EPA 2024d) were assumed to remain constant over the projected timeseries.

4.8.b. Uncertainties and Areas for Improvement

The methodology used to project carbon sequestration in landfilled yard trimmings and food scraps assumed that the amount of landfilled yard trimmings and food scraps in Hawaiʻi will follow a trend consistent with the past. The methodology did not consider increases in composting yard trimmings and food scraps. For example, Honolulu County prohibits commercial and government entities from

disposing yard trimmings in landfills (City & County of Honolulu 2005). Further research into Hawaiʻi trends in diverting yard trimmings and food scraps from landfills may be considered in future analyses.

4.9. Urban Trees

4.9.a. Methodology

Estimates of carbon sequestration in urban trees were projected by projecting urban area and other inputs, and applying the same methodology used to estimate 2022 emissions. Urban area was projected based on projected changes in developed area from 2011 to 2061 by the USGS (Selmants et al. 2017). Specifically, the percent change in developed area was annualized and applied to the 2020 estimate of urban area to project 2025, 2030, 2035, 2040, and 2045 estimates. Urban tree canopy coverage was estimated for 2025, 2030, 2035, 2040, and 2045 based on the trend in in percent tree cover observed by county between 2011 to 2021 reported by the NLCD. The estimated carbon sequestration rates for urban trees and the percent tree cover in urban areas in Hawaiʻi were assumed to remain constant with 2021 estimates (Nowak et al. 2012; Nowak 2018a and 2018b; EPA 2024).

4.9.b. Uncertainties and Areas for Improvement

The methodology used to project carbon sequestration in urban trees was based on USGS projections of area that are specific to Hawaiʻi and consider land transitions, impacts of climate change, and other factors under a BAU scenario (Selmants et al. 2017). There is potential for these projections to change as the impacts of climate change are realized and policies evolve. The projections were also based on the assumption that urban area and carbon sequestration will increase linearly over the projected timeseries. This methodology did not consider potential changes in the rate of urbanization over time. Similarly, the current methodology did not consider potential changes in urban density that would be assumed as urban expansion becomes limited. The sequestration rate in urban trees may also vary over time due to possible changes in the percent tree cover, which can be impacted by urban planning initiatives. In addition, the Hawaiʻi Greenhouse Gas Sequestration Task Force established by Act 15 of 2018 will work to identify opportunities to increase urban tree cover. Further research into urban planning initiatives that involve tree cover and trends in urbanization may be considered in future analyses.

4.10. Forest Carbon

4.10.a. Methodology

Average net C sequestration rates by forest type in Hawaiʻi from 2011 through 2030 were calculated using net ecosystem production estimates from USGS (Selmants 2020). These estimates were assumed to remain constant over the projected timeseries, based on USGS estimates that statewide carbon density in Hawaiʻi will remain relatively stable through 2061 (Selmants et al. 2017).

Estimates of carbon sequestration in forests and shrubland were projected by projecting forest and shrubland area and emission factors, and applying the same methodology used to estimate 2022

emissions. Forest and shrubland areas were projected based on projected changes in forest and shrubland area from 2011 to 2061 by the USGS (Selmants et al. 2017). Specifically, the percent change in forest and shrubland area from 2011 to 2061 was annualized and applied to the 2022 estimates of forest and shrubland area by county from the State of Hawaiʻi Data Book to obtain 2025, 2030, 2035, 2040, and 2045 estimates (DBEDT 2023).

To obtain annual net C flux, the total net ecosystem production for forest and shrubland in Hawaiʻi were divided by the projected area of the respective land cover type.

4.10.b. Uncertainties and Areas for Improvement

The methodology used to project carbon sequestration in forests and shrubland was based on USGS projections of area that are specific to Hawaiʻi and consider land transitions, impacts of climate change, and other factors under multiple future scenarios (Selmants 2020). There is potential for these projections to change as the impacts of climate change are realized and policies evolve. Further research into the annual changes in composition of forest and shrubland in Hawaiʻi may be considered in future analyses.

The projections similarly assumed that carbon sequestration rates will remain constant and did not consider potential changes in sequestration rates due to the age of the forest ecosystem and forest management practices. USGS notes that there are uncertainties associated with the age of Hawaiʻi forest ecosystems, which can impact sequestration rates (Selmants et al. 2017). In addition, the Hawaiʻi Greenhouse Gas Sequestration Task Force established by Act 15 of 2018 will work to identify practices to increase forest carbon and promote sequestration, which may increase future sequestration rates in forests. Further research into the age of Hawaiʻi forests, improved forest management practices, and their emissions reduction potential may be considered in future analyses.

5. Waste

5.1. Landfills

5.1.a. Methodology

Landfill emissions were projected by extrapolating historical emission trends for the counties of Hawaiʻi, Honolulu, and Kauaʻi. Extrapolations were done using county specific power-functions. These functions were derived by finding a best fit line through inventory years, starting from the year prior to installation of methane capture technology.[85] A power function relates to historical changes in the amount of waste disposed by better reflecting the diminishing rate of emissions over time. In contrast, linear functions tend to overestimate future changes in emissions as a result in changes in landfill tonnage because they

[85] Methane capture technology usually leads to a large drop in emissions. Historical years that were included are 2010, and 2015-2022 for Hawaiʻi and Honolulu counties and 2015-2022 for Kauaʻi.

assume a constant rate of change, which doesn't account for the fact that emissions from landfills decrease as decomposition slows. Historical data may show relatively rapid changes in emissions initially, but using a linear projection would extend that growth unrealistically into the future, whereas a power function better mirrors the natural slowdown of emissions as waste decomposes and landfill capacity is reached.

Emissions for each county were projected as follows:

$$E_{t,c} = a_c \times t_c^b$$

where,

$E_{t,c}$ = emissions in year t in county c

a_c = scaling factor for county c determined from historical emissions

t = time since first inventory year

b_c = exponent representing the growth rate for county c derived from historical emissions

Table J-9 shows the scaling factors and growth rates used in the county-specific power functions to project landfill emissions.

Table J-9: Parameters Used in the County-Specific Power Functions

County	Scaling Factor	Growth Rate
Hawai'i	0.2002	-0.192
Honolulu	0.6686	-0.786
Kaua'i	0.6760	-0.825
Maui[a]	0.2002	-0.192

[a] Hawai'i County parameters used to project Maui County landfill emissions.

Due to recent fluctuations in landfill emissions caused by infrastructure issues between 2019 and 2023, this approach was not suitable for Maui. Instead, it was assumed that Maui's emissions will change at the same rate as Hawai'i County using Maui's 2018 inventory year as a jumping off point. Finally, the county-level emissions were summed to calculate statewide landfill emissions.

5.1.b. Uncertainties and Areas for Improvement

Emissions from landfill waste are influenced by a complicated mix of variables including but not limited to the amount and composition of landfilled waste, the type and depth of landfill cover, climate, and the efficiency of methane capture activities. Some of these variables, such as climate, are likely to change very little and most variables, such as waste tonnage and composition, affect emissions slowly, as methane from decomposing organic matter is released slowly over time. On the other hand, technological changes can affect emissions almost instantly. And, conversely, emissions can also change

drastically due to technological failures that affect methane capture effectiveness. This analysis was based on historical emissions trends and therefore did not account for future changes in methane capture activity or waste diversion policies or programs that could impact future waste generation. Because a substantial portion of waste on Oʻahu is already diverted to waste-to-power, this is more relevant for the counties of Maui, Hawaiʻi and Kauaʻi.

5.2. Composting

5.2.a. Methodology

For each county, emissions from composting were assumed to grow at the rate of population (DBEDT 2018). County-level emissions were then summed together to estimate statewide emissions. Population is a good metric for projecting composting emissions because more people tend to generate more organic waste, if all other factors stay the same. Unlike landfills, which have slow anaerobic decomposition, composting occurs in aerobic conditions, resulting in faster breakdown of organic material and quicker emission release. Changes in the amount of waste composted are therefore reflected more quickly in the emissions from composting.

5.2.b. Uncertainties and Areas for Improvement

The methodology used to project emissions from composting assumed that per capita composting tonnage will remain constant through 2045. This analysis did not account for policies or programs that could impact composting activities but may be considered in future analyses.

5.3. Wastewater Treatment

5.3.a. Methodology

For each county, emissions from wastewater treatment were assumed to grow at the rate of population (DBEDT 2018).[86] County-level emissions were then summed together to estimate statewide emissions. As the population increases, both domestic and industrial wastewater generation rises proportionally, leading to higher emissions from treatment processes, such as methane released from anaerobic digestion in wastewater treatment plants. This correlation between population growth and wastewater emissions makes population a reliable metric for projecting future emissions.

[86] The City and County of Honolulu in 2018 implemented a biogas project at the Honouliuli Wastewater Treatment Plant. Each year the project will capture and reuse 800,000 therms of biogas (County & City of Honolulu 2018b). While this biogas, which is otherwise flared, is used to displace other fuel types used to generate energy and therefore leads to emission reductions from the energy sector, this activity does not lead to a reduction in GHG emissions from wastewater treatment.

5.3.b. Uncertainties and Areas for Improvement

The methodology used to project emissions from wastewater treatment assumed that wastewater flows are mainly impacted by population growth. Because wastewater N_2O emissions are primarily impacted by protein consumption, any economic, political, or social shifts that impact per capita protein consumption would change overall wastewater emissions.

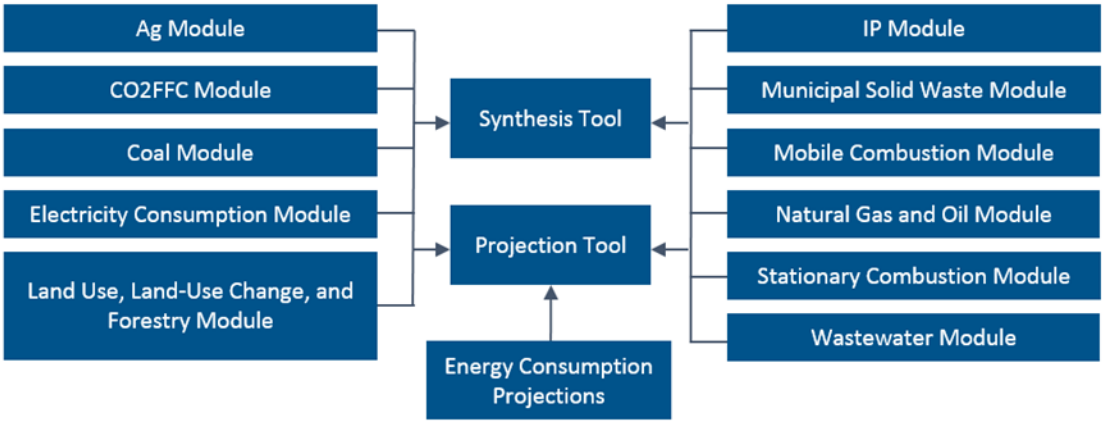
Appendix K. Comparison of Results with the State Inventory Tool and Projection Tool

EPA's State Inventory and Projection Tool is an interactive spreadsheet model designed to help states develop greenhouse gas (GHG) emissions inventories. The tool has two components:

- **The State Inventory Tool** (SIT) consists of 11 estimation modules applying a top-down approach to calculate GHG emissions, and one module to synthesize estimates across all modules. The SIT gives users the option of applying their own state-specific data or using default data pre-loaded for each state. The default data are gathered by federal agencies and other resources covering fossil fuels, electricity consumption, agriculture, forestry, waste management, and industry. All of the modules estimate direct GHG emissions, with the exception of the electricity consumption module, which estimates indirect GHG emissions from electricity consumption. The methods used are, for the most part, consistent with the U.S. GHG Inventory.
- **The Projection Tool** allows users to create a simple forecast of emissions through 2050 based on historical emissions that are imported from the SIT modules, combined with projections of future energy consumption, population, and economic factors.

Figure K-1 provides an overview of the files that make up the SIT and Projection tool.

Figure K-1: Overview of the SIT and Projection Tool File Structure



In an effort to evaluate the accuracy and usability of the SIT and Projection Tool estimates for the state of Hawaiʻi, ICF ran the tool for Hawaiʻi using default values and compared the output against the 2021 inventory and inventory projections for 2025, 2030, and 2045, as developed by ICF, the Institute of

Resilience and Sustainability (ISR), and the University of Hawaiʻi Economic Research Organization (UHERO).[87] This document presents the results of this comparison.

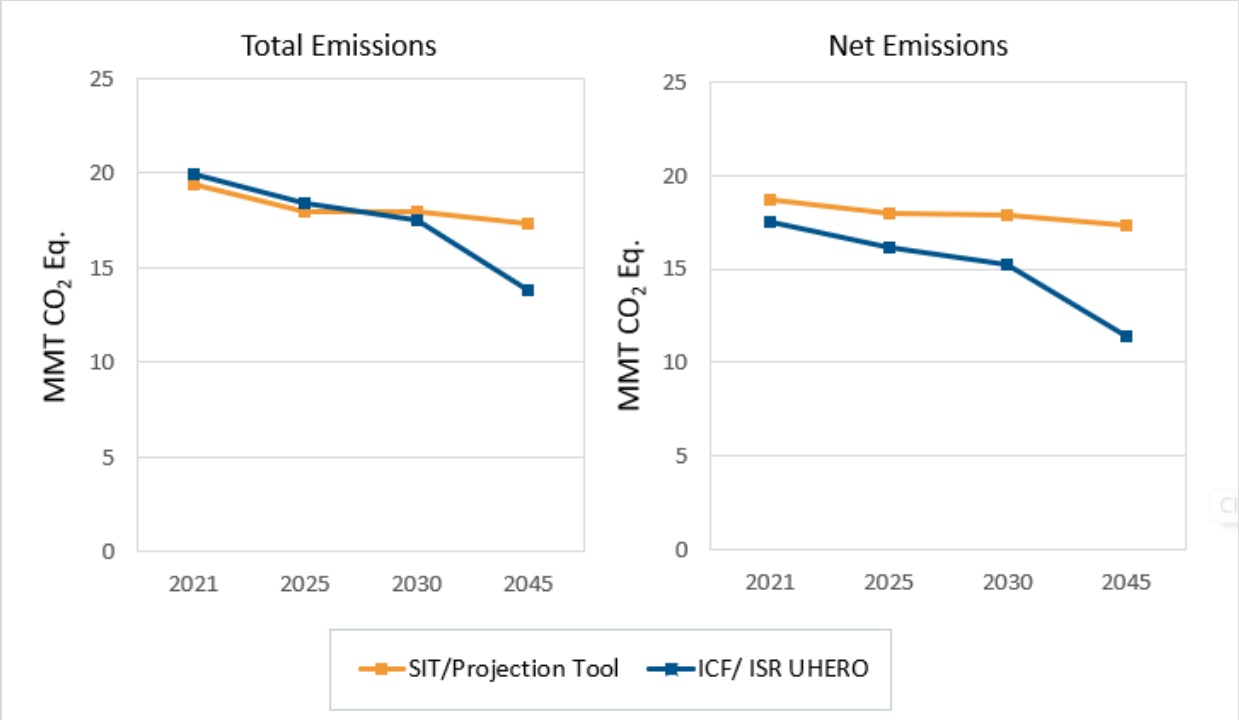
Key Observations and Conclusions

SIT's estimate of total GHG emissions for Hawaiʻi in 2021 is 3 percent lower than the ICF estimate, while the difference in net GHG emissions is 7 percent higher than the ICF estimate.[88] The difference in net emissions is largely due to the lack of default forest carbon flux data available in the SIT land-use change module.

