Hawaii Greenhouse Gas Inventory: 1990 and 2007

Prepared by ICF International

for the

Hawaii Department of Business, Economic Development & Tourism

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1990 and 2007 Hawaii Greenhouse Gas Emissions

Overview

Hawaii's Greenhouse Gas Emissions Reduction Law, Act 234, was signed into law by Governor Linda Lingle on June 30, 2007, and became effective July 1, 2007. Act 234 aims to establish and cost-effectively achieve the State policy of greenhouse gas (GHG) emissions reductions and limits at or below the best estimates and updates of the inventory levels of GHG emissions for 1990, by January 1, 2020. To achieve this purpose, Act 234 requires that the Hawaii Department of Business, Economic Development, and Tourism (DBEDT) and the Department of Health (DOH) update the Inventory of Hawaii's Greenhouse Gas Emissions Estimates for 1990, by December 31, 2008.

ICF International was hired by DBEDT in July 2008 to update estimates of 1990 emissions presented in the *Inventory of Hawaii Greenhouse Gas Emissions: Estimates for 1990* (hereafter referred to as the July 1997 Report) and develop emission estimates for 2007 using the best available data and methods. The data and methods applied to each sector and source covered in the July 1997 Report were thoroughly reviewed and evaluated at the outset of this effort. In the decade since the July 1997 Report was released, there have been several important advances in GHG accounting, such as the revision of emission factors and global warming potentials as well as the development of inventory methods for some GHG sinks (e.g., carbon storage in urban trees). This Updated Inventory includes revised estimates for 1990 and newly developed estimates for 2007.

Both sets of estimates rely on the best available data and methods. The development of the 1990 estimates included extensive efforts to re-collect and verify activity data (e.g., fuel consumption, acres of forest land) wherever possible. In some cases, the interpretation and inclusion of this data has had a significant impact on overall emission estimates. This is particularly true with respect to fuels used for air and marine transportation from Hawaii to the mainland.

Both 1990 and 2007 estimates rely on the latest methodologies and emission factors available from the Intergovernmental Panel on Climate Change (IPCC), U.S. EPA's *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006* (hereafter referred to as the U.S. Inventory), and other sources. This approach ensures that the Hawaii GHG Inventory aligns with the accounting methodologies being used by other states as well as at the national and international levels. The emission calculation methodology for 2007 is largely the same as the methodology used for 1990, though for a few sources a more refined methodology was employed, where more detailed data were available for the later year. IPCC guidance regarding organization and categorization of sources was applied to the inventory for the purpose of reporting 1990 emissions, resulting in some re-categorization of emission sources presented in the July 1997 Report.

The Updated Inventory includes estimates of the following GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Although the first three gases are also emitted from natural sources, these inventory estimates focus exclusively on emissions due to human activities (commonly referred to as anthropogenic emissions). This inventory estimates emissions from the following four sectors: (1) energy, (2) industrial processes (IP), (3) waste, and (4) agriculture, forestry, and other land use (AFOLU). Table 1 below shows a mapping of GHGs estimated for each sector.

Table 1. GHGs Estimated in Each Sector

Gases	Energy	IP	Waste	AFOLU
CO_2	✓	✓	✓	✓
CH_4	✓		✓	✓
N_2O	✓		✓	✓
HFCs/PFCs		✓		
SF_6		✓		

Summary of Estimated 1990 and 2007 Emissions

Table 2 shows 1990 and 2007 emissions and sinks by sector, source, and GHG. Total emissions for Hawaii are reported including or excluding both sinks and aviation emissions. Sinks are reservoirs that take up carbon dioxide from another part of its cycle; they are reported as negative emissions, and are excluded from some totals to provide an indication of the magnitude of total "positive" emissions. While aviation emissions are counted in Inventory totals, Act 234 specifies that they cannot be regulated as part of the emissions reduction effort. Therefore, these emissions have been excluded from some totals to show all emissions that are covered under Act 234.

Exhibit 1 and Exhibit 2 show total gross emissions including aviation summarized by the major sources for 1990 and 2007, respectively. In each year, emissions from the Transportation and the Electric Power source categories accounted for the vast majority (more than 85 percent) of emissions in Hawaii.[1] Exhibit 3, Exhibit 4, and Exhibit 5 show emissions by gas. Each gas differs in its atmospheric warming properties; for example, methane has 21 times the warming potential of carbon dioxide. As a result, the relative contribution of each gas is shown in million metric tons of carbon dioxide equivalent ($MMTCO_2Eq$), using the IPCC-approved conversion factors. At 91 percent of the total, carbon dioxide is the largest single contributor to emissions from in-state sources.

[1] Unless otherwise specified, percentages represent a portion of total gross emissions (excluding sinks, including aviation).

Table 2. Hawaii GHG Emissions Summary: Sector & Source by Gas, 1990 & 2007 ($MMTCO_2Eq$)

Hawaii GHG Emissions Summary: Sector & Source by Gas, 1990 & 2007 ($MMTCO_2Eq$)												
Sector / Source	**1990**						**2007**					
Energy	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**
Residential	0.03	+	+	-	-	**0.03**	0.05	+	+	-	-	**0.05**
Commercial	0.38	+	+	-	-	**0.38**	0.26	+	+	-	-	**0.26**
Industrial	0.69	+	+	-	-	**0.70**	0.18	+	+	-	-	**0.18**
Transportation	12.94	0.03	0.24	-	-	**13.21**	12.37	0.02	0.20	-	-	**12.58**
Ground	3.23	+	+	-	-	3.23	4.47	+	+	-	-	4.47
Marine	1.63	+	0.01	-	-	1.65	2.14	+	0.02	-	-	2.16
Aviation	6.72	+	0.07	-	-	6.80	4.77	+	0.06	-	-	4.83
Other	1.35	0.03	0.15	-	-	1.53	0.99	0.01	0.12	-	-	1.13
Electric Power	6.77	0.01	0.02	-	-	**6.79**	8.72	0.01	0.02	-	-	**8.76**
Oil and Gas	-	+	-	-	-	**+**	-	+	-	-	-	**+**
International Bunker Fuels	*1.00*	*+*	*0.01*	*-*	*-*	***1.01***	*1.31*	*+*	*0.01*	*-*	*-*	***1.32***
Energy Total (Excluding International Bunkers)	**20.82**	**0.04**	**0.26**	**-**	**-**	**21.12**	**21.58**	**0.02**	**0.23**	**-**	**-**	**21.83**
Industrial Processes	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**
Cement Manufacture	0.10	-	-	-	-	**0.10**	-	-	-	-	-	**-**
Electricity T&D	-	-	-	-	0.08	**0.08**	-	-	-	-	0.04	**0.04**
Substitutes of ODS	-	-	-	-	-	**-**	-	-	-	0.50	-	**0.50**
Industrial Processes Total	**0.10**	**-**	**-**	**-**	**0.08**	**0.18**	**-**	**-**	**-**	**0.50**	**0.04**	**0.54**
Waste	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**
Municipal Solid Waste - Landfills	-	0.54	-	-	-	**0.54**	-	0.77	-	-	-	**0.77**
Municipal Solid Waste - Combustion	0.17	-	+	-	-	**0.18**	0.15	-	+	-	-	**0.15**
Wastewater	-	0.06	0.07	-	-	**0.13**	-	0.07	0.08	-	-	**0.15**
Waste Total	**0.17**	**0.60**	**0.07**	**-**	**-**	**0.85**	**0.15**	**0.83**	**0.08**	**-**	**-**	**1.07**
Agriculture, Forestry and Other Land Use (AFOLU)	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**	**CO_2**	**CH_4**	**N_2O**	**HFCs / PFCs**	**SF_6**	**Total**
Enteric Fermentation	-	0.27	-	-	-	**0.27**	-	0.25	-	-	-	**0.25**
Manure Management	-	0.10	0.02	-	-	**0.12**	-	0.04	0.01	-	-	**0.05**
Agricultural Soil Management	-	-	0.19	-	-	**0.19**	-	-	0.17	-	-	**0.17**
Field Burning of Agricultural Residues	-	0.02	+	-	-	**0.03**	-	+	+	-	-	**0.01**
Urea Application	+	-	-	-	-	**+**	+	-	-	-	-	**+**
Agricultural Soil C	0.22	-	-	-	-	**0.22**	0.24	-	-	-	-	**0.24**