Total GHG emissions for Hawaiʻi are 2 percent lower in 2025 using the Projection Tool compared to ICF/ISR/UHERO's analysis, 2 percent higher in 2030, and 25 percent higher in 2045. Net GHG emissions for Hawaiʻi are 12 percent higher in 2025 using the Projection Tool compared to ICF/ISR/UHERO's analysis, 18 percent higher in 2030, 52 percent higher in 2045. The Projection Tool notably does not estimate emissions from Land Use, Land Use Change, and Forestry (LULUCF) source and sink categories. Total and net emissions for 2021, 2025, 2030, and 2045 as estimated by ICF/ISR/UHERO and the SIT/Projection Tool, are shown in Figure K-2.

[87] The SIT and Projection Tool are available online at https://www.epa.gov/statelocalenergy/download-state-inventory-and-projection-tool. The SIT modules, Synthesis Tool, and Projection Tool used for this analysis were downloaded from EPA's website in November 2024. 2021 is the most recent inventory year available.
[88] Net emissions take into account both emission sources and carbon sinks.

Figure K-2: Comparison of Total and Net GHG Emission Estimates (MMT CO_2 Eq.) (2021, 2025, 2030, and 2045)



Key observations from using the SIT for 2021 GHG estimates include the following:

- Total GHG estimates from the SIT are 0.54 MMT CO_2e lower than ICF/ISR/UHERO. Net GHG estimates from the SIT are 1.19 MMT CO_2e higher than ICF/ISR/UHERO.
- ICF assessed contributions to differences in emissions using absolute values. While total emissions estimates from the SIT and ICF/ISR/UHERO are similar, the magnitude of the difference at the sector level varies. Higher emission estimates for the SIT for some sectors (e.g., in IPPU and Waste) counterbalances lower emissions estimates in other sectors (e.g., in the Energy sector).
- About 33 percent of the difference in net emissions is from Forest Carbon (see Table K-2). The SIT does not provide default data for estimating Forest Carbon sinks.
- About 37 percent of the difference in total emissions and 22 percent of the difference in net emissions is from Transportation (see Table K-2). One of the reasons for this difference is due to the inclusion of emissions from military non-aviation transportation, which is not accounted for in the SIT.
- Estimates for seven categories comprise 90 percent of the difference in net emissions between the SIT and ICF analysis. These include Forest Carbon, Transportation, Landfills, Iron and Steel Production, Stationary Combustion, Agricultural Soil Carbon, and Forest Fires. The likely reasons for these differences are discussed below in Methodology Comparison.
- Relative to ICF's estimates, the SIT estimated higher emissions from the IPPU, AFOLU, and Waste sectors, but lower emissions from Energy emission sources.

Key observations from using the Projection Tool for 2025, 2030, and 2045 GHG estimates include the following:

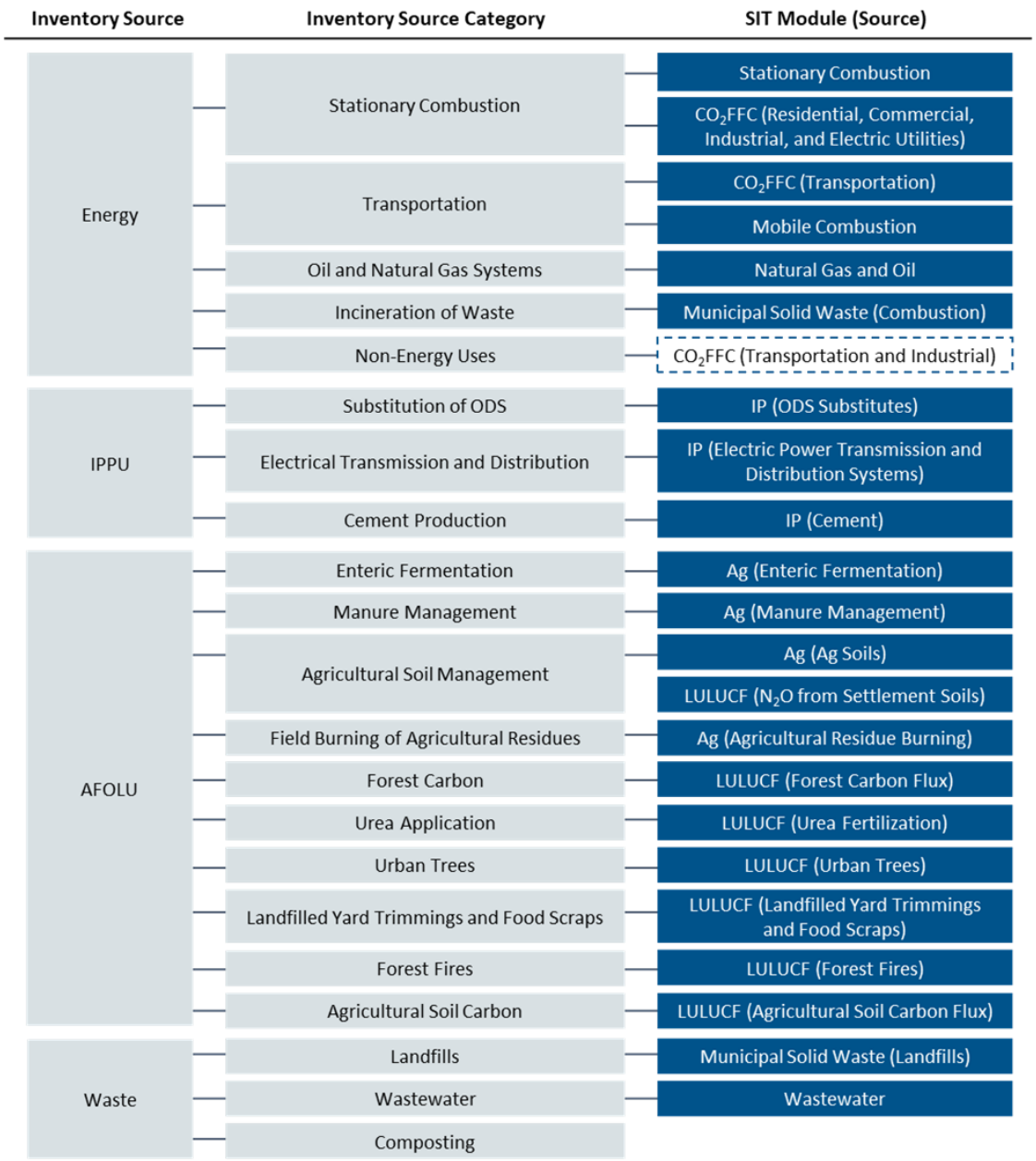
- The Projection Tool does not estimate emissions from LULUCF source and sink categories.
- About 58 percent of the difference in 2025 net emission projections is from Forest Carbon, Stationary Combustion, and Agricultural Soil Carbon source and sink categories (see Table K-4).
- The estimate for Transportation is 9 percent higher in 2025 using the SIT. Some of this difference is because ICF/ISR/UHERO accounted for Light Duty Vehicle Miles Traveled reduction from the Honolulu Rail Project. Additionally, ICF/ISR/UHERO projections for military transportation emissions were assumed to remain constant in the future relative to 2021 due to a lack of available data and inconsistencies in the historical emissions trend.
- About 73 percent of the difference in 2030 net emission projections are from the Forest Carbon, Stationary Combustion, Substitution of Ozone Depleting Substances (ODS), Agricultural Soil Carbon, and Urban Trees source and sink categories (see Table K-6).
- Relative to ICF/ISR/UHERO's estimates, the Projection Tool estimates higher emissions from the IPPU, AFOLU, and Waste sectors in 2025, 2030, and 2045. UHERO projections incorporate the hydrofluorocarbon phasedown under the American Innovation and Manufacturing (AIM) Act. ICF/ISR/UHERO estimates slightly higher emissions for Energy in 2025 and 2030, but the Projection Tool estimates higher emissions for 2045.
- ICF/ISR/UHERO's projected emissions are much lower in 2045 than the Projection Tool. For this analysis, the Projection Tool estimates future emissions based on default historical activity data for Hawai'i. There is a large degree of uncertainty associated with the default activity data within the Projection Tool, as most of the data is from national sources, rather than Hawai'i -specific sources. Additionally, some of the default activity data within the Projection Tool are from older sources and may not capture recent economic, political, or social trends that impact activity data, such as decreased consumption of certain fuels or decreased livestock populations. The ICF/ISR/UHERO team used Hawai'i -specific assumptions for each sector to project future emissions, which is likely the cause of the disparity between the Projection Tool and ICF/ISR/UHERO in 2045. The likely reasons for these differences are discussed in more detail in Methodology Comparison.

Comparison of Results

To compare the results from the SIT against the 2021 inventory developed by ICF, results from each estimation module were compared against the source and sink categories defined in the 2021 inventory.[89] Figure K-3 summarizes how the results from the SIT were mapped to the 2021 inventory.

[89] All modules were run except for the Electricity Consumption Module and the Coal Module; the Electricity Consumption Module double counts emissions estimated by the Fossil Fuel Combustion Module and the Coal Module, which estimates emissions from coal mining, is not applicable to the state of Hawai'i.

Figure K-3: Mapping of SIT Modules to Hawai'i's 2021 Inventory



2021 Inventory Comparison

For the state of Hawai'i, ICF estimates that in 2021 total GHG emissions were 19.92 MMT CO_2 Eq., which is 3 percent higher than the SIT's estimate of 19.38 MMT CO_2 Eq. ICF estimates that in 2021 net emissions were 17.50 MMT CO_2 Eq., while the SIT estimates 18.69 MMT CO_2 Eq., a difference of 7% percent. A summary of 2021 emissions and sinks by sector and category, as estimated by ICF and the SIT, are provided in Table K-1.

Table K-1: Comparison of 2021 Emission Results (MMT CO_2 Eq.)

Sector/Category	ICF	SIT	Difference	% Difference
Energy	**17.47**	**15.70**	**(1.77)**	**(10%)**
Transportation	9.59	8.38	(1.22)	(13%)
Stationary Combustion	7.44	7.16	(0.28)	(4%)
Incineration of Waste for Energy Purposes	0.30	0.16	(0.14)	(46%)
Oil and Natural Gas Systems [a]	0.10	NO	(0.10)	NA
Non-Energy Uses [b]	0.04	IE	NA	NA
IPPU	**0.82**	**1.07**	**0.25**	**30%**
Substitution of ODS	0.81	0.74	(0.07)	(8%)
Electrical Transmission and Distribution	0.01	0.01	+	2%
Cement Production	NO	NO	0.00	NA
Soda Ash Manufacture and Consumption [c]	NO	0.01	0.01	NA
Urea Consumption [c]	NO	+	+	NA
Iron and Steel Production [c]	NO	0.30	0.30	NA
Limestone and Dolomite Use [c]	NO	NO	0.00	NA
AFOLU	**(1.20)**	**0.57**	**1.76**	**(147%)**
Agricultural Soil Carbon	0.58	0.81	0.23	39%
Enteric Fermentation	0.27	0.28	0.01	4%
Agricultural Soil Management	0.21	NE	NA	NA
Forest Fires [a]	0.14	0.13	(0.01)	(6%)
Manure Management	0.01	0.02	+	18%
Urea Application	+	+	+	5%
Field Burning of Agricultural Residues	NO	NO	0.00	NA
Landfilled Yard Trimmings and Food Scraps	(0.05)	(0.05)	+	6%
Urban Trees	(0.59)	(0.64)	(0.05)	8%
Forest Carbon [a]	(1.78)	NO	1.78	NA
Liming	NO	NO	NA	NA
N_2O from Settlement Soils [d]	IE	0.01	NA	NA
Waste	**0.41**	**1.36**	**0.96**	**234%**
Landfills	0.33	1.23	0.89	269%
Wastewater Treatment	0.06	0.14	0.08	146%
Composting [e]	0.02	NE	NA	NA
Total Emissions (Excluding Sinks)	**19.92**	**19.38**	**(0.54)**	**(3%)**
Net Emissions (Including Sinks)	**17.50**	**18.69**	**1.19**	**7%**

+ Does not exceed 0.005 MMT CO_2 Eq.

NO (emissions are Not Occurring); NE (emissions are Not Estimated); NA (Not Applicable); IE (Included Elsewhere).

[a] The SIT does not provide default data for Oil and Natural Gas Systems, Forest Fires, or Forest Carbon in Hawai'i.