Landfilled Yard Trimmings and Food Scraps	(0.11)	-	-	-	-	**(0.11)**	(0.03)	-	-	-	-	**(0.03)**
Urban Trees	(0.11)	-	-	-	-	**(0.11)**	(0.13)	-	-	-	-	**(0.13)**
Forest C	(2.45)	-	-	-	-	**(2.45)**	(2.59)	-	-	-	-	**(2.59)**
Forest Fires	0.15	0.01	+	-	-	**0.16**	0.11	0.01	+	-	-	**0.12**
AFOLU (Sources)	**0.37**	**0.40**	**0.22**	**-**	**-**	**0.98**	0.35	0.30	0.18	-	-	**0.83**
AFOLU (Sinks)	***(2.67)***	***-***	***-***	***-***	***-***	***(2.67)***	***(2.75)***	***-***	***-***	***-***	***-***	***(2.75)***
TOTAL Emissions (Excluding Sinks)	**21.46**	**1.04**	**0.55**	**-**	**0.08**	**23.13**	**22.08**	**1.16**	**0.49**	**0.50**	**0.04**	**24.27**
TOTAL Net Emissions (Including Sinks)	**18.79**	**1.04**	**0.55**	**-**	**0.08**	**20.46**	**19.33**	**1.16**	**0.49**	**0.50**	**0.04**	**21.52**
TOTAL Emissions (Excluding Sinks, Excluding Aviation)*	**14.74**	**1.04**	**0.48**	**-**	**0.08**	**16.33**	**17.32**	**1.16**	**0.43**	**0.50**	**0.04**	**19.44**
TOTAL Net Emissions (Including Sinks, Excluding Aviation)*	**12.06**	**1.04**	**0.48**	**-**	**0.08**	**13.66**	**14.57**	**1.16**	**0.43**	**0.50**	**0.04**	**16.69**

+ Less than 0.01 $MMTCO_2Eq$; - No emissions occurring/estimated

* Act 234 specifies that emissions from aviation cannot be regulated as part of the emissions reduction effort.

Exhibit 1. Composition of Hawaii GHG Emissions (Excluding Sinks, Including Aviation), 1990 ($MMTCO_2Eq$)

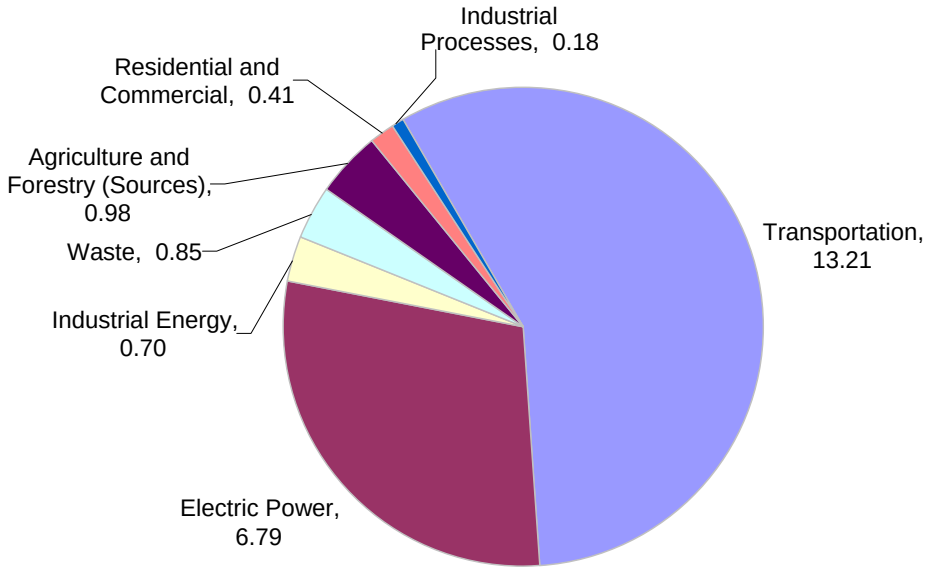


Exhibit 2. Composition of Hawaii GHG Emissions (Excluding Sinks, Including Aviation), 2007 ($MMTCO_2Eq$)

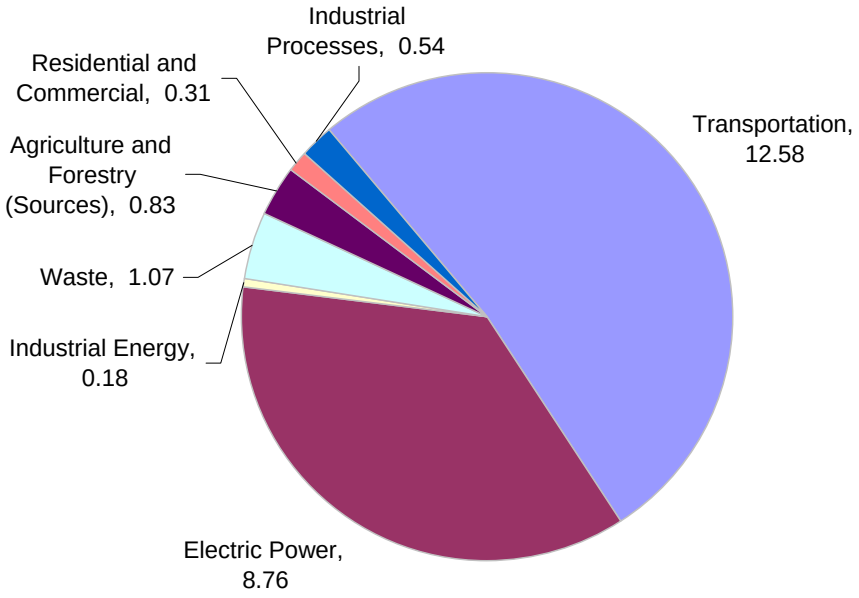


Exhibit 3. Hawaii GHG Emissions by Gas (Excluding Sinks, Including Aviation), 1990 & 2007 ($MMTCO_2Eq$)

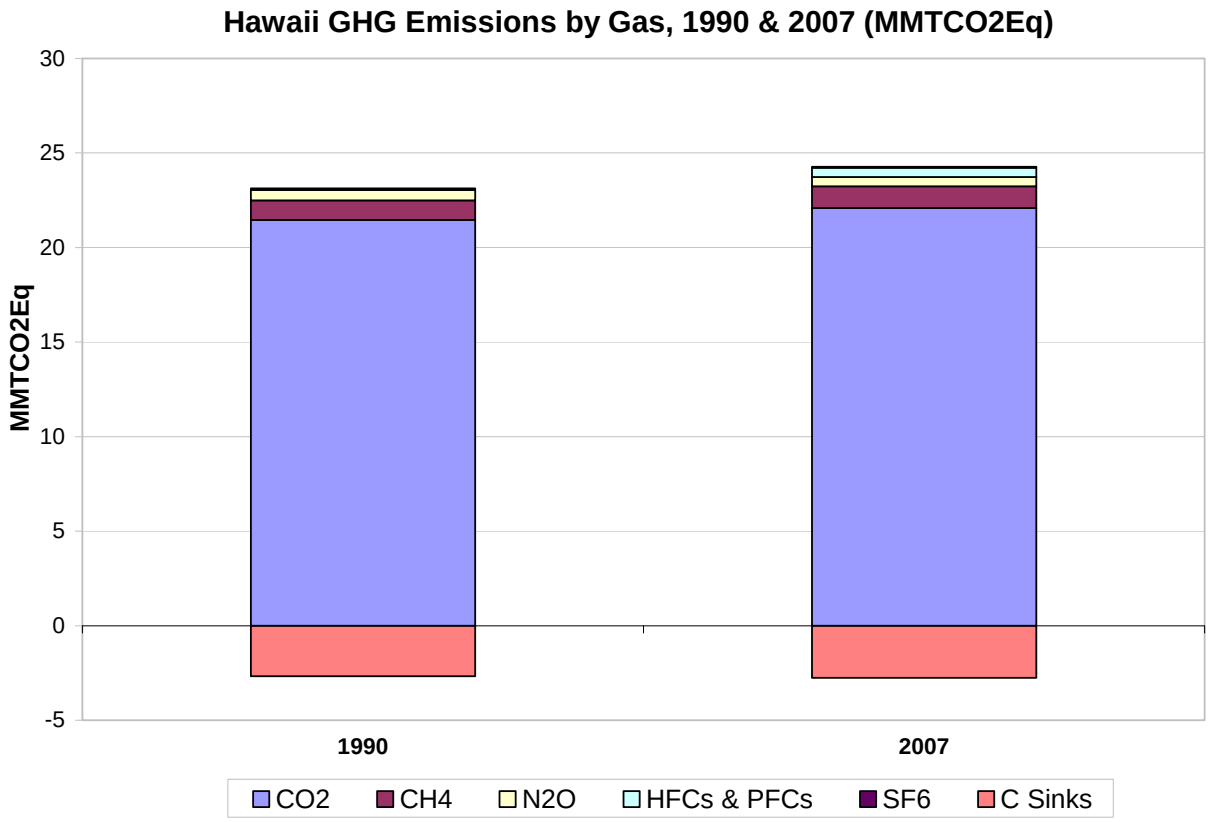
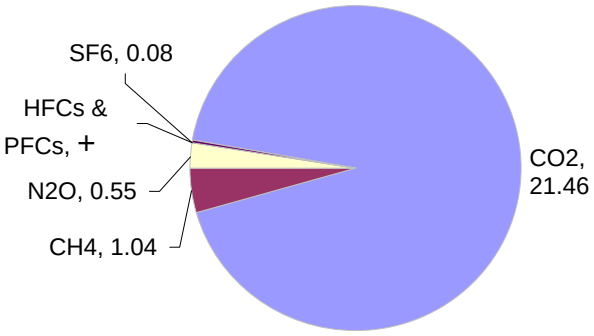


Exhibit 4. Hawaii GHG Emissions by Gas (Excluding Sinks, Including Aviation), 1990 ($MMTCO_2Eq$)



+ Less than 0.01 $MMTCO_2Eq$

Exhibit 5. Hawaii GHG Emissions by Gas (Excluding Sinks, Including Aviation), 2007 ($MMTCO_2Eq$)

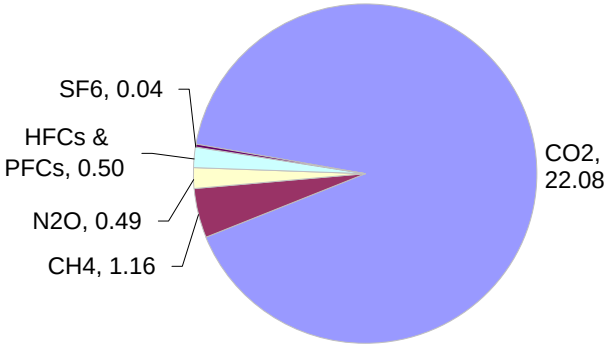


Table 3 shows 1990 and 2007 emissions and sinks by island. Exhibit 6 and Exhibit 7 show emissions by island for 1990 and 2007, respectively. Total gross emissions (including aviation) are greatest on Oahu in both 1990 and 2007. The Big Island and Maui represented the second and third greatest totals, respectively.