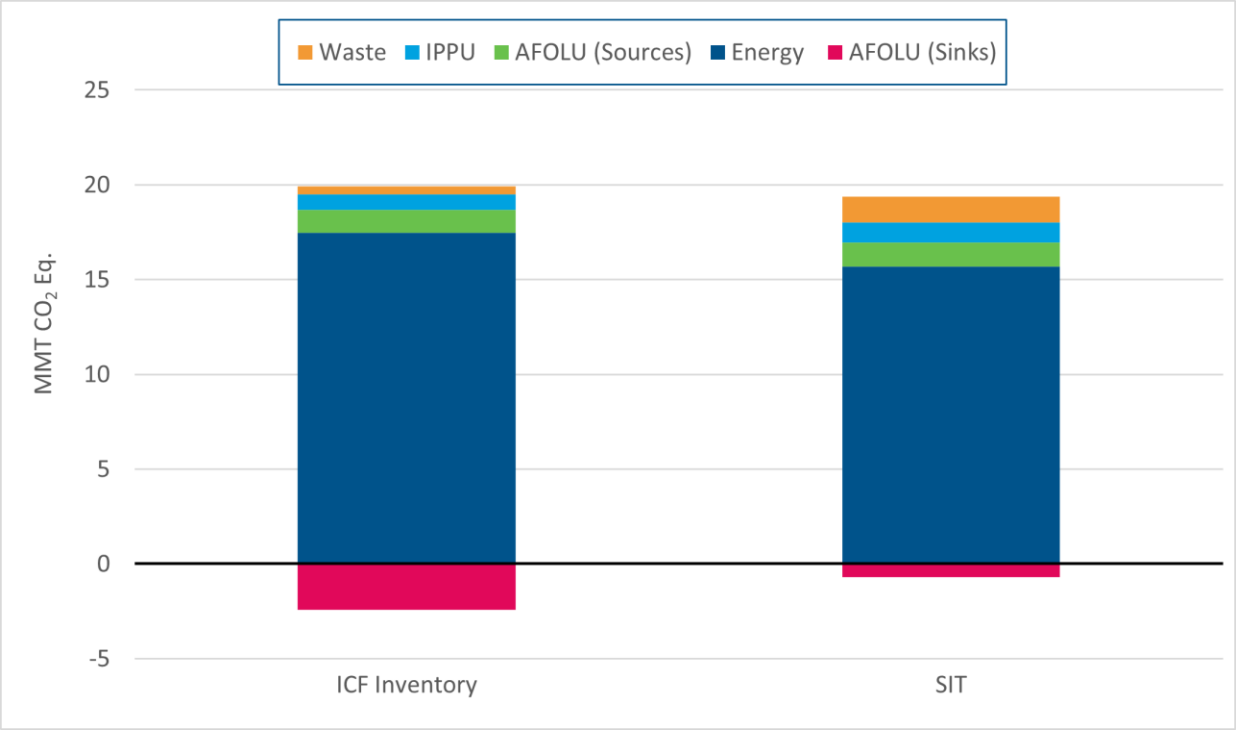
[b] The SIT includes emissions from Non-Energy Uses in emissions CO_2 from Fossil Fuel Combustion (CO_2FFC). Therefore, these emissions are captured within the Stationary Combustion and Transportation emission sources.

[c] ICF estimates that this activity is not applicable to Hawai'i, and therefore emissions are not occurring.

[d] Emissions are included under Agricultural Soil Management.
[e] The SIT does not estimate emissions from Composting.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Emissions by sector as calculated by ICF and the SIT are presented in Figure K-4.

Figure K-4: Comparison of 2021 Emission Results (Including Sinks)



Seven source and sink categories account for 90 percent of the absolute difference between ICF's Inventory and the SIT's estimates. summarizes the absolute and cumulative difference in emission estimates for these seven categories. The likely reasons for these differences are discussed below in Methodology Comparison.

Table K-2: Key Sources of Differences between ICF Inventory and SIT 2021 Net Emission Results

Category	ICF	SIT	Absolute Difference	Cumulative % of Total Difference
Forest Carbon	(1.78)	NE	1.78	33%
Transportation	9.59	8.38	1.22	55%
Landfills	0.33	1.23	0.89	71%
Iron and Steel Production	NO	0.30	0.30	77%
Stationary Combustion	7.44	7.16	0.28	82%
Agricultural Soil Carbon	0.58	0.81	0.23	86%
Forest Fires	0.21	NE	0.21	90%
All Other Categories			0.54	100%

NO (emissions are Not Occurring); NE (emissions are Not Estimated).

2025 Projection Comparison

ICF, with support from UHERO, projects 2025 total GHG emissions to be 18.45 MMT CO_2 Eq., while net emissions are projected to be 16.11 MMT CO_2 Eq. The Projection Tool projects total and net emissions to be 18.01 MMT CO_2 Eq. in 2025. A summary of projected emissions and sinks by sector and category, as estimated by ICF/ISR/UHERO and the Projection Tool for 2025, are provided in Table K-3.

Table K-3: Comparison of 2025 Emission Projection Results (MMT CO_2 Eq.)

Sector/Category	ICF/ISR/ UHERO	Projection Tool	Difference	% Difference
Energy	**16.03**	**14.78**	**(1.25)**	**(8%)**
Transportation	10.07	10.25	0.18	2%
Stationary Combustion	5.52	3.86	(1.66)	(30%)
Incineration of Waste for Energy Purposes	0.29	0.66	0.37	125%
Oil and Natural Gas Systems	0.11	0.01	(0.10)	(91%)
Non-Energy Uses [a]	0.03	IE	NA	NA
IPPU	**0.77**	**1.82**	**1.06**	**138%**
Substitution of ODS	0.76	1.40	0.65	85%
Electrical Transmission and Distribution	0.01	0.01	+	(30%)
Cement Production	NO	NO	0.00	NA
Soda Ash Manufacture and Consumption	NO	0.01	0.01	NA
Urea Consumption	NO	+	+	NA
Iron and Steel Production	NO	0.40	0.40	NA
Limestone and Dolomite Use	NO	NO	0.00	NA
AFOLU	**(1.11)**	**0.43**	**1.54**	**(139%)**
Agricultural Soil Carbon [b]	0.75	NE	NA	NA
Enteric Fermentation	0.27	0.25	(0.01)	(6%)
Agricultural Soil Management	0.14	0.15	0.02	11%
Forest Fires [b]	0.05	NE	NA	NA
Manure Management	0.02	0.02	+	(1%)
Manure Management	0.02	0.02	+	(1%)
Field Burning of Agricultural Residues	NO	NO	0.00	NA
Landfilled Yard Trimmings and Food Scraps [b]	(0.04)	NE	NA	NA
Urban Trees [b]	(0.58)	NE	NA	NA
Forest Carbon	(1.71)	NE	NA	NA
Liming	NO	+	+	NA
N_2O from Settlement Soils [b,c]	IE	NE	NA	NA
Waste	**0.43**	**0.98**	**0.55**	**128%**
Landfills	0.31	0.83	0.52	166%
Wastewater Treatment	0.08	0.15	0.07	83%
Composting	0.04	NE	NA	NA
Total Emissions (Excluding Sinks)	**18.45**	**18.01**	**(0.44)**	**(2%)**
Net Emissions (Including Sinks)	**16.11**	**18.01**	**1.90**	**12%**

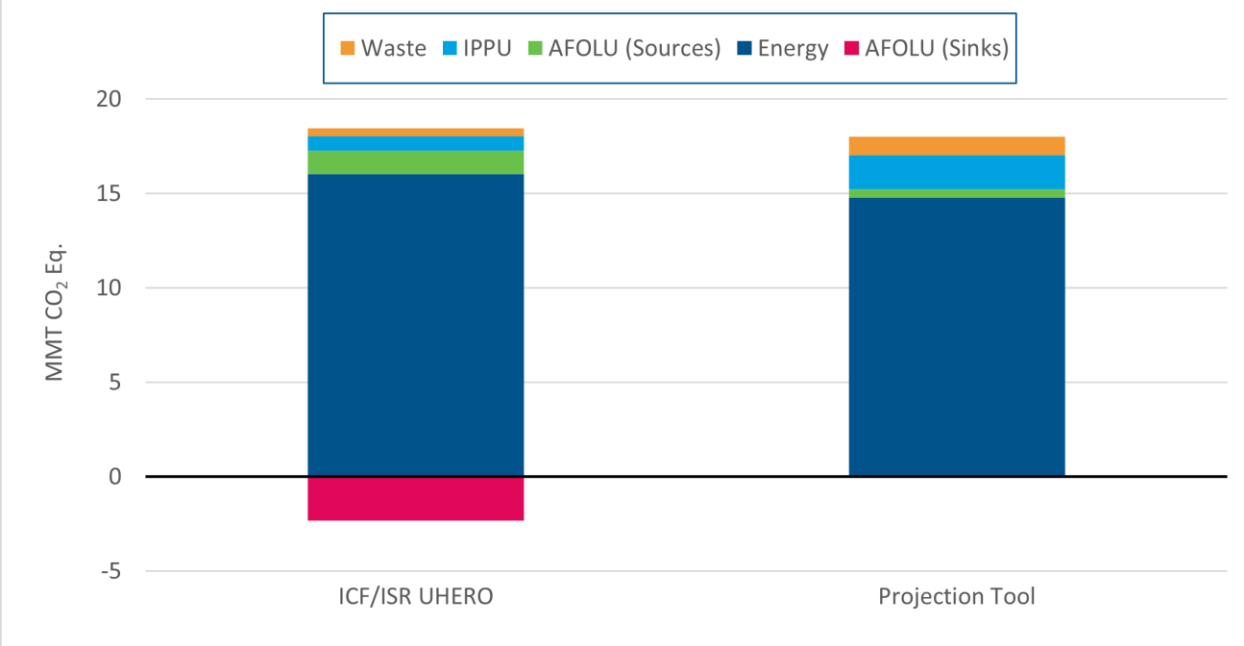
+ Does not exceed 0.005 MMT CO_2 Eq.

NO (emissions are Not Occurring); NE (emissions are Not Estimated); NA (Not Applicable).

[a] The Projection Tool includes projected emissions from Non-Energy Uses under CO_2 emissions from Fossil Fuel Combustion (CO_2FFC). Therefore, these emissions are captured within the Stationary Combustion and Transportation emission sources.
[b] The Projection Tool does not project emissions from LULUCF categories or Composting.
[c] Emissions are included under Agricultural Soil Management.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Emissions projections for 2025 by sector calculated by ICF/ISR/UHERO and the Projection Tool are presented in Figure K-5.

Figure K-5: Comparison of 2025 Emission Projection Results (Including Sinks)



Seven source and sink categories account for 88 percent of the absolute difference between the ICF/ISR/UHERO projections and the Projection Tool estimates. Table K-4 summarizes the absolute and cumulative difference in emission estimates for these top seven categories. The likely reasons for these differences are discussed below in Methodology Comparison.

Table K-4: Key Sources of Differences between ICF/ISR/UHERO Projections and Projection Tool Net Estimates in 2025

Sector/Category	ICF/ISR/ UHERO	Projection Tool	Absolute Difference	Cumulative % of Total Difference
Forest Carbon	(1.71)	NE	1.71	24%
Stationary Combustion	5.52	3.86	1.66	47%
Agricultural Soil Carbon	0.75	NE	0.75	58%
Substitution of ODS	0.76	1.40	0.65	67%
Urban Trees	(0.58)	NE	0.58	75%
Landfills	0.31	0.83	0.52	82%

Iron and Steel Production	NO	0.40	0.40	88%
All Other Categories			0.87	100%

NO (emissions are Not Occurring); NE (emissions are Not Estimated).

2030 Projection Comparison

ICF, with support from UHERO, projects 2030 total GHG emissions to be 17.51 MMT CO_2 Eq., while net emissions are projected to be 15.21 MMT CO_2 Eq. The Projection Tool projects total and net emissions to be 17.93 MMT CO_2 Eq. in 2030. A summary of projected emissions and sinks by sector and category, as estimated by ICF/ISR/UHERO and the Projection Tool for 2030, are provided in Table K-5.

Table K-5: Comparison of 2030 Emission Projection Results (MMT CO_2 Eq.)

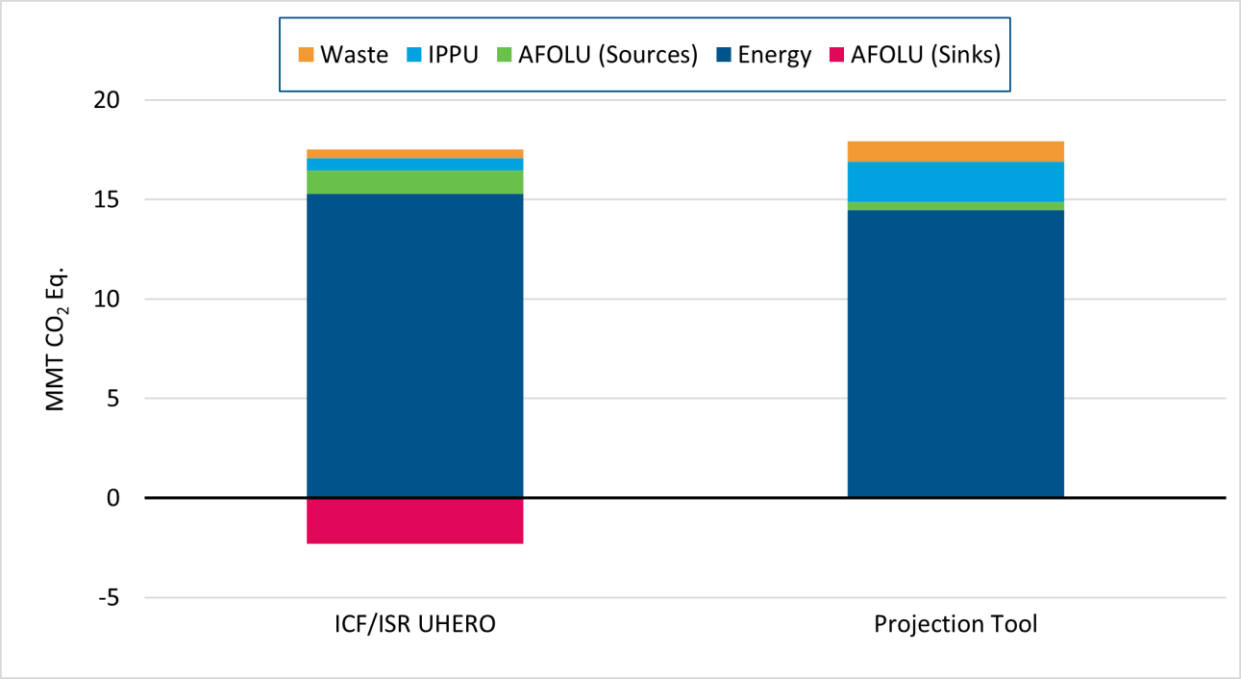
Sector/Category	ICF/ISR/ UHERO	Projection Tool	Difference	% Difference
Energy	15.30	14.46	(0.84)	(5%)
Transportation	9.91	10.04	0.13	1%
Stationary Combustion	4.95	3.68	(1.27)	(26%)
Incineration of Waste for Energy Purposes	0.29	0.73	0.44	150%
Oil and Natural Gas Systems	0.11	0.01	(0.10)	(91%)
Non-Energy Uses [a]	0.04	IE	NA	NA
IPPU	0.62	2.03	1.41	227%
Substitution of ODS	0.61	1.59	0.98	161%
Electrical Transmission and Distribution	0.01	0.01	+	(36%)
Cement Production	NO	NO	0.00	NA
Soda Ash Manufacture and Consumption	NO	0.01	0.01	NA
Urea Consumption	NO	+	+	NA
Iron and Steel Production	NO	0.43	0.43	NA
Limestone and Dolomite Use	NO	NO	0.00	NA
AFOLU	(1.14)	0.42	1.56	(136%)
Agricultural Soil Carbon [b]	0.69	NE	NA	NA
Enteric Fermentation	0.27	0.25	(0.02)	(8%)
Agricultural Soil Management	0.14	0.15	0.01	7%
Forest Fires [b]	0.05	NE	NA	NA
Manure Management	0.02	0.02	+	7%
Manure Management	0.02	0.02	+	7%
Field Burning of Agricultural Residues	NO	NO	0.00	NA
Landfilled Yard Trimmings and Food Scraps [b]	(0.04)	NE	NA	NA
Urban Trees [b]	(0.63)	NE	NA	NA
Forest Carbon [b]	(1.63)	NE	NA	NA
Liming	NO	+	+	NA
N_2O from Settlement Soils [b,c]	IE	NE	NA	NA
Waste	0.43	1.02	0.59	136%
Landfills	0.31	0.87	0.56	181%
Wastewater Treatment	0.09	0.15	0.07	78%
Composting	0.04	NE	NA	NA
Total Emissions (Excluding Sinks)	17.51	17.93	0.42	2%

Sector/Category	ICF/ISR/ UHERO	Projection Tool	Difference	% Difference
Net Emissions (Including Sinks)	15.21	17.93	2.72	18%

+ Does not exceed 0.005 MMT CO_2 Eq.
NO (emissions are Not Occurring); NE (emissions are Not Estimated); NA (Not Applicable).
[a] The Projection Tool includes projected emissions from Non-Energy Uses under CO_2 emissions from Fossil Fuel Combustion (CO_2FFC). Therefore, these emissions are captured within the Stationary Combustion and Transportation emission sources.
[b] The Projection Tool does not project emissions from LULUCF categories or Composting.
[c] Emissions are included under Agricultural Soil Management.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Emissions projections for 2030 by sector as calculated by ICF/ISR/UHERO and the Projection Tool are presented in Figure K-6.