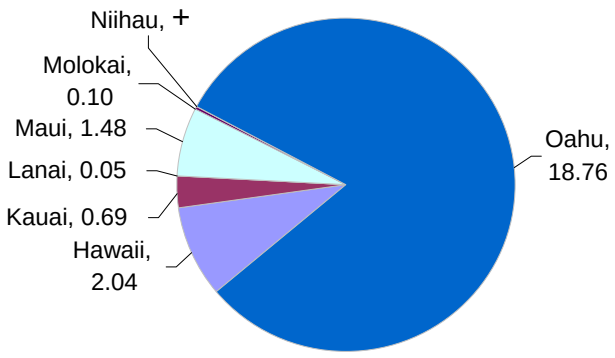
Table 3. Hawaii GHG Emissions Summary: Island by Sector, 1990 & 2007 ($MMTCO_2Eq$)

Hawaii GHG Emissions Summary: Island by Sector, 1990 & 2007 ($MMTCO_2Eq$)		
Island/Sector	**1990**	**2007**
Hawaii	**2.04**	**2.81**
Energy	1.45	2.10
Industrial Processes	0.01	0.08
Waste	0.07	0.14
AFOLU (Sources)	0.52	0.48
AFOLU (Sinks)	*(0.55)*	*(1.73)*
Kauai	**0.69**	**1.10**
Energy	0.55	0.91
Industrial Processes	+	0.02
Waste	0.03	0.07
AFOLU (Sources)	0.11	0.10
AFOLU (Sinks)	*(0.30)*	*(0.27)*
Lanai	**0.05**	**0.08**
Energy	0.04	0.07
Industrial Processes	+	+
Waste	+	+
AFOLU (Sources)	0.02	0.01
AFOLU (Sinks)	*(0.02)*	*(0.02)*
Maui	**1.48**	**2.69**
Energy	1.25	2.36
Industrial Processes	0.01	0.07
Waste	0.05	0.13
AFOLU (Sources)	0.17	0.13
AFOLU (Sinks)	*(0.36)*	*(0.35)*
Molokai	**0.10**	**0.17**
Energy	0.08	0.15
Industrial Processes	+	+
Waste	+	0.01
AFOLU (Sources)	0.01	0.01
AFOLU (Sinks)	*(0.03)*	*(+)*
Niihau	**+**	**+**
Energy	+	+
Industrial Processes	-	+
Waste	+	+
AFOLU (Sources)	+	+
AFOLU (Sinks)	*(+)*	*(+)*
Oahu	**18.76**	**17.42**
Energy	17.76	16.24
Industrial Processes	0.16	0.36
Waste	0.68	0.72

AFOLU (Sources)	0.15	0.09
AFOLU (Sinks)	*(0.41)*	*(0.38)*
TOTAL Emissions (Excluding Sinks)	**23.13**	**24.27**
TOTAL Emissions (Including Sinks)	**20.46**	**21.52**
TOTAL Emissions (Excluding Sinks, Excluding Aviation)	**16.33**	**19.44**
TOTAL Net Emissions (Including Sinks, Excluding Aviation)	**13.66**	**16.69**

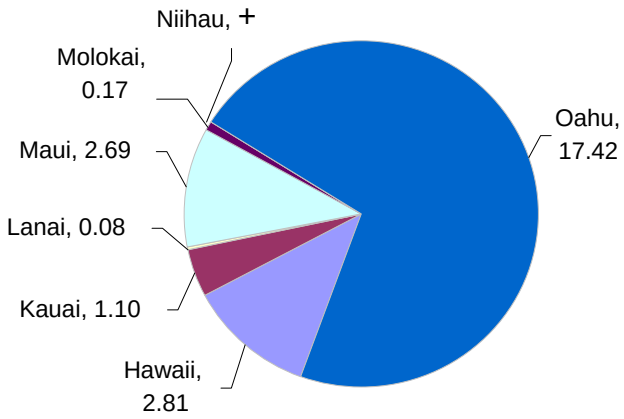
+ Less than 0.01 $MMTCO_2Eq$; - No emissions occurring/estimated

Exhibit 6. Hawaii Emissions by Island (Excluding Sinks, Including Aviation), 1990 ($MMTCO_2Eq$)



+ Less than 0.01 $MMTCO_2Eq$

Exhibit 7. Hawaii Emissions by Island (Excluding Sinks, Including Aviation), 2007 ($MMTCO_2Eq$)



+ Less than 0.01 $MMTCO_2Eq$

Comparison of 1990 Emission Estimates in Updated Inventory Versus July 1997 Report

Net[2] Hawaii GHG emissions (including aviation) estimated in the Updated Inventory are 37 percent higher than the amount reported in the July 1997 Report. Differences in energy sector emissions estimates drove the major differences between the July 1997 Report and the Updated Inventory.

Energy sector emissions for the Updated Inventory are 51% greater than in the July 1997 report, largely due to the difference in fuel consumption estimates for the transportation sector. The July 1997 Report only accounted for in-state transportation fuels. In contrast, the Updated Inventory also includes fuel consumed for travel from Hawaii to U.S. destinations. The decision to include this fuel was verified by EPA's State and Local Branch as the correct convention for state GHG inventory reporting (US EPA 2008).[3] A second reason for differences in emissions for the transportation sector are due to inclusion of estimates of military fuel consumption in the Updated Inventory; the July 1997 Report did not include military fuel in state totals.

Differences in estimates of 1990 emissions for non-energy sources resulted for a variety of reasons.

[2] "Net" emissions include the sum of all "positive" emissions and carbon sinks (negative emissions).
[3] Note that the Updated Inventory estimates for 1990 and 2007 do not include any emissions associated with fuel consumed in Hawaii for air or marine travel to other countries. Fuels consumed for air or marine travel originating from the mainland with Hawaii as the destination are assumed to be captured in the inventories of states where the travel originated and is therefore excluded from Hawaii's inventory.

Industrial process emissions increased by 82 percent between the July 1997 Report and Updated Inventory due to the inclusion of emissions of SF_6 from electrical transmission and distribution in the Updated Inventory.

Waste emissions between the July 1997 Report and Updated Inventory decreased by 33 percent overall. This decrease resulted from excluding CO_2 emissions from landfills in the Updated Inventory, since these emissions are biogenic and should not be included in inventory totals according to IPCC guidance.[4] In addition, the Updated Inventory incorporates the First Order Decay method, which produces more accurate estimates of annual emissions.

AFOLU sinks increased more than four fold between the July 1997 Report and Updated Inventory. The main driver for this increase was updated forest carbon estimates, which are now calculated based on a more complete estimate of total acreage of managed forest; the July 1997 Report calculated carbon sequestration only from forest plantations, which represented only 2 percent of total reported acres.

2007 Emissions

Emissions in 2007 were 24.3 $MMTCO_2Eq$ for all sources (excluding sinks, including aviation). The Energy sector (excluding International Bunker fuels[5]) represented 90 percent of total emissions. Two energy sector source categories (Transportation and Electric Power) accounted for over 88 percent of 2007 emissions. Transportation[6] represented 52 percent of total emissions from all sources, while Electric Power represented 36 percent of total emissions from all sources. For non-energy sources, waste (including wastewater) represented 4 percent, while industrial processes represented 2 percent of total emissions in 2007. AFOLU sources represented 3 percent of total emissions, while AFOLU sinks offset 11 percent of Hawaii's total emissions in 2007.

Changes between 1990 and 2007

Changes in Total Emissions

The Updated Inventory indicates a modest growth in total emissions (including aviation emissions) between 1990 and 2007 of 5 percent, largely driven by the overall trend in the Energy sector. The sources most responsible for growth in emissions include electric power, ground transportation, marine transportation, and substitutes of ozone depleting substances (ODS). Sources most responsible for decreases in emissions include aviation and industrial energy use.

Emissions (including aviation emissions) from energy sources increased by 3 percent between 1990 and 2007. This change in the energy sector was due to increases in emissions in the electric power sector, tempered by decreases in transportation and industrial sector emissions.

Emissions from Industrial Processes increased by nearly 3 times from 1990 to 2007 to 0.5 $MMTCO_2Eq$, due to the increase in substitutes of ODS.

Emissions from the Waste sector (including wastewater) increased by 26 percent from 1990 to 2007, driven by a 42 percent increase in landfill emissions.

[4] Biogenic materials are produced by living organisms. The combustion of these materials (such as biofuels or waste) is considered carbon neutral, since this carbon was sequestered from the atmosphere.

[5] Fuel supplied to ships and aircraft for international transportation, irrespective of the flag of the carrier, consisting primarily of residual and distillate fuel oil for ships and jet fuel for aircraft.

[6] Note that while aviation emissions have been included in total emissions estimates reported here, Act 234 specifies that this source shall not be included in the GHG emissions limits to be achieved by 2020. These emissions will, thus, be subtracted out prior to development of emissions reductions workplans.

AFOLU sources decreased by 16 percent as a result of the decrease in agricultural residue burning, landfilled yard trimmings and food scraps, and manure management.

AFOLU sinks increased as a result of the increasing sinks in urban trees and forest carbon.

Changes in Total Emissions (excluding aviation emissions)

While aviation emissions have been counted in Inventory totals, Act 234 specifies that they cannot be regulated as part of the emissions reduction effort. Therefore, it is useful to examine trends in emissions from 1990 to 2007 excluding those emissions from aviation.

As stated earlier, total emissions from Hawaii increase by a modest 5 percent when aviation emissions are included, largely due to the fact that emissions from transportation decrease over this period. When aviation emissions are excluded, as shown in Table 4 below, the trend in emissions from 1990 to 2007 changes substantially. Total net emissions (excluding aviation) increase by 22 percent, as emissions from transportation and the energy sector as a whole increase by 21 percent and 19 percent, respectively.

Table 4. Changes in Emissions Including and Excluding Aviation ($MMTCO_2$ Eq)

Source	1990	2007	Percent change
Including Aviation			
TOTAL Emissions (Excluding Sinks)	23.13	24.27	5%
TOTAL Net Emissions (Including Sinks)	20.46	21.52	5%
Energy	21.12	21.83	3%
Transportation	13.21	12.58	-5%
Aviation	6.80	4.82	-29%
Excluding Aviation			
TOTAL Emissions (Excluding Sinks)	16.33	19.44	19%
TOTAL Net Emissions (Including Sinks)	13.66	16.69	22%
Energy	14.32	17.01	19%
Transportation	6.41	7.76	21%

Note: All values exclude international bunker fuels

Methodology and Data Sources

Introduction to Approach

The approach for this effort involved a detailed review of the July 1997 Report, use of the latest national and international guidance for developing GHG inventories, and the review of methods and data used in national, state, and regional inventories.

The emission source categorization, methods, and the types of data used for each sector and source category in the July 1997 Report were reviewed and compared against the *1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories*, the *2003 IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry,* and the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.[7] These guidelines are developed and approved by the IPCC and are followed by the US and all other countries that are signatories to the United Nations Framework Convention on Climate Change (UNFCCC).

Other inventories and inventory tools that serve as a model for conducting greenhouse gas (GHG) inventories at the state-level were also reviewed, including: the U.S. Inventory; the *Inventory of California Greenhouse Gas Emissions and Sinks: 1990 to 2004*; and, EPA's *State Greenhouse Gas Inventory Tools* (SITs).

Decisions about the inclusion of source categories, their assignment to particular inventory sectors, and the selection of appropriate methodologies and data reflect a consideration of the 1996, 2003 and 2006 IPCC guidelines, as well as the recognition that data availability drives methodological choices within the somewhat flexible IPCC framework. This assessment also took into account the expected relative significance of each source to total emissions.

The methodologies used 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 categories, IPCC Guidelines suggest three tiers; Tier 1 being the most basic, Tier 2 an intermediate approach, and Tier 3 the most resource intensive, requiring highly specific data inputs. In the methodological discussions that follow, the IPCC Tier approach is referred to on a source-by-source basis.

Some level of uncertainty in GHG estimates is associated with all emissions inventories. This uncertainty can be attributed to a number of factors such as incomplete data, uncertainty in the activity data collected, the use of average or default emission factors that may not reflect the specific nature of how emissions are generated from certain sources, 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 and N_2O emissions from wastewater), emission estimates have greater uncertainty. Overall, it is important to recognize that some level of uncertainty exists with all GHG estimates, and these uncertainties vary between sector, source, and gas.

The U.S. Inventory (1990-2006) estimated the range of uncertainty for total U.S. emissions estimates to be -2 to +7%. Considerable resources are expended at the national level to develop these estimates of uncertainty. Detailed uncertainty estimates were not developed for Hawaii, given the time and resource constraints. Since fuel combustion in Hawaii drives about 90 percent of

[7] While countries are still required to report emissions using the 1996 and 2000 IPCC guidelines, they may use revised methodologies in the 2006 guidelines. Thus, we considered all three sets of guidelines in this evaluation. The approaches outlined in these guidelines are all still used, and have not changed substantially in most instances.

total emissions, uncertainty around this source (which is typically lower than other sources) likely drives the uncertainty around the inventory totals. Conducting an uncertainty analysis in the future could help identify areas for improvement and prioritize future actions to update GHG emission estimates for Hawaii.