Figure K-6: Comparison of 2025 Emission Projection Results (Including Sinks)



Seven source and sink categories account for 87% percent of the absolute difference between the ICF/ISR/UHERO projections and the Projection Tool estimates. Table K-6 summarizes the absolute and cumulative difference in emission estimates for these top seven categories. The likely reasons for these differences are discussed below in Methodology Comparison.

Table K-6: Key Sources of Differences between ICF/ISR/UHERO Projections and Projection Tool Estimates in 2030

Sector/Category	ICF/ISR/ UHERO	Projection Tool	Absolute Difference	Cumulative % of Total Difference
Forest Carbon	(1.63)	NE	1.63	23%

Stationary Combustion	4.95	3.68	1.27	41%
Substitution of ODS	0.61	1.59	0.98	55%
Agricultural Soil Carbon	0.69	NE	0.69	64%
Urban Trees	(0.63)	NE	0.63	73%
Landfills	0.31	0.87	0.56	81%
Incineration of Waste	0.29	0.73	0.44	87%
All Other Categories			0.90	100%

NO (emissions are Not Occurring); NE (emissions are Not Estimated).

2045 Projection Comparison

ICF, with support from UHERO, projects 2045 total GHG emissions to be 13.86 MMT CO_2 Eq., while net emissions are projected to be 11.44 MMT CO_2 Eq. The Projection Tool projects total and net emissions to be 17.35 MMT CO_2 Eq. in 2045. A summary of projected emissions and sinks by sector and category, as estimated by ICF/ISR/UHERO and the Projection Tool for 2045, are provided in Table K-7.

Table K-7: Comparison of 2045 Emission Projection Results (MMT CO_2 Eq.)

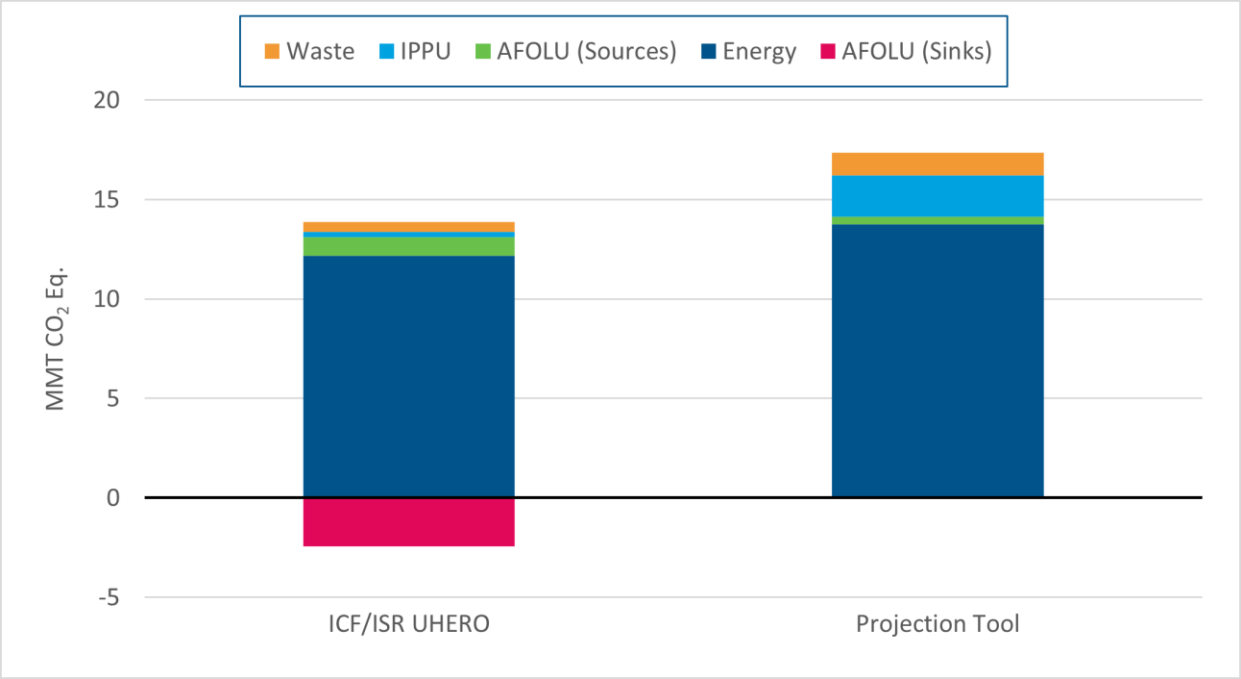
Sector/Category	ICF/ISR/ UHERO	Projection Tool	Difference	% Difference
Energy	**12.16**	**13.76**	**1.60**	**13%**
Transportation	8.77	10.36	1.59	18%
Stationary Combustion	3.00	2.45	(0.55)	(18%)
Incineration of Waste for Energy Purposes	0.22	0.94	0.72	331%
Oil and Natural Gas Systems	0.12	0.01	(0.11)	(91%)
Non-Energy Uses [a]	0.05	IE	NA	NA
IPPU	**0.25**	**2.10**	**1.85**	**746%**
Substitution of ODS	0.24	1.59	1.36	574%
Electrical Transmission and Distribution	0.01	0.01	(0.01)	(45%)
Cement Production	NO	NO	0.00	NA
Soda Ash Manufacture and Consumption	NO	0.01	0.01	NA
Urea Consumption	NO	+	+	NA
Iron and Steel Production	NO	0.49	0.49	NA
Limestone and Dolomite Use	NO	NO	0.00	NA
AFOLU	**(1.46)**	**0.37**	**1.83**	**(125%)**
Agricultural Soil Carbon [b]	0.53	NE	NA	NA
Enteric Fermentation	0.25	0.23	(0.02)	(10%)
Agricultural Soil Management	0.12	0.12	(0.01)	(6%)
Forest Fires [b]	0.05	NE	NA	NA
Manure Management	0.01	0.02	0.01	61%
Manure Management	0.01	0.02	0.01	61%
Field Burning of Agricultural Residues	NO	NO	0.00	NA
Landfilled Yard Trimmings and Food Scraps [b]	(0.02)	NE	NA	NA
Urban Trees [b]	(0.78)	NE	NA	NA
Forest Carbon [b]	(1.63)	NE	NA	NA
Liming	NO	+	+	NA
N_2O from Settlement Soils [b,c]	IE	NE	NA	NA

Waste	**0.49**	**1.13**	**0.64**	**131%**
Landfills	0.35	0.96	0.62	179%
Wastewater Treatment	0.10	0.17	0.07	69%
Composting	0.05	NE	NA	NA
Total Emissions (Excluding Sinks)	**13.86**	**17.35**	**3.49**	**25%**
Net Emissions (Including Sinks)	**11.44**	**17.35**	**5.92**	**52%**

+ Does not exceed 0.005 MMT CO_2 Eq.
NO (emissions are Not Occurring); NE (emissions are Not Estimated); NA (Not Applicable).
[a] The Projection Tool includes projected emissions from Non-Energy Uses under CO_2 emissions from Fossil Fuel Combustion (CO_2FFC). Therefore, these emissions are captured within the Stationary Combustion and Transportation emission sources.
[b] The Projection Tool does not project emissions from LULUCF categories or Composting.
[c] Emissions are included under Agricultural Soil Management.
Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Emissions projections for 2045 by sector as calculated by ICF/ISR/UHERO and the Projection Tool are presented in Figure K-7.

Figure K-7: Comparison of 2045 Emission Projection Results (Including Sinks)



Seven source and sink categories account for 82 percent of the absolute difference between the ICF/ISR/UHERO projections and the Projection Tool estimates. Table K-8 summarizes the absolute and cumulative difference in emission estimates for these top seven categories. The likely reasons for these differences are discussed below in Methodology Comparison.

Table K-8: Key Sources of Differences between ICF/ISR/UHERO Projections and Projection Tool Estimates in 2045

Sector/Category	ICF/ISR/ UHERO	Projection Tool	Absolute Difference	Cumulative % of Total Difference
Transportation	8.77	10.36	1.59	18%
Forest Carbon	(1.63)	NE	1.63	37%
Urban Trees	(0.78)	NE	0.78	46%
Substitution of ODS	0.24	1.59	1.36	62%
Iron and Steel Production	NO	0.49	0.49	68%
Agricultural Soil Carbon	0.53	NE	0.53	74%
Incineration of Waste	0.22	0.94	0.72	82%
All Other Categories			1.55	100%

NO (emissions are Not Occurring); NE (emissions are Not Estimated).

Methodology Comparison

2021 Inventory Estimates

This section compares the methodology and data sources used by ICF and the SIT for each source and sink category to develop the 2021 inventory estimates.

Energy

For the Energy sector, the methodology and activity data used by ICF and SIT to calculate emissions from stationary combustion and transportation are similar. For emissions from the incineration of waste for energy purposes and oil and natural gas systems, both the methodologies and data sources used by ICF and SIT differ. The SIT estimates emissions from non-energy uses of fossil fuels directly within CO_2FFC calculations, rather than by summarizing emissions in a distinct source category. A description of the key differences in methodology and data sources used by ICF and the SIT to estimate emissions for the Energy sector are presented in Table K-9.

Table K-9: Key Differences in Methodology and Data Sources for the Energy Sector

Source	ICF Inventory	SIT
Stationary Combustion	• Fuel consumption data is primarily taken from the Energy Information Administration's (EIA) State Energy Data System (SEDS) database, with naphtha and fuel gas data for the energy industries sector coming from the Environmental Protection Agency's Greenhouse Gas Reporting Program (GHGRP). • ICF does not include petroleum coke consumption in its estimates as it was determined that it is not used in Hawai'i.	• Fuel consumption data is taken from EIA's SEDS database and EIA's Natural Gas Annual report.

Source	ICF Inventory	SIT
Transportation	• Fuel consumption data is taken from EIA's SEDS database. Fuel consumption data collected by the Department of Business, Economic Development, and Tourism (DBEDT) are used to apportion SEDS data to subsectors. • Additional EIA fuel consumption data for military non-aviation applications are compiled through a data request to EIA, which is not accounted for in the SIT.	• Fuel consumption data is taken from EIA's SEDS database. Emissions from alternative fuel vehicles are calculated separately.
Incineration of Waste for Energy Purposes	• Emissions are taken from EPA's GHGRP.	• Calculates combustion of fossil-derived carbon in waste for plastics, synthetic fibers, and synthetic rubber by estimating the mass of waste combusted (obtained from BioCycle), applying a carbon content, and assuming a 98% oxidation rate.
Oil and Natural Gas Systems	• Emissions from refineries are taken from EPA's GHGRP. • Emissions from natural gas distribution and transmission pipelines are estimated using miles and services data from the Department of Transportation's Pipeline and Hazardous Materials Safety Administration database.	• Uses activity data on natural gas production, number of wells, the transmission and distribution of natural gas, and the refining and transportation of oil.
Non-Energy Uses	• The percentage of non-energy use consumption by fuel type are based on estimates from the U.S. Inventory.	• The percentage of non-energy use consumption by fuel type are based on estimates from the U.S. Inventory; however, emission estimates are included in emissions CO_2 from Fossil Fuel Combustion (CO_2FFC). Therefore, these emissions are captured within the Stationary Combustion and Transportation emission sources.

IPPU

For the IPPU sector, the methodology used by ICF and SIT to calculate emissions from electrical transmission and distribution and substitution of ODS is similar, while the source of activity data differs. ICF determined that soda ash manufacturing and consumption, urea consumption, and iron and steel production do not occur in Hawai'i; however, the SIT includes estimates for these sources based on allocations of national or regional data. A description of the key differences in methodology and data sources used by ICF and the SIT to estimate emissions for the IPPU sector are presented in Table K-10.

Table K-10: Key Differences in Methodology and Data Sources for the IPPU Sector

Source	ICF Inventory	SIT
Electrical Transmission and Distribution	• National electricity sales data are taken from EIA. Hawai'i's electricity sales data are taken from the State of Hawai'i Data Book.	• Both national and state-level electricity sales data are taken from EIA.
Substitution of ODS	• Population data are taken from the U.S. Census Bureau. Hawai'i's population data are taken from the State of Hawai'i Data Book. • National emissions estimates are taken from the 1990-2020 U.S. Inventory.	• Both national and state-level population are taken from the U.S. Census Bureau. • National emissions estimates are taken from the 1990-2020 U.S. Inventory.
Soda Ash Manufacture and Consumption	• Emissions from soda ash manufacturing and consumption were determined to not occur in Hawai'i.	• Allocates national emissions from soda ash consumption using the ratio of state population to national population.
Urea Consumption	• Emissions from urea consumption were determined to not occur in Hawai'i.	• Multiplies the total urea applied to Ag Soils in each state (from LULUCF module) by 0.13 to obtain urea consumption.
Iron and Steel Production	• Emissions from iron and steel production were determined to not occur in Hawai'i.	• Evenly distributes regional production data among states within the region.