Table 5 on the following page summarizes the differences between the 1990 emissions estimates reported in the July 1997 Report and this Updated Inventory. It also provides a comparison of the key differences in source categorization, methods, and data used in the two inventories.

Table 5. 1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory Categorization of GHG Sources and Sinks Follows the Updated Inventory							
	July 1997 Report ($MMTCO_2$ Eq)	Updated Inventory ($MMTCO_2Eq$)	Difference	% Difference	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Sector/Source	1990	1990	(Updated Estimate - 1997 Report)	(Updated Estimate - 1997 Report) / 1997 Report			
Energy	**13.98**	**21.12**	**7.13**	**51%**			
Residential Sector[1]	0.09	0.03	(0.05)	-64%		Updated estimates use recently updated emission factors and carbon content coefficients.	Updated estimates do not report SNG as being consumed at all in the residential sector. This is an area of further research as DBEDT Records (2008) has some intermixing propane, SNG, and propane data.
Commercial Sector[1]	0.26	0.38	0.13	49%		Updated estimate includes emissions from military combustion of residual fuel to produce electricity.	SNG is no longer reported as being consumed (as in the residential sector). This is an area of further research as DBEDT Records (2008) has some intermixing propane, SNG, and propane data.

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector / Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Industrial Sector[1]	0.84	0.70	(0.14)	-17%			Updated estimate includes higher coal and gasoline consumption, and lower residual, distillate, and propane consumption.
Electricity Sector[1]	6.94	6.79	(0.15)	-2%	Updated estimates do not include landfill methane and MSW combustion, which are now reported in the Waste sector.		

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector / Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Transportation Sector[2]	5.86	13.21	7.36	126%		Updated estimate includes travel to the mainland resulting in significantly higher fuel consumption; July 1997 Report did not include fuel consumed for travel to the mainland. This guidance from the EPA was cited on page 5-5 in Section 5.2.1.4 of the July 1997 Report. Updated estimate also includes fuels consumed by the military, whereas the July 1997 Report does not include these estimates in sector totals. Updated estimates also include an updated transportation methodology that incorporates vehicle specific characteristics, such as vehicle type, model year, and engine type.	

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector / Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Oil and Gas[3]	+	+	(+)	-99%	Included in Industrial Processes sector in 1997 Report.	Updated estimate includes methane emissions from the transportation, refining, and distribution of petroleum.	Updated estimate includes data from PIMAR on the amount of crude oil imported and refined.
International Bunker Fuels (excluded from total)	-	*1.01*	*1.01*	*NA*	Not included in July 1997 Report.	Updated estimate includes aviation and marine international bunker fuels (note these are not included in totals).	Updated estimate for marine travel uses Department of Commerce data, which provided the amount of diesel and residual fuel consumed in marine vessels leaving Honolulu with an international destination. The Bureau of Transportation Statistics Transtats database was used to obtain domestic and international flight mileage for aviation bunkers.

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector/Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Industrial Processes	**0.10**	**0.18**	**0.08**	**82%**			
Cement Manufacture[4]	0.10	0.10	+	2%		Updated estimate accounts for CO_2 emissions from cement kiln dust (CKD); masonry cement not considered an additional source of emissions in the Updated Inventory.	
Electricity T&D	-	0.08	0.08	NA	Not included in July 1997 Report.		
Substitutes of ODS	-	+	+	NA	Not included in July 1997 Report.		
Waste	**1.26**	**0.85**	**(0.41)**	**-33%**			
Municipal Solid Waste - Landfills[5]	1.20	0.54	(0.66)	-55%	Updated estimate does not include CO_2 emissions from landfills, which are considered biogenic and should not be counted in emissions totals; 1997 Report included CO_2 emissions from landfills.	Updated estimate incorporates the First Order Decay (FOD) method, producing more accurate estimate of annual emissions.	Updated estimate uses Island-specific waste disposal data; July 1997 Report used Oahu-specific data as proxy for entire state.

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector / Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Municipal Solid Waste - Combustion[5]	0.04	0.18	0.14	354%		Updated estimate is based on specific proportion of materials within MSW stream; July 1997 Report used an assumed C content of entire MSW stream.	
Wastewater[5]	0.02	0.13	0.11	536%	Updated estimate includes CH_4 and N_2O; July 1997 Report included only CH_4.	Updated estimate uses emission factor for the amount of CH_4 emitted per pound of BOD treated, which significantly increases the emission estimates.	
AFOLU	**(0.40)**	**(1.69)**	**(1.29)**	**323%**			
Enteric Fermentation[6]	0.27	0.27	+	0%			Updated estimate includes additional animal types (goats and horses).
Manure Management[6]	0.12	0.12	+	2%	Updated estimate includes CH_4 and N_2O; July 1997 Report included only CH_4.	Updated estimate uses more specific emission factors and a different assumed distribution of manure among manure management system types.	Updated estimate includes additional animal types (goats and horses).

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector/Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Field Burning of Agricultural Residues[6]	0.01	0.03	0.01	108%		Updated estimate uses a conversion factor (converting CH_4-C to CH_4 and N_2O-N to N_2O); July 1997 Report did not use a conversion factor, which led to artificially low estimates. Updated estimate also uses different factors for sugarcane burning based on Hawaii-specific information provided by the Hawaii Agricultural Research Center.	

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector / Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Agricultural Soil Management[6]	0.05	0.19	0.14	288%	Updated estimate includes direct emissions from crop residue and manure inputs, and indirect emissions from fertilizer, crop residues, and manure, in addition to direct fertilizer emissions; July 1997 Report included only direct N_2O emissions from synthetic fertilizer application.		

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector / Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Forest C[6]	(0.38)	(2.45)	(2.07)	551%		Updated estimate includes carbon sequestration for the entire acreage of managed forest; July 1997 Report only calculated carbon sequestration from forest plantations, which represented 2 percent of total reported acres. Updated estimate also applied a forest:shrubland ratio in order to more accurately capture the character of Hawaiian forests.	

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector / Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Agricultural Soil C[6]	(0.47)	0.22	0.69	-147%	Updated estimate accounts for all changes in cropland and grassland tracked by the National Resources Inventory; while C flux from a known pool of abandoned lands was estimated in the July 1997 Report, this source category did not account for all agricultural lands.		
Urea Application	-	+	+	NA	Not included in July 1997 Report.		
Landfilled Yard Trimmings and Food Scraps	-	(0.11)	(0.11)	NA	Not included in July 1997 Report.		
Urban Trees	-	(0.11)	(0.11)	NA	Not included in July 1997 Report.		
Forest Fires	-	0.16	0.16	NA	Not included in July 1997 Report.		
AFOLU (Sources)	0.45	0.98	0.54	119%			
AFOLU (Sinks)	(0.85)	(2.67)	(1.82)	215%			

1990 Hawaii Emissions Comparison by Sector: July 1997 Report vs. Updated Inventory

Categorization of GHG Sources and Sinks Follows the Updated Inventory

Sector/Source	July 1997 Report ($MMTCO_2$ Eq) 1990	Updated Inventory ($MMTCO_2Eq$) 1990	Difference (Updated Estimate - 1997 Report)	% Difference (Updated Estimate - 1997 Report) / 1997 Report	Differences in Categorization	Key Differences in Methods	Key Differences in Data
Total Emissions (Excluding AFOLU Sinks)	**15.79**	**23.13**	**7.34**	**46%**			
Total Net Emissions (Including AFOLU Sinks)	**14.94**	**20.46**	**5.52**	**37%**			

Table Notes:

+ Less than 0.01 $MMTCO_2Eq$; - No emissions occurring/estimated

References to July 1997 Report (note that all emissions in the July 1997 Report are presented in short tons; values presented in the table above from the July 1997 Report have been converted from short tons to $MMTCO_2Eq$):

[1]Page 4-2, Table 4.1; Page 5-3, Table 5.2; Page 5-9, Table 5.6

[2]Page 5-2, Table 5.1; Page 5-8, Table 5.5

[3]Page 7-1, Table 7.1

[4]Page 7-4, Table 7.3

[5]Page 8-2, Table 8.1

[6]Page 9-1, Table 9.1

Discussion of Methodology and Data Sources by Sector

The Updated Inventory estimates for each sector and source for 1990 and 2007 are presented in the sections that follow. Within each section, the methodology and data sources are summarized. In addition, differences between the 1990 estimates calculated in this Updated Inventory versus the 1990 estimates calculated in the July 1997 report are briefly summarized in boxes at the end of each source category discussion.

Energy

A summary of the energy sector emissions appears in Table 6 below.

Table 6. Emissions from the Energy Sector ($MMTCO_2$ Eq)

Source	1990	2007
Residential	0.03	0.05
Commercial	0.38	0.26
Industrial	0.70	0.18
Transportation	13.21	12.58
Ground	3.23	4.47
Marine	1.65	2.16
Aviation	6.80	4.83
Other	1.53	1.13
Electric Power	6.79	8.76
Oil and Gas	+	+
International Bunker Fuels	*1.01*	*1.32*
Total (Excluding International Bunkers)	**21.12**	**21.83**

+ Less than 0.01 $MMTCO_2Eq$

Emissions from the energy sector account for 91 percent and 90 percent of all GHG emissions from Hawaii in 1990 and 2007, respectively. The sources of emissions in the Energy sector were estimated using the following categories: stationary combustion (includes fossil fuels used in the residential, commercial, industrial, and electric power sectors), mobile combustion (includes highway, aviation, marine, and off-highway), military combustion, and fugitive emissions from the oil and gas sector. Emissions from fuels consumed for international travel leaving Hawaii and arriving in a foreign destination were estimated separately and not included in totals.

Most of the emissions from the Energy sector are due to CO_2 emissions from fossil fuel use for transportation and electric power. Transportation sector emissions accounts for 63 percent and 58 percent of energy emissions in 1990 and 2007, respectively. Electric power sector emissions accounts for 32 percent and 40 percent energy emissions in 1990 and 2007, respectively. The remaining 2-5 percent of emissions from the Energy sector are from the industrial, commercial, and residential sectors. A large majority of emissions from the Energy sector occur on Oahu.

Emissions from the consumption of jet fuel and residual fuel account for more than two-thirds of total emissions from the Energy Sector. Residual fuel accounts for 36 percent and 33 percent of emissions in 1990 and 2007, respectively. Jet fuel accounts for 36 percent and 26 percent of emissions in 1990 and 2007, respectively. Motor gasoline accounts for 16 percent and 20 percent in these years, with distillate accounting for 11 percent and 13 percent,

respectively. The remaining 1 percent in 1990 and 8 percent in 2007 are largely due to the combustion of coal and propane. The combustion of biofuels is assumed not to result in net CO_2 emissions, as the carbon in these fuels is sequestered from the atmosphere.

Discussion of Energy Consumption Data

As with most state inventories, energy consumption is by far the largest source of emissions for Hawaii. Further, the methodology for calculating emissions is fairly straightforward and less uncertain compared to other sources of emissions. Thus, fuel consumption data underpins Hawaii GHG estimates, and drives overall emission trends.

Energy emissions were calculated based on 1990 and 2007 fuel consumption in the residential, commercial, transportation, industrial, and military sectors using data from DBEDT Records (2008). This dataset was compiled from a number of data sources and reports of fuel consumption to DBEDT. It includes data from AES; Chevron; Hawaii Department of Taxation; the Energy Information Administration of the U.S. Department of Energy; Gay & Robinson; Hawaiian Commercial & Sugar Company (HC&S); the Petroleum Industry Monitoring, Analysis, and Reporting Program (PIMAR), Hawaiian Electric Company (HECO), Hawaii Electric Light Company (HELCO), Maui Electric Company (MECO), and Kauai Island Utility Cooperative (KIUC). This dataset, referred to as DBEDT Records (2008), was used to estimate consumption data for both 1990 and 2007. This data was compared against multiple data sources and was chosen as the best available estimate for energy consumed in Hawaii for both of these years. This comparison exercise is explained below.

For 2007, consumption data from DBEDT Records (2008) was compared against 2 datasets from the PIMAR program and two datasets from the Energy Information Administration (EIA) of the Department of Energy. The Hawaii Public Utilities Commission (PUC) administers the PIMAR Program to collect and report data on the petroleum markets in Hawaii and provide greater transparency for the public. Specifically, these 4 comparison datasets were:

1. PIMAR (transaction) – Sales data compiled from Form W-130 data.
2. PIMAR (supply) – Estimate of supply compiled from the following PIMAR data: imports (W-110), exports (W-111), inventory (W-120), and production (W-140).
3. EIA (pet nav) – Prime supplier sales data from the EIA petroleum navigator.
4. EIA (SEDS) – Consumption data from the State Energy Data System.