AFOLU

For the AFOLU sector, the methodology used by ICF and SIT to calculate emissions and sinks from enteric fermentation and urban trees are similar, while the activity data differs. For emissions from manure management, agricultural soil management, field burning of agricultural residues, urea application, and landfilled yard trimmings, both the methodologies and data sources used by ICF and SIT differ. The SIT does not provide default estimates for forest fires or forest carbon. ICF does not present emissions from N_2O from Settlement Soils but rather includes these emissions under the Agricultural Soil Management source category. ICF also does not estimate emissions from Liming. A description of the key differences in methodology and data sources used by ICF and the SIT to estimate emissions and sinks for the AFOLU sector are presented in Table K-11.

Table K-11: Key Differences in Methodology and Data Sources for the AFOLU Sector

Source	ICF Inventory	SIT
Enteric Fermentation	• Obtains sheep and goat population data from the USDA Census of Agriculture.	• Obtains sheep population data from the U.S. Inventory.
Manure Management	• Includes hens within the chicken population but does not include turkeys. • Obtains chicken, sheep, and goat population data from the USDA Census of Agriculture. • Uses constant VS rates for non-cattle animal types.	• Estimates emissions from turkeys and hens greater than one year old. • Obtains sheep population data from the U.S. Inventory. • Uses volatile solids (VS) rates for breeding swine, poultry, and horses that vary slightly by year.

Source	ICF Inventory	SIT
Agricultural Soil Management	• Assumes no commercial organic fertilizer is consumed in Hawaiʻi based on the Association of American Plant Food Control Officials (AAPFCO) Commercial Fertilizer reports. • Obtains 1990-2014 fertilizer consumption estimates from AAPFCO and estimates consumption in 2021 based on a five-year trend from 2010 to 2014 • Calculates emissions from sugarcane, pineapple, sweet potatoes, ginger root, taro, and seed production. • Obtains corn for grain production data from the USDA Census of Agriculture.	• Estimates state-level organic fertilizer consumption by applying the percentage of national fertilizer consumption that is organic fertilizer to total state-level fertilizer consumption. • Uses the 2016 fertilizer consumption estimate from AAPFCO as a proxy for 2021. • Does not calculate emissions from sugarcane, pineapple, sweet potatoes, ginger root, taro, or seed production. • Obtains crop production data from USDA National Agricultural Statistics Service (NASS) Surveys. USDA NASS Surveys do not include corn for grain production data for Hawaiʻi.
Field Burning of Agricultural Residues	• Assumes the fraction of sugarcane residue burned is zero in 2021, as the last sugarcane mill in Hawaiʻi closed in 2017. Emissions from the field burning of agriculture residue are assumed to be zero in 2021.	• Assumes that the fraction of Hawaiʻi sugarcane residue burned is zero. Data on the burning of sugarcane residue is not available from U.S. Inventory. Emissions from the field burning of agriculture residue are assumed to be zero.
Urea Application	• Extrapolates urea fertilization consumption to 2021 based on the historical five-year trend.	• Uses 2016 data from AAPFCO (2022) as a proxy for 2021 urea fertilization.
Agricultural Soil Carbon	• Emissions estimates are from the 1990-2021 U.S. Inventory.	• Emissions estimates are from the 1990-2021 U.S. Inventory.
Forest Fires	• Obtains forest area burned data from the Hawaiʻi Department of Land and Natural Resources.	• Does not include default data of forest area burned.
Landfilled Yard Trimmings	• Hawaiʻi population data were obtained from the State of Hawaiʻi Data Book. • Extrapolates waste generation to 2021 based on the historical five-year trend.	• Hawaiʻi population data were obtained from U.S. Census. • Uses 2018 waste generation data as reported in EPA's Advancing Sustainable Materials Management Fact Sheet as a proxy for 2021.
Urban Trees	• Uses carbon sequestration rates are calculated based on state-specific values from the U.S. Inventory.	• Uses carbon sequestration rates for Hawaiian urban trees based on Nowak et al. (2013).
Forest Carbon	• Uses carbon flux estimates calculated by the Tier 1 Gain Loss Method outlined by the 2006 IPCC Guidelines.	• Does not include carbon flux estimates for Hawaiʻi.
N_2O from Settlement Soils	• Emissions included under Agricultural Soil Management.	• Assumes one percent of synthetic fertilizer consumption is used on settlement soils.
Liming	• Emissions from lime used for agricultural purposes are not estimated by ICF.	• Estimated using data on limestone used for agricultural purposes from the USGS's 2018 Mineral Yearbook.

Waste

For the Waste sector, the methodology used by ICF and SIT to calculate emissions from landfills and wastewater treatment are similar, while the activity data differs. The SIT does not provide estimates of emissions from composting. A description of the key differences in methodology and data sources used by ICF and the SIT to estimate emissions for the Waste sector are presented in Table K-12.

Table K-12: Key Differences in Methodology and Data Sources for the Waste Sector

Source	ICF Inventory	SIT
Landfills	• Data on the tons of waste landfilled per year were provided by the Hawaiʻi Department of Health (DOH), Solid & Hazardous Waste Branch. • Volumes of landfill gas recovered for flaring and energy were obtained from EPA's GHGRP. • Historical MSW generation and disposal volumes were calculated using population data from the State of Hawaiʻi Data Book.	• Estimates state-level waste disposal by allocating national waste data from EPA's Municipal Solid Waste Report and BioCycle and based on population. • Hawaiʻi flaring data is from EPA's Landfill Methane Outreach Program (LMOP) Landfill and Landfill Gas Energy Project Database.
Composting	• Estimated based on data from the Hawaiʻi DOH, Solid & Hazardous Waste Branch.	• Does not estimate emissions from composting.
Wastewater Treatment	• Data on non-National Pollutant Discharge Elimination System (NPDES) wastewater treatment plants, including flow rate and BOD5 are provided by Hawaiʻi DOH, Wastewater Branch and Clean Water Branch. • Population data from the State of Hawaiʻi Data Book were used to calculate wastewater treatment volumes. • The number of households on septic systems were calculated using data from the U.S. Inventory.	• Uses data from the 1990-2021 U.S. Inventory. • Municipal Wastewater emissions estimated using state population data from the U.S. Census Bureau. • State-specific red meat production data from USDA are used to estimate industrial emissions.

2025, 2030, and 2045 Emission Projections

This section compares the methodology used by ICF/ISR/UHERO and the Projection Tool to develop the 2025, 2030, and 2045 inventory projections. While the projections developed by ICF/ISR/UHERO take into account the potential impact of COVID-19 on future emissions, the Projection Tool does not currently account for these impacts. In addition, the methodologies differ significantly between the ICF/ISR/UHERO and Projection Tool estimates. A description of the key differences in methodology used by ICF and the Projection Tool to project emissions for each sector are presented in Table K-13. A more detailed description of the methodology and data sources used by ICF/ISR/UHERO can be found in the Technical Support Document: Preliminary Inventory Projections of Statewide Greenhouse Gas Emissions for 2025 – 2045, and Assessment of Statewide Progress.

Table K-13: Key Differences in Methodology Used to Project Emissions

Sector	ICF/ISR/UHERO	Projection Tool
Energy	• For energy industries and incineration of waste for energy purposes, emissions were projected based on direct communication with the utilities and the utility's Power Supply Improvement Plan (PSIP). • For stationary combustion, electric sector emissions were based on facility emissions reported to the GHGRP. • For residential energy use, commercial energy use, industrial energy use, and non-energy uses, emissions were projected using forecasted gross state product, and adjusted to account for RNG consumption in place of SNG consumption. • For ground transportation, emissions were projected based on estimates of future vehicle miles traveled, fuel efficiency by vehicle type, types of vehicles on the road, and their related fuel sources. Light Duty Vehicle emission projections account for Vehicle Miles Traveled reduction due to the Honolulu Rail Project. • For domestic aviation, emissions were projected based on visitor arrivals, resident travel, and cargo shipments based on 2019 emissions. • For oil and natural gas systems, emissions were projected based on projected growth in aviation emissions.	• Forecasts regional energy consumption data based on EIA's AEO. Allocates regional consumption to states based on 2021 state-level consumption taken from EIA's State Energy Data.
IPPU	• Emissions from Electric Power Transmission and Distribution Systems were projected based on the electricity sales forecast. • Emissions from ODS Substitutes were projected using forecasted gross state product and adjusted to account for the implementation of the American Innovation and Manufacturing (AIM) Act.	• Forecasts emissions from Soda Ash Manufacture and Consumption, Iron & Steel Production, and Urea Consumption based on historical trends. • Forecasts emissions from Electric Power Transmission and Distribution Systems and ODS Substitutes based on publicly available forecasts.
AFOLU	• Emissions were projected by forecasting activity data using historic trends and published information on future trends.	• Forecasts emissions based on either historical trends or publicly available forecasts (varies by category). Results differ due to minor differences in how activity data is projected and differences in historical estimates. • Emission sinks are not estimated.
Waste	• Emissions from landfills were taken from EPA Facility Level Information on Greenhouse Gases Tool (FLIGHT) data and	• Forecasts activity data based on projected population from the U.S. Census Bureau.

Sector	ICF/ISR/UHERO	Projection Tool
	then scaled to match reported landfill tonnage as described for waste in the 2021 inventory. • Composting and Wastewater Treatment emissions were projected based on DBEDT population growth projections.	

Appendix L. Full Emissions Data Series

Table L-1: Hawai'i GHG Emissions by Sector/Category for 1990, 2005, 2007, 2010, and 2015 – 2022 (MMT CO_2 Eq.)

Sector/Category	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Energy	**20.25**	**22.72**	**24.34**	**19.38**	**18.50**	**18.52**	**18.97**	**19.23**	**19.45**	**14.66**	**17.47**	**17.95**
Stationary Combustion	8.47	9.56	9.37	8.89	8.16	7.96	8.09	8.16	8.32	7.29	7.44	7.44
Energy Industries	6.38	8.33	8.31	7.86	7.11	7.01	7.00	7.11	7.21	6.48	6.38	6.37
Residential	0.05	0.07	0.06	0.09	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.06
Commercial	0.76	0.37	0.30	0.37	0.47	0.48	0.54	0.56	0.60	0.50	0.56	0.55
Industrial	1.29	0.80	0.69	0.56	0.51	0.39	0.48	0.43	0.45	0.25	0.44	0.45
Transportation	11.13	12.58	14.40	9.92	9.72	9.96	10.31	10.46	10.69	6.96	9.59	10.12
Ground	3.71	5.04	5.14	4.20	4.29	4.22	4.16	4.10	4.05	3.13	3.50	3.47
Domestic Marine	1.53	0.37	2.81	0.58	0.28	0.40	0.49	0.40	0.63	0.34	0.52	0.65
Domestic Aviation	3.69	6.13	4.86	3.98	4.29	4.38	4.61	4.78	4.96	2.73	4.58	4.90
Military Aviation	1.42	1.03	0.80	0.66	0.80	0.80	0.85	0.86	0.88	0.45	0.67	0.77
Military Non-Aviation	0.77	0.02	0.79	0.51	0.05	0.17	0.20	0.32	0.16	0.32	0.32	0.32
Incineration of Waste for Energy Purposes[a]	0.18	0.15	0.15	0.19	0.27	0.27	0.23	0.26	0.28	0.28	0.30	0.25
Oil and Natural Gas Systems	0.43	0.39	0.39	0.32	0.31	0.29	0.31	0.30	0.12	0.10	0.10	0.10
Non-Energy Uses	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.04
International Bunker Fuels[b]	1.56	2.23	1.09	1.31	1.56	1.55	1.76	1.78	1.65	0.69	0.40	0.83
CO_2 from Wood Biomass and Biofuels Consumption[b]	2.43	0.59	0.88	1.24	1.41	1.51	1.28	1.30	1.25	1.16	1.18	1.19
IPPU	**0.18**	**0.50**	**0.55**	**0.67**	**0.79**	**0.79**	**0.80**	**0.80**	**0.82**	**0.76**	**0.82**	**0.85**
Cement Production	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Substitution of Ozone Depleting Substances	+	0.46	0.52	0.65	0.77	0.78	0.78	0.79	0.80	0.75	0.81	0.84
Electrical Transmission and Distribution	0.08	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Sector/Category	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
AFOLU (Sources)	**1.47**	**1.10**	**1.18**	**1.08**	**1.09**	**1.08**	**1.01**	**1.25**	**1.06**	**1.10**	**1.22**	**1.11**
Enteric Fermentation	0.35	0.31	0.32	0.30	0.26	0.28	0.28	0.28	0.29	0.28	0.27	0.29
Manure Management	0.14	0.05	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Agricultural Soil Management	0.16	0.14	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15
Field Burning of Agricultural Residues	0.03	0.03	0.01	0.01	0.01	0.01	+	0.00	0.00	0.00	0.00	0.00
Urea Application	+	+	+	+	+	+	+	+	+	+	+	+
Agricultural Soil Carbon	0.76	0.50	0.50	0.57	0.57	0.60	0.54	0.58	0.56	0.58	0.58	0.58
Forest Fires	0.02	0.06	0.16	0.03	0.09	0.03	0.01	0.22	0.05	0.09	0.21	0.08
AFOLU (Sinks)	**(2.40)**	**(2.50)**	**(2.54)**	**(2.62)**	**(2.73)**	**(2.69)**	**(2.66)**	**(2.56)**	**(2.54)**	**(2.43)**	**(2.42)**	**(2.48)**
Landfilled Yard Trimmings and Food Scraps	(0.12)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)
Urban Trees	(0.48)	(0.60)	(0.61)	(0.62)	(0.60)	(0.60)	(0.60)	(0.59)	(0.59)	(0.58)	(0.59)	(0.60)
Forest Carbon	(1.79)	(1.86)	(1.89)	(1.95)	(2.07)	(2.04)	(2.02)	(1.90)	(1.90)	(1.80)	(1.78)	(1.83)
Waste	**1.01**	**0.98**	**0.88**	**0.60**	**0.51**	**0.46**	**0.42**	**0.41**	**0.44**	**0.41**	**0.41**	**0.40**
Landfills	0.89	0.84	0.74	0.50	0.41	0.36	0.32	0.31	0.34	0.32	0.33	0.32
Composting	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.02	0.03
Wastewater Treatment	0.09	0.11	0.11	0.06	0.07	0.07	0.07	0.07	0.07	0.05	0.06	0.05
Total Emissions (Excluding Sinks)	**22.90**	**25.29**	**26.95**	**21.71**	**20.88**	**20.85**	**21.20**	**21.69**	**21.77**	**16.93**	**19.92**	**20.31**
Net Emissions (Including Sinks)	**20.51**	**22.78**	**24.41**	**19.09**	**18.16**	**18.16**	**18.54**	**19.14**	**19.23**	**14.50**	**17.50**	**17.83**
Aviation[c]	5.11	7.16	5.66	4.64	5.09	5.17	5.46	5.64	5.84	3.17	5.25	5.67
Net Emissions (Including Sinks, Excluding Aviation)	**15.40**	**15.62**	**18.75**	**14.45**	**13.06**	**12.99**	**13.08**	**13.50**	**13.39**	**11.33**	**12.25**	**12.15**

+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).

[a] Emissions from the incineration of waste for energy purposes are reported under the Energy sector, consistent with the U.S. Inventory, since the incineration of waste for energy purposes generally occurs at facilities where energy is recovered.

[b] Emissions from international bunker fuels and CO_2 from Wood Biomass and Biofuel Consumption are estimated as part of this inventory report but are not included in emission totals, as per IPCC (2006) guidelines.

[c] Domestic aviation and military aviation emissions, which are reported under the transportation source category under the Energy sector, are excluded from Hawai'i's 2020 GHG emissions reduction goal established in Act 234.

Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Table L-2: GHG Emissions by County/Sector for 1990, 2005, 2007, 2010, and 2015 – 2022 (MMT CO_2 Eq.)

Sector/ Category	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Energy	**20.25**	**22.72**	**24.34**	**19.38**	**18.50**	**18.52**	**18.97**	**19.23**	**19.45**	**14.66**	**17.47**	**17.95**
Hawai‘i	1.35	2.20	2.12	1.80	1.79	1.77	1.96	2.08	2.17	1.63	1.93	1.94
Honolulu	16.59	16.48	18.55	14.33	13.34	13.44	13.48	13.57	13.63	10.80	12.25	12.45
Kauai‘i	0.60	0.96	0.92	0.85	0.92	0.88	1.02	1.05	1.01	0.56	0.76	0.96
Maui	1.71	3.08	2.75	2.40	2.44	2.42	2.51	2.53	2.65	1.66	2.53	2.61
IPPU	**0.18**	**0.50**	**0.55**	**0.67**	**0.79**	**0.79**	**0.80**	**0.80**	**0.82**	**0.76**	**0.82**	**0.85**
Hawai‘i	0.01	0.07	0.08	0.10	0.11	0.11	0.11	0.11	0.12	0.11	0.12	0.13
Honolulu	0.16	0.33	0.36	0.44	0.52	0.53	0.53	0.53	0.54	0.52	0.54	0.56
Kauai‘i	0.00	0.03	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05
Maui	0.01	0.07	0.08	0.09	0.11	0.11	0.11	0.11	0.11	0.10	0.11	0.12
Waste	**1.01**	**0.98**	**0.88**	**0.60**	**0.51**	**0.46**	**0.42**	**0.41**	**0.44**	**0.41**	**0.41**	**0.40**
Hawai‘i	0.13	0.20	0.20	0.20	0.13	0.14	0.13	0.14	0.14	0.13	0.12	0.12
Honolulu	0.68	0.58	0.48	0.26	0.18	0.18	0.15	0.15	0.14	0.11	0.13	0.13
Kauai‘i	0.14	0.11	0.10	0.10	0.09	0.04	0.04	0.02	0.03	0.02	0.02	0.02
Maui	0.04	0.09	0.10	0.05	0.10	0.11	0.10	0.11	0.14	0.15	0.14	0.12
AFOLU (Sources)	**1.47**	**1.10**	**1.18**	**1.08**	**1.09**	**1.08**	**1.01**	**1.25**	**1.06**	**1.10**	**1.22**	**1.11**
Hawai‘i	0.83	0.69	0.73	0.67	0.64	0.63	0.59	0.75	0.62	0.65	0.73	0.66
Honolulu	0.19	0.08	0.08	0.07	0.08	0.08	0.07	0.09	0.08	0.08	0.09	0.08
Kauai‘i	0.16	0.13	0.14	0.13	0.15	0.15	0.13	0.16	0.14	0.14	0.16	0.14
Maui	0.29	0.20	0.23	0.21	0.22	0.23	0.21	0.25	0.22	0.23	0.25	0.24
AFOLU (Sinks)	**(2.40)**	**(2.50)**	**(2.54)**	**(2.62)**	**(2.73)**	**(2.69)**	**(2.66)**	**(2.56)**	**(2.54)**	**(2.43)**	**(2.42)**	**(2.48)**
Hawai‘i	(1.18)	(1.27)	(1.24)	(1.27)	(1.35)	(1.34)	(1.30)	(1.29)	(1.29)	(1.31)	(1.30)	(1.31)
Honolulu	(0.57)	(0.59)	(0.60)	(0.62)	(0.62)	(0.62)	(0.61)	(0.50)	(0.49)	(0.48)	(0.48)	(0.50)
Kauai‘i	(0.28)	(0.30)	(0.32)	(0.35)	(0.39)	(0.38)	(0.37)	(0.32)	(0.32)	(0.31)	(0.31)	(0.31)
Maui	(0.37)	(0.35)	(0.39)	(0.39)	(0.36)	(0.36)	(0.38)	(0.45)	(0.45)	(0.33)	(0.33)	(0.37)
Total Emissions (Excluding Sinks)	**22.90**	**25.29**	**26.95**	**21.71**	**20.88**	**20.85**	**21.20**	**21.69**	**21.77**	**16.93**	**19.92**	**20.32**
Net Emissions (Including Sinks)	**20.51**	**22.78**	**24.41**	**19.09**	**18.16**	**18.16**	**18.54**	**19.14**	**19.23**	**14.50**	**17.50**	**17.83**

Sector/ Category	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Net Emissions (Including Sinks, Excluding Aviation)[a]	**15.40**	**15.62**	**18.75**	**14.45**	**13.06**	**12.99**	**13.08**	**13.50**	**13.39**	**11.33**	**12.25**	**12.16**

[a] Domestic aviation and military aviation emissions, which are reported under the transportation source category under the Energy sector, are excluded from Hawai'i's 2020 GHG emissions reduction goal established in Act 234.

Notes: Maui County includes emissions from Kalawao County. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Table L-3: GHG Emissions from the Energy Sector by Source and Year (MMT CO2 Eq.)

Source	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Stationary Combustion	**8.47**	**9.56**	**9.37**	**8.89**	**8.16**	**7.96**	**8.09**	**8.16**	**8.32**	**7.29**	**7.44**	**7.44**
Energy Industries	6.38	8.33	8.31	7.86	7.11	7.01	7.00	7.11	7.21	6.48	6.38	6.37
Residential	0.05	0.07	0.06	0.09	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.06
Commercial	0.76	0.36	0.30	0.37	0.47	0.48	0.54	0.56	0.60	0.50	0.56	0.55
Industrial	1.29	0.81	0.69	0.56	0.51	0.39	0.48	0.43	0.45	0.25	0.44	0.45
Transportation[a]	**11.13**	**12.58**	**14.40**	**9.92**	**9.72**	**9.96**	**10.31**	**10.46**	**10.69**	**6.96**	**9.59**	**10.12**
Ground	3.71	5.04	5.14	4.20	4.29	4.22	4.16	4.10	4.05	3.13	3.50	3.47
Marine	1.53	0.37	2.81	0.58	0.28	0.40	0.49	0.40	0.63	0.34	0.52	0.65
Aviation	3.69	6.13	4.86	3.98	4.29	4.38	4.61	4.78	4.96	2.73	4.58	4.90
Military Aviation	1.42	1.03	0.80	0.66	0.80	0.80	0.85	0.86	0.88	0.45	0.67	0.77
Military Non-Aviation	0.77	0.02	0.79	0.51	0.05	0.17	0.20	0.32	0.16	0.32	0.32	0.32
Incineration of Waste for Energy Purposes	**0.18**	**0.15**	**0.15**	**0.19**	**0.27**	**0.27**	**0.23**	**0.26**	**0.28**	**0.28**	**0.30**	**0.26**
Oil and Natural Gas[b]	**0.43**	**0.39**	**0.39**	**0.32**	**0.31**	**0.29**	**0.31**	**0.30**	**0.12**	**0.10**	**0.10**	**0.10**
Non-Energy Uses	**0.04**	**0.04**	**0.04**	**0.05**	**0.05**	**0.04**	**0.05**	**0.05**	**0.04**	**0.04**	**0.04**	**0.04**
International Bunker Fuels[c]	*1.56*	*2.23*	*1.09*	*1.31*	*1.56*	*1.55*	*1.76*	*1.78*	*1.65*	*0.69*	*0.40*	*0.83*
CO_2 from Wood Biomass and Biofuels Consumption[c]	*2.43*	*1.04*	*0.88*	*1.24*	*1.41*	*1.51*	*1.28*	*1.30*	*1.25*	*1.16*	*1.18*	*1.19*
Total	**20.25**	**22.72**	**24.34**	**19.38**	**18.50**	**18.52**	**18.97**	**19.23**	**19.45**	**14.66**	**17.47**	**17.95**

[a] Includes CH_4 and N_2O emissions from Biofuel Consumption.

[b] Includes fuel combustion emissions from electric power plants and petroleum refineries.

[c] Emissions from international bunker fuels and CO_2 emissions from wood biomass and biofuel consumption are estimated as part of this inventory report but are not included in emission totals, as per IPCC (2006) guidelines.
Note: Totals may not sum due to independent rounding.

Table L-4: GHG Emissions from Stationary Combustion by Economic Sector and Gas (MMT CO_2 Eq.)

Economic Sector/Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Energy Industries	**6.38**	**8.33**	**8.31**	**7.86**	**7.11**	**7.01**	**7.00**	**7.11**	**7.21**	**6.48**	**6.38**	**6.37**
CO_2	6.35	8.30	8.28	7.83	7.09	6.98	6.97	7.09	7.18	6.45	6.35	6.35
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Residential	**0.05**	**0.07**	**0.06**	**0.09**	**0.06**	**0.07**	**0.07**	**0.06**	**0.06**	**0.06**	**0.07**	**0.06**
CO_2	0.05	0.07	0.06	0.09	0.06	0.07	0.07	0.06	0.06	0.06	0.07	0.06
CH_4	+	+	+	+	+	+	+	+	+	+	+	+
N_2O	+	+	+	+	+	+	+	+	+	+	+	+
Commercial	**0.76**	**0.36**	**0.30**	**0.37**	**0.47**	**0.48**	**0.54**	**0.56**	**0.60**	**0.50**	**0.56**	**0.55**
CO_2	0.76	0.33	0.28	0.34	0.44	0.44	0.51	0.52	0.57	0.47	0.52	0.52
CH_4	+	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
N_2O	+	+	+	+	+	+	+	+	+	+	+	+
Industrial	**1.29**	**0.81**	**0.69**	**0.56**	**0.51**	**0.39**	**0.48**	**0.43**	**0.45**	**0.25**	**0.44**	**0.45**
CO_2	1.25	0.79	0.68	0.55	0.50	0.39	0.47	0.43	0.45	0.25	0.43	0.45
CH_4	0.02	0.01	0.01	+	+	+	+	+	+	+	+	+
N_2O	0.02	0.01	0.01	0.01	+	+	+	+	+	+	+	+
Total	**8.47**	**9.56**	**9.37**	**8.89**	**8.16**	**7.96**	**8.09**	**8.16**	**8.32**	**7.29**	**7.44**	**7.44**

+ Does not exceed 0.005 MMT CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Table L-5: GHG Emissions from Transportation by End-Use Sector and Gas (MMT CO_2 Eq.)

End-Use Sector/Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Ground	**3.71**	**5.04**	**5.14**	**4.20**	**4.29**	**4.22**	**4.16**	**4.10**	**4.05**	**3.13**	**3.50**	**3.47**

End-Use Sector/Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	3.56	4.93	5.04	4.12	4.24	4.18	4.12	4.07	4.02	3.10	3.47	3.44
CH_4	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	+	+	0.01
N_2O	0.13	0.10	0.09	0.07	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.03
Domestic Marine	**1.53**	**0.37**	**2.81**	**0.58**	**0.28**	**0.40**	**0.49**	**0.40**	**0.63**	**0.34**	**0.52**	**0.65**
CO_2	1.52	0.36	2.77	0.57	0.28	0.40	0.48	0.40	0.62	0.33	0.52	0.64
CH_4	+	+	0.01	+	+	+	+	+	+	+	+	+
N_2O	0.01	0.01	0.03	0.01	+	+	+	+	0.01	+	+	0.01
Domestic Aviation	**3.69**	**6.13**	**4.86**	**3.98**	**4.29**	**4.38**	**4.61**	**4.78**	**4.96**	**2.73**	**4.58**	**4.90**
CO_2	3.66	6.08	4.82	3.94	4.25	4.34	4.57	4.74	4.92	2.70	4.55	4.86
CH_4	+	+	+	+	+	+	+	+	+	+	+	+
N_2O	0.03	0.05	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.02	0.04	0.04
Military Aviation	**1.42**	**1.03**	**0.80**	**0.66**	**0.80**	**0.80**	**0.85**	**0.86**	**0.88**	**0.45**	**0.67**	**0.77**
CO_2	1.41	1.02	0.79	0.66	0.80	0.79	0.84	0.86	0.87	0.44	0.66	0.76
CH_4	NO	NO	NO	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	+	0.01	0.01
Military Non-Aviation	**0.77**	**0.02**	**0.79**	**0.51**	**0.05**	**0.17**	**0.20**	**0.32**	**0.16**	**0.32**	**0.32**	**0.32**
CO_2	0.75	0.02	0.77	0.50	0.05	0.16	0.20	0.31	0.16	0.32	0.32	0.32
CH_4	+	+	+	+	+	+	+	+	+	+	+	+
N_2O	0.02	+	0.01	0.01	+	+	+	+	+	+	+	0.01
Total	**11.13**	**12.58**	**14.40**	**9.92**	**9.72**	**9.96**	**10.31**	**10.46**	**10.69**	**6.96**	**9.59**	**10.12**

+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Note: Totals may not sum due to independent rounding.

Table L-6: GHG Emissions from Electric Vehicles (BEVs and PHEVs) by Gas (MMT CO_2 Eq.) – INFORMATIONAL ONLY

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	NO	NO	NO	NO	+	0.01	0.01	0.01	0.01	0.02	0.02	0.03
CH_4	NO	NO	NO	NO	+	+	+	+	+	+	+	+

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
N_2O	NO	NO	NO	NO	+	+	+	+	+	+	+	+
Total	**NO**	**NO**	**NO**	**NO**	**+**	**0.01**	**0.01**	**0.01**	**0.01**	**0.02**	**0.02**	**0.03**

+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Note: Totals may not sum due to independent rounding.

Table L-7: Emissions from Incineration of Waste for Energy Purposes by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	0.17	0.15	0.15	0.18	0.26	0.26	0.21	0.25	0.27	0.27	0.28	0.25
CH_4	+	+	+	+	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	+	+	+	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**0.18**	**0.15**	**0.15**	**0.19**	**0.27**	**0.27**	**0.23**	**0.26**	**0.28**	**0.28**	**0.30**	**0.26**

+ Does not exceed 0.005 MMT CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Table L-8: Emissions from Oil and Natural Gas Systems by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	0.42	0.37	0.37	0.31	0.30	0.29	0.30	0.29	0.11	0.09	0.10	0.09
CH_4	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
N_2O	+	+	+	+	+	+	+	+	+	+	+	+
Total	**0.43**	**0.39**	**0.39**	**0.32**	**0.31**	**0.29**	**0.31**	**0.30**	**0.12**	**0.10**	**0.10**	**0.10**

+ Does not exceed 0.005 MMT CO_2 Eq.
Notes: Totals may not sum due to independent rounding.

Table L-9: Emissions from Non-Energy Uses (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	0.04	0.04	0.04	0.05	0.05	0.04	0.05	0.05	0.04	0.04	0.04	0.04

Table L-10: Emissions from International Bunker Fuels by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	1.55	2.21	1.08	1.30	1.55	1.54	1.75	1.76	1.63	0.68	0.39	0.83
CH_4	+	+	+	+	+	+	+	+	+	+	+	+
N_2O	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	+	0.01
Total	**1.56**	**2.23**	**1.09**	**1.31**	**1.56**	**1.55**	**1.76**	**1.78**	**1.65**	**0.69**	**0.40**	**0.83**

+ Does not exceed 0.005 MMT CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Table L-11: Emissions from Wood Biomass and Biofuel Consumption by Gas (MMT CO_2 Eq.)

Gas	1990[a]	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	2.43	1.04	0.88	1.24	1.41	1.51	1.28	1.30	1.25	1.16	1.18	1.19

[a] Emissions from biodiesel were not estimated for 1990 due to a lack of available data. Emissions reported for 1990 reflect emissions from solid biomass consumption only.

Table L-12: GHG Emissions from the IPPU Sector by Source and Year (MMT CO_2 Eq.)

Source	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Substitution of Ozone Depleting Substances	+	0.46	0.52	0.65	0.77	0.78	0.78	0.79	0.80	0.75	0.81	0.84
Electrical Transmission and Distribution	0.08	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Cement Production	0.10	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	**0.18**	**0.50**	**0.55**	**0.67**	**0.79**	**0.79**	**0.80**	**0.80**	**0.82**	**0.76**	**0.82**	**0.85**

+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).
Note: Totals may not sum due to independent rounding.

Table L-13: Emissions from Cement Production by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	0.10	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

NO (emissions are Not Occurring).

Table L-14: Emissions from Electrical Transmission and Distribution by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
SF_6	0.08	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CF_4	+	+	+	+	NO	+	+	NO	+	+	+	+
Total	**0.08**	**0.03**	**0.03**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**

Table L-15: Emissions from Substitutes of ODS by Gas (MMT CO2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
HFCs/PFCs	+	0.46	0.52	0.65	0.77	0.78	0.78	0.79	0.80	0.75	0.81	0.84
CO_2	+	+	+	+	+	+	+	+	+	+	+	+
Total	**+**	**0.46**	**0.52**	**0.65**	**0.77**	**0.78**	**0.78**	**0.79**	**0.80**	**0.75**	**0.81**	**0.84**

+ Does not exceed 0.005 MMT CO_2 Eq.

Table L-16: GHG Emissions from the AFOLU Sector by Source and Sink Category (MMT CO_2 Eq.)

Category	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Agriculture	**0.68**	**0.54**	**0.52**	**0.48**	**0.43**	**0.45**	**0.45**	**0.45**	**0.45**	**0.44**	**0.43**	**0.45**
Enteric Fermentation	0.35	0.31	0.32	0.30	0.26	0.28	0.28	0.28	0.29	0.28	0.27	0.29
Manure Management	0.14	0.05	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
Agricultural Soil Management	0.16	0.14	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15
Field Burning of Agricultural Residues	0.03	0.03	0.01	0.01	0.01	0.01	+	0.00	0.00	0.00	0.00	0.00
Urea Application	+	+	+	+	+	+	+	+	+	+	+	+
Land Use, Land-Use Change, and Forestry	**(1.61)**	**(1.95)**	**(1.88)**	**(2.02)**	**(2.07)**	**(2.07)**	**(2.10)**	**(1.76)**	**(1.94)**	**(1.76)**	**(1.62)**	**(1.82)**
Agricultural Soil Carbon	0.76	0.50	0.50	0.57	0.57	0.60	0.54	0.58	0.56	0.58	0.58	0.58

Landfilled Yard Trimmings and Food Scraps	(0.12)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)
Urban Trees	(0.48)	(0.60)	(0.61)	(0.62)	(0.60)	(0.60)	(0.60)	(0.59)	(0.59)	(0.58)	(0.59)	(0.60)
Forest Carbon	(1.79)	(1.86)	(1.89)	(1.95)	(2.07)	(2.04)	(2.02)	(1.90)	(1.90)	(1.80)	(1.78)	(1.83)
Forest Fires	0.02	0.06	0.16	0.03	0.09	0.03	0.01	0.22	0.05	0.09	0.21	0.08
Total (Sources)	**1.47**	**1.10**	**1.18**	**1.08**	**1.09**	**1.08**	**1.01**	**1.25**	**1.06**	**1.10**	**1.22**	**1.11**
Total (Sinks)	**(2.40)**	**(2.50)**	**(2.54)**	**(2.62)**	**(2.73)**	**(2.69)**	**(2.66)**	**(2.56)**	**(2.54)**	**(2.43)**	**(2.42)**	**(2.48)**
Total Net Emissions	**(0.93)**	**(1.41)**	**(1.36)**	**(1.55)**	**(1.63)**	**(1.61)**	**(1.65)**	**(1.31)**	**(1.49)**	**(1.32)**	**(1.20)**	**(1.37)**

+ Does not exceed 0.005 MMT CO_2 Eq.

Notes: Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Table L-17: Emissions from Enteric Fermentation by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	0.35	0.31	0.32	0.30	0.26	0.28	0.28	0.28	0.29	0.28	0.27	0.29

Table L-18: Emissions from Manure Management by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	0.13	0.05	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
N_2O	0.01	+	+	+	+	+	+	+	+	+	+	+
Total	**0.14**	**0.05**	**0.04**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**

+ Does not exceed 0.005 MMT CO_2 Eq.

Note: Totals may not sum due to independent rounding.

Table L-19: Emissions from Agricultural Soil Management by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
N_2O	0.16	0.14	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15

Table L-20: Emissions from Field Burning of Agricultural Residues Emissions by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	0.03	0.03	0.01	0.01	0.01	0.01	+	NO	NO	NO	NO	NO
N_2O	+	+	+	+	+	+	+	NO	NO	NO	NO	NO
Total	**0.03**	**0.03**	**0.01**	**0.01**	**0.01**	**0.01**	**+**	**NO**	**NO**	**NO**	**NO**	**NO**

+ Does not exceed 0.005 MMT CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Table L-21: Emissions from Urea Application by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	+	+	+	+	+	+	+	+	+	+	+	+

+ Does not exceed 0.005 MMT CO_2 Eq.

Table L-22: Emissions from Agricultural Soil Carbon by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	0.76	0.50	0.50	0.57	0.57	0.60	0.54	0.58	0.56	0.58	0.58	0.58

Table L-23: Emissions from Forest Fires by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	0.02	0.05	0.14	0.02	0.08	0.03	0.01	0.19	0.04	0.08	0.18	0.07
CH_4	+	+	0.01	+	0.01	+	+	0.02	+	0.01	0.02	0.01
N_2O	+	+	0.01	+	+	+	+	0.01	+	+	0.01	+
Total	**0.02**	**0.06**	**0.16**	**0.03**	**0.09**	**0.03**	**0.01**	**0.22**	**0.05**	**0.09**	**0.21**	**0.08**

+ Does not exceed 0.005 MMT CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Table L-24: CO_2 Flux from Landfilled Yard Trimmings (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	(0.12)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.04)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)

Note: Parentheses indicate negative values or sequestration.

Table L-25: CO_2 Flux from Urban Trees (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2 Flux	(0.48)	(0.60)	(0.61)	(0.62)	(0.60)	(0.60)	(0.60)	(0.59)	(0.59)	(0.58)	(0.59)	(0.60)

Note: Parentheses indicate negative values or sequestration.

Table L-26: CO_2 Flux from Forest Carbon (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	(1.79)	(1.86)	(1.89)	(1.95)	(2.07)	(2.04)	(2.02)	(1.90)	(1.90)	(1.80)	(1.78)	(1.83)

Note: Parentheses indicate negative values or sequestration.

Table L-27: GHG Emissions from the Waste Sector by Source (MMT CO_2 Eq.)

Source	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Landfills	0.89	0.84	0.74	0.50	0.41	0.36	0.32	0.31	0.34	0.32	0.33	0.32
Composting	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.02	0.03
Wastewater Treatment	0.09	0.11	0.11	0.06	0.07	0.07	0.07	0.07	0.07	0.05	0.06	0.05
Total	**1.01**	**0.98**	**0.88**	**0.60**	**0.51**	**0.46**	**0.42**	**0.41**	**0.44**	**0.41**	**0.41**	**0.40**

Note: Totals may not sum due to independent rounding.

Table L-28: Emissions from Landfills by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	0.89	0.84	0.74	0.50	0.41	0.36	0.32	0.31	0.34	0.32	0.33	0.32

Table L-29: Emissions from Composting by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02
N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	**0.02**	**0.03**	**0.03**	**0.03**	**0.03**	**0.04**	**0.04**	**0.03**	**0.03**	**0.04**	**0.02**	**0.03**

Note: Totals may not sum due to independent rounding.

Table L-30: Emissions from Wastewater Treatment by Gas (MMT CO_2 Eq.)

Gas	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	0.06	0.07	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01
N_2O	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Total	**0.09**	**0.11**	**0.11**	**0.06**	**0.07**	**0.07**	**0.07**	**0.07**	**0.07**	**0.05**	**0.06**	**0.05**

Note: Totals may not sum due to independent rounding.

Table L-31: Energy Sector GHG Emissions by County for 1990, 2005, 2007, 2010, and 2015 – 2022 (MMT CO2 Eq.)

County / Energy Subsector	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai‘i County	**1.35**	**2.20**	**2.12**	**1.80**	**1.79**	**1.77**	**1.96**	**2.08**	**2.17**	**1.63**	**1.93**	**1.94**
Stationary Combustion	0.64	0.72	0.70	0.67	0.59	0.60	0.60	0.71	0.81	0.73	0.68	0.68
Energy Industries	0.46	0.60	0.60	0.57	0.48	0.49	0.49	0.59	0.68	0.63	0.55	0.56
Residential	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Commercial	0.08	0.05	0.04	0.05	0.07	0.07	0.08	0.08	0.08	0.07	0.08	0.08
Industrial	0.09	0.06	0.05	0.04	0.03	0.03	0.03	0.04	0.04	0.02	0.04	0.04
Transportation	0.70	1.48	1.42	1.12	1.20	1.17	1.35	1.37	1.36	0.90	1.24	1.25
Ground	0.47	0.76	0.80	0.64	0.68	0.67	0.67	0.67	0.67	0.52	0.58	0.58
Domestic Marine	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Domestic Aviation	0.23	0.71	0.62	0.48	0.53	0.50	0.68	0.71	0.69	0.38	0.66	0.67
Military Aviation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Military Non-Aviation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Incineration of Waste for Energy Purposes[a]	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Oil and Natural Gas Systems	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Non-Energy Uses	+	+	+	+	+	+	+	+	+	+	+	+
International Bunker Fuels[b]	NO	+	+	+	0.01	0.01	0.07	0.07	0.06	0.02	+	0.02
CO_2 from Wood Biomass and Biofuels Consumption[b]	0.27	0.14	0.12	0.17	0.19	0.21	0.18	0.18	0.17	0.16	0.17	0.17
Honolulu County	**16.59**	**16.48**	**18.55**	**14.33**	**13.34**	**13.44**	**13.48**	**13.57**	**13.63**	**10.80**	**12.25**	**12.45**
Stationary Combustion	6.63	7.49	7.35	6.95	6.52	6.42	6.48	6.45	6.48	5.75	5.85	5.76
Energy Industries	5.03	6.57	6.55	6.20	5.75	5.73	5.68	5.70	5.69	5.17	5.09	5.01
Residential	0.03	0.05	0.04	0.06	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04
Commercial	0.55	0.24	0.20	0.25	0.32	0.32	0.36	0.37	0.40	0.34	0.37	0.36
Industrial	1.01	0.64	0.55	0.45	0.41	0.32	0.39	0.34	0.36	0.20	0.35	0.35
Transportation	9.32	8.42	10.63	6.82	6.21	6.43	6.43	6.52	6.71	4.64	5.97	6.30
Ground	2.54	3.22	3.27	2.70	2.72	2.66	2.62	2.57	2.52	1.95	2.18	2.15
Domestic Marine	1.53	0.37	2.81	0.58	0.28	0.40	0.49	0.40	0.63	0.34	0.52	0.65
Domestic Aviation	3.05	3.80	2.97	2.37	2.36	2.40	2.28	2.37	2.51	1.59	2.27	2.41
Military Aviation	1.42	1.03	0.80	0.66	0.80	0.80	0.85	0.86	0.88	0.45	0.67	0.77
Military Non-Aviation	0.77	0.02	0.79	0.51	0.05	0.17	0.20	0.32	0.16	0.32	0.32	0.32
Incineration of Waste for Energy Purposes[a]	0.18	0.15	0.15	0.19	0.27	0.27	0.23	0.26	0.28	0.28	0.30	0.26

Oil and Natural Gas Systems	0.43	0.39	0.39	0.32	0.31	0.29	0.31	0.30	0.12	0.10	0.10	0.10
Non-Energy Uses	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.03	0.03	0.03	0.03
International Bunker Fuels[b]	1.56	2.19	1.05	1.26	1.46	1.45	1.61	1.63	1.47	0.63	0.37	0.74
CO_2 from Wood Biomass and Biofuels Consumption[b]	1.77	0.70	0.59	0.84	0.94	1.01	0.85	0.86	0.83	0.79	0.78	0.78
Kaua'i County	**0.60**	**0.96**	**0.92**	**0.85**	**0.92**	**0.88**	**1.02**	**1.05**	**1.01**	**0.56**	**0.76**	**0.96**
Stationary Combustion	0.28	0.31	0.30	0.29	0.26	0.22	0.23	0.24	0.21	0.15	0.16	0.18
Energy Industries	0.20	0.26	0.26	0.25	0.22	0.18	0.18	0.19	0.16	0.12	0.12	0.14
Residential	+	+	+	0.01	+	+	+	+	+	+	+	+
Commercial	0.04	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03
Industrial	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	+	0.01	0.01
Transportation	0.32	0.65	0.62	0.56	0.65	0.66	0.79	0.81	0.80	0.41	0.60	0.77
Ground	0.22	0.34	0.34	0.28	0.28	0.28	0.28	0.28	0.27	0.21	0.23	0.23
Domestic Marine	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Domestic Aviation	0.09	0.31	0.28	0.29	0.37	0.38	0.51	0.53	0.52	0.20	0.37	0.54
Military Aviation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Military Non-Aviation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Incineration of Waste for Energy Purposes[a]	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Oil and Natural Gas Systems	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Non-Energy Uses	+	+	+	+	+	+	+	+	+	+	+	+
International Bunker Fuels[b]	+	NO	NO	+	0.01	0.01	0.01	0.01	0.01	0.01	+	0.01
CO_2 from Wood Biomass and	0.13	0.06	0.05	0.07	0.08	0.09	0.08	0.08	0.07	0.06	0.07	0.07

Biofuels Consumption[b]												
Maui County	**1.71**	**3.08**	**2.75**	**2.40**	**2.44**	**2.42**	**2.51**	**2.53**	**2.65**	**1.66**	**2.53**	**2.61**
Stationary Combustion	0.91	1.04	1.02	0.97	0.79	0.72	0.77	0.76	0.82	0.65	0.74	0.81
Energy Industries	0.69	0.90	0.90	0.85	0.67	0.61	0.65	0.64	0.68	0.56	0.62	0.67
Residential	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Commercial	0.08	0.05	0.04	0.05	0.06	0.06	0.07	0.08	0.08	0.06	0.08	0.08
Industrial	0.14	0.09	0.07	0.06	0.05	0.03	0.04	0.04	0.04	0.02	0.04	0.05
Transportation	0.79	2.03	1.73	1.42	1.65	1.70	1.73	1.76	1.82	1.00	1.78	1.80
Ground	0.48	0.72	0.73	0.58	0.61	0.61	0.60	0.59	0.59	0.45	0.50	0.51
Domestic Marine	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Domestic Aviation	0.31	1.31	1.00	0.84	1.04	1.09	1.13	1.17	1.23	0.55	1.28	1.29
Military Aviation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Military Non-Aviation	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Incineration of Waste for Energy Purposes[a]	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Oil and Natural Gas Systems	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Non-Energy Uses	+	+	+	0.01	+	+	+	+	+	+	+	+
International Bunker Fuels[b]	NO	0.03	0.03	0.04	0.07	0.07	0.07	0.07	0.10	0.03	0.02	0.07
CO_2 from Wood Biomass and Biofuels Consumption[b]	0.27	0.14	0.12	0.16	0.19	0.20	0.17	0.18	0.17	0.14	0.16	0.16
Energy Sector (All Counties)	**20.25**	**22.72**	**24.34**	**19.38**	**18.50**	**18.52**	**18.97**	**19.23**	**19.45**	**14.66**	**17.47**	**17.95**

+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).

[a] Emissions from the incineration of waste for energy purposes are reported under the Energy sector, consistent with the U.S. Inventory, since the incineration of waste for energy purposes generally occurs at facilities where energy is recovered.

[b] Emissions from International Bunker Fuels and CO_2 from Wood Biomass and Biofuel Consumption are estimated as part of this inventory report but are not included in emission totals, as per IPCC (2006) guidelines.
Notes: Maui County includes emissions from Kalawao County. Totals may not sum due to independent rounding.

Table L-32: IPPU Sector GHG Emissions by County for 1990, 2005, 2007, 2010, and 2015 – 2022 (MMT CO2 Eq.)

County / IPPU Subsector	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai'i County	**0.01**	**0.07**	**0.08**	**0.10**	**0.11**	**0.11**	**0.11**	**0.11**	**0.12**	**0.11**	**0.12**	**0.13**
Cement Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Substitution of Ozone Depleting Substances	+	0.07	0.08	0.09	0.11	0.11	0.11	0.11	0.11	0.11	0.12	0.13
Electrical Transmission and Distribution	0.01	+	+	+	+	+	+	+	+	+	+	+
Honolulu County	**0.16**	**0.33**	**0.36**	**0.44**	**0.52**	**0.53**	**0.53**	**0.53**	**0.54**	**0.52**	**0.54**	**0.56**
Cement Production	0.10	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Substitution of Ozone Depleting Substances	+	0.30	0.34	0.43	0.51	0.52	0.52	0.52	0.53	0.51	0.53	0.55
Electrical Transmission and Distribution	0.06	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Kaua'i County	**0.00**	**0.03**	**0.03**	**0.04**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**	**0.05**	**0.05**
Cement Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Substitution of Ozone Depleting Substances	+	0.03	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.05	0.05
Electrical Transmission and Distribution	+	+	+	+	+	+	+	+	+	+	+	+
Maui County	**0.01**	**0.07**	**0.08**	**0.09**	**0.11**	**0.11**	**0.11**	**0.11**	**0.11**	**0.10**	**0.11**	**0.12**

Cement Production	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Substitution of Ozone Depleting Substances	+	0.06	0.07	0.09	0.10	0.11	0.11	0.11	0.11	0.09	0.11	0.12
Electrical Transmission and Distribution	0.01	+	+	+	+	+	+	+	+	+	+	+
IPPU Sector (All Counties)	**0.18**	**0.50**	**0.55**	**0.67**	**0.79**	**0.79**	**0.80**	**0.80**	**0.82**	**0.76**	**0.82**	**0.85**

+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).

Notes: Maui County includes emissions from Kalawao County. Totals may not sum due to independent rounding.

Table L-33: AFOLU Sector GHG Emissions by County for 1990, 2005, 2007, 2010, and 2015 – 2022 (MMT CO2 Eq.)

County / AFOLU Subsector	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
AFOLU (Sources)												
Hawai‘i County	**0.83**	**0.69**	**0.73**	**0.67**	**0.64**	**0.63**	**0.59**	**0.75**	**0.62**	**0.65**	**0.73**	**0.66**
Enteric Fermentation	0.22	0.23	0.23	0.23	0.19	0.19	0.20	0.20	0.20	0.20	0.19	0.21
Manure Management	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	+
Agricultural Soil Management	0.08	0.08	0.08	0.08	0.07	0.08	0.08	0.08	0.08	0.09	0.08	0.09
Field Burning of Agricultural Residues	0.01	0.01	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+	+	+	+	+	+	+	+
Agricultural Soil Carbon	0.45	0.31	0.31	0.34	0.31	0.33	0.30	0.32	0.30	0.31	0.31	0.31
Forest Fires	0.01	0.04	0.09	0.02	0.05	0.02	0.01	0.13	0.03	0.06	0.14	0.05
Honolulu County	**0.19**	**0.08**	**0.08**	**0.07**	**0.08**	**0.08**	**0.07**	**0.09**	**0.08**	**0.08**	**0.09**	**0.08**

Enteric Fermentation	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Manure Management	0.06	0.01	0.01	0.01	0.01	0.01	+	0.01	0.01	+	+	+
Agricultural Soil Management	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Field Burning of Agricultural Residues	0.01	0.01	NO	NO	NO	NO	+	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+	+	+	+	+	+	+	+
Agricultural Soil Carbon	0.06	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Forest Fires	+	0.01	0.02	+	0.01	+	+	0.01	+	0.01	0.01	0.01
Kaua‘i County	**0.16**	**0.13**	**0.14**	**0.13**	**0.15**	**0.15**	**0.13**	**0.16**	**0.14**	**0.14**	**0.16**	**0.14**
Enteric Fermentation	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Manure Management	0.01	+	+	+	+	+	+	+	+	+	+	+
Agricultural Soil Management	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Field Burning of Agricultural Residues	0.01	0.01	+	+	+	+	+	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+	+	+	+	+	+	+	+
Agricultural Soil Carbon	0.09	0.06	0.06	0.08	0.08	0.08	0.07	0.08	0.07	0.07	0.07	0.07
Forest Fires	+	0.01	0.02	+	0.01	+	+	0.03	0.01	0.01	0.03	0.01
Maui County	**0.29**	**0.20**	**0.23**	**0.21**	**0.22**	**0.23**	**0.21**	**0.25**	**0.22**	**0.23**	**0.25**	**0.24**
Enteric Fermentation	0.06	0.04	0.05	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Manure Management	0.02	0.01	0.01	+	+	+	+	+	+	+	+	+

Agricultural Soil Management	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
Field Burning of Agricultural Residues	0.01	0.01	0.01	+	+	0.01	+	NO	NO	NO	NO	NO
Urea Application	+	+	+	+	+	+	+	+	+	+	+	+
Agricultural Soil Carbon	0.16	0.10	0.11	0.13	0.14	0.15	0.13	0.15	0.15	0.16	0.16	0.16
Forest Fires	+	0.01	0.03	+	0.01	+	+	0.04	0.01	0.01	0.03	0.01
AFOLU Sector (Sources) (All Counties)	**1.47**	**1.10**	**1.18**	**1.08**	**1.09**	**1.08**	**1.01**	**1.25**	**1.06**	**1.10**	**1.22**	**1.11**
AFOLU (Sinks)												
Hawai‘i County	**(1.18)**	**(1.27)**	**(1.24)**	**(1.27)**	**(1.35)**	**(1.34)**	**(1.30)**	**(1.29)**	**(1.29)**	**(1.31)**	**(1.30)**	**(1.31)**
Landfilled Yard Trimmings and Food Scraps	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Urban Trees	(0.07)	(0.10)	(0.10)	(0.11)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)	(0.13)	(0.13)	(0.13)
Forest Carbon	(1.10)	(1.16)	(1.13)	(1.15)	(1.23)	(1.21)	(1.17)	(1.16)	(1.16)	(1.18)	(1.16)	(1.17)
Honolulu County	**(0.57)**	**(0.59)**	**(0.60)**	**(0.62)**	**(0.62)**	**(0.62)**	**(0.61)**	**(0.50)**	**(0.49)**	**(0.48)**	**(0.48)**	**(0.50)**
Landfilled Yard Trimmings and Food Scraps	(0.09)	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
Urban Trees	(0.30)	(0.37)	(0.37)	(0.37)	(0.35)	(0.35)	(0.34)	(0.34)	(0.34)	(0.33)	(0.33)	(0.34)
Forest Carbon	(0.17)	(0.19)	(0.20)	(0.21)	(0.24)	(0.24)	(0.24)	(0.12)	(0.12)	(0.12)	(0.12)	(0.12)
Kaua‘i County	**(0.28)**	**(0.30)**	**(0.32)**	**(0.35)**	**(0.39)**	**(0.38)**	**(0.37)**	**(0.32)**	**(0.32)**	**(0.31)**	**(0.31)**	**(0.31)**
Landfilled Yard Trimmings and Food Scraps	(0.01)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)	(+)
Urban Trees	(0.05)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Forest Carbon	(0.22)	(0.23)	(0.24)	(0.27)	(0.31)	(0.31)	(0.30)	(0.25)	(0.25)	(0.24)	(0.24)	(0.24)
Maui County	**(0.37)**	**(0.35)**	**(0.39)**	**(0.39)**	**(0.36)**	**(0.36)**	**(0.38)**	**(0.45)**	**(0.45)**	**(0.33)**	**(0.33)**	**(0.37)**

Landfilled Yard Trimmings and Food Scraps	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Urban Trees	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Forest Carbon	(0.30)	(0.27)	(0.31)	(0.31)	(0.29)	(0.29)	(0.31)	(0.38)	(0.38)	(0.26)	(0.26)	(0.30)
AFOLU (Sinks) (All Counties)	**(2.40)**	**(2.50)**	**(2.54)**	**(2.62)**	**(2.73)**	**(2.69)**	**(2.66)**	**(2.56)**	**(2.54)**	**(2.43)**	**(2.42)**	**(2.48)**
AFOLU (Sources and Sinks) (All Counties)	**(0.93)**	**(1.41)**	**(1.36)**	**(1.55)**	**(1.63)**	**(1.61)**	**(1.65)**	**(1.31)**	**(1.49)**	**(1.32)**	**(1.20)**	**(1.37)**

+ Does not exceed 0.005 MMT CO_2 Eq.; NO (emissions are Not Occurring).

Notes: Maui County includes emissions from Kalawao County. Totals may not sum due to independent rounding. Parentheses indicate negative values or sequestration.

Table L-34: Waste Sector GHG Emissions by County for 1990, 2005, 2007, 2010, and 2015 – 2022 (MMT CO2 Eq.)

County / Waste Subsector	1990	2005	2007	2010	2015	2016	2017	2018	2019	2020	2021	2022
Hawai‘i County	**0.13**	**0.20**	**0.20**	**0.20**	**0.13**	**0.14**	**0.13**	**0.14**	**0.14**	**0.13**	**0.12**	**0.12**
Landfills	0.12	0.18	0.18	0.18	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.11
Composting	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
Wastewater Treatment	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Honolulu County	**0.68**	**0.58**	**0.48**	**0.26**	**0.18**	**0.18**	**0.15**	**0.15**	**0.14**	**0.11**	**0.13**	**0.13**
Landfills	0.61	0.50	0.40	0.19	0.12	0.12	0.08	0.08	0.07	0.05	0.07	0.08
Composting	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01
Wastewater Treatment	0.07	0.07	0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04
Kaua‘i County	**0.14**	**0.11**	**0.10**	**0.10**	**0.09**	**0.04**	**0.04**	**0.02**	**0.03**	**0.02**	**0.02**	**0.02**
Landfills	0.14	0.10	0.09	0.09	0.09	0.03	0.03	0.01	0.02	0.02	0.02	0.01
Composting	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wastewater Treatment	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maui County	**0.04**	**0.09**	**0.10**	**0.05**	**0.10**	**0.11**	**0.10**	**0.11**	**0.14**	**0.15**	**0.14**	**0.12**

Landfills	0.03	0.07	0.07	0.03	0.09	0.09	0.09	0.09	0.12	0.13	0.13	0.12
Composting	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Wastewater Treatment	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
Waste Sector (All Counties)	**1.01**	**0.98**	**0.88**	**0.60**	**0.51**	**0.46**	**0.42**	**0.41**	**0.44**	**0.41**	**0.41**	**0.40**

+ Does not exceed 0.005 MMT CO_2 Eq.

Notes: Maui County includes emissions from Kalawao County. Totals may not sum due to independent rounding.