The DBEDT dataset for 2007 was chosen for the following reasons:

- PIMAR data, while helpful to compare against, was not designed to track the amount of consumption, or the sectors where fuels were consumed. PIMAR is also a new system, and is still being refined.
- EIA (pet nav) does not display all fuel sales data, citing confidentiality reasons for some fuel types (such as residual fuel). Additionally, this data is not available by county.
- EIA (SEDS) was only available for 2006. The database provides data summed by sector and fuel type (for example, distillate use in the transportation sector.) Additionally, this data is not available by county.
- DBEDT Records (2008) was compiled from thousands of data points reported to or compiled by DBEDT. Data was reported and compiled by fuel provider, activity, and county. This data has been analyzed internally by DBEDT, and is believed to be the best available estimate of consumption for the State of Hawaii.

For 1990, consumption data being compiled by DBEDT was compared against the fuel consumption estimate in the July 1997 Report and EIA consumption data from the State Energy Data System (EIA SEDS).

The DBEDT dataset for 1990 was selected for the following reasons:

- Detailed fuel consumption data was not available for the July 1997 Report. In addition, the July 1997 Report did not include fuel consumed from Hawaii to the U.S. mainland, Alaska, or U.S. Territories. Due largely to the exclusion of most marine and aviation fuel, fuel consumption in the July 1997 report is much lower than both DBEDT Records and EIA.
- EIA (SEDS) was only available for 2006. It only provides data summed by sector and fuel type (for example, distillate use in the transportation sector.) Additionally, this data is not available by county.
- DBEDT Records (2008) was compiled from thousands of data points reported to or compiled by DBEDT. Data was reported and compiled by fuel provider, activity, and county. This data has been analyzed internally by DBEDT, and is believed to be the best available estimate of consumption for the State of Hawaii.

While this dataset was judged as the best available dataset, further research could more thoroughly verify and improve the fuel consumption estimates.

Stationary fuel combustion by the military is included in the commercial sector, while mobile fuel combustion by the military is included in the transportation sector. Military fuel consumption estimates are also reported separately for informational purposes.

Key Differences in 1990 Total Consumption (from July 1997 Report)

Overall, CO_2 emissions from the Energy sector for the Updated Inventory are 46 percent higher than the estimate in the July 1997 Report, due to the fact that fuel consumption estimates are 43 percent higher. Both the data from the July 1997 Report and the Updated Inventory were provided by DBEDT Records (2008).

Differences in overall consumption estimates by fuel type are presented in Table 7. The differences in overall fuel consumption are driven primarily by the increase in jet fuel reported. Diesel and residual fuel also show large increases.

Table 7. Differences in Total Consumption from July 1997 Report and Updated Inventory (BBtu)

All Sectors	July 1997 Report[1]	Updated Inventory[2]	Difference
Avgas	218	226	8
Coal	527	701	174
Diesel/Distillate	17,697	30,395	12,698
Gasoline	46,622	47,169	547
Jet Fuel	23,089	102,869	79,780
Propane/SNG	6,992	5,978	1,014

Residual	82,408	94,780	12,372
Total Consumption	**177,554**	**282,118**	**104,564**

[1]Data from Table 3.3 of the July 1997 Report. Does not include military fuels and travel outside Hawaii.
[2]Data from DBEDT Records (2008). Does not include international bunker fuels.

A major reason for these differences is that in the July 1997 Report, only in-state transportation fuels were taken into account. In the Updated Inventory, fuel consumed for travel from Hawaii to U.S. destinations was also included. The decision to include this fuel was verified by EPA's State and Local Branch as the correct convention for state inventory reporting (US EPA 2008). (Note that fuel consumed for travel from Hawaii to international destinations were not included, per IPCC guidance.)

Consumption of each fuel was categorized by sector. The sections below report the results of fuel consumed in each sector. While some of the differences between the July 1997 Report and the Updated Inventory are due to differences in total fuel being consumed, some differences may be simply a result of fuel consumption being reclassified in a different sector than the July 1997 report.

Sources and Gases Covered:

- Stationary Combustion (CO_2, CH_4, N_2O)
- Mobile Combustion (CO_2, CH_4, N_2O)
- Military Combustion (CO_2, CH_4, N_2O)
- Oil and Gas: (CH_4)
- International Bunker Fuel Combustion (CO_2, CH_4, N_2O)

Stationary Combustion

Fossil fuel combustion emissions were estimated for the residential, commercial, industrial, and electric power sectors. While data was available for 1990 and 2007 at the county level, these data were not available at the island level. Consumption for Kauai and Maui counties were downscaled to each island by population.

Methodology

The methodology presented in the IPCC 2006 Guidelines was used to estimate emissions from this source category. The methodologies for estimating CO_2 emissions versus CH_4 and N_2O emissions differ, and are presented separately below. Since 1990 and 2007 consumption data was provided by county, fuel consumption was downscaled in Maui and Kauai counties to each island using population data.

Methodology for CO_2 Emissions

CO_2 emissions from stationary combustion were calculated using the IPCC Tier 1 methodology, which uses the following equation:

CO_2 Emissions = Fuel Consumption x Carbon Content Coefficient x Fraction Oxidized

The heat contents and carbon content coefficients for estimating CO_2 emissions were specific to each fuel type and relied on data provided by EIA, the U.S. Inventory, and IPCC 2006 Guidelines. Oxidation fractions were also updated according to IPCC 2006 Guidelines.

Methodology for Estimating CH_4 and N_2O Emissions

CH_4 and N_2O emissions from stationary combustion were calculated using the IPCC Tier 1 methodology, which uses the following equation:

Emissions = Fuel Consumption x Fuel Emission Factor

CH_4 and N_2O emission factors were applied for the residential, commercial, industrial, and electric power sectors using emission factors provided by the IPCC 2006 Guidelines.

Data

Fuel consumption data for both 1990 and 2007 were largely provided by DBEDT Records (2008) for stationary combustion, which included consumption by fuel type, by county. The 1990 data was categorized into residential, commercial, industrial, transportation, military, and electric power sectors based on the consumption activity, and the sector specified in the consumption data on the recommended categorization. Definitions for each sector were based on EIA sector definitions.

Key Differences in 1990 Residential Consumption/Emissions (from July 1997 Report)

Residential CO_2 emissions in 1990 for the Updated Inventory are 64 percent lower than the estimate in the July 1997 Report, due to the fact that fuel consumption estimates are 67 percent lower.

The updated residential consumption estimates are shown in Table 8. This drop is due changes in reported propane and SNG consumption. This may be area of further research.

Table 8. Differences in Residential Consumption from July 1997 Report and Updated Inventory (BBtu)

Residential	July 1997 Report[1]	Updated Inventory[2]
Propane/SNG	1,474	490

[1]Data from Table 3.3 of the July 1997 Report.
[2]Data from DBEDT Records (2008).

Key Differences in 1990 Commercial Consumption/Emissions (from July 1997 Report)

Commercial CO_2 emissions in 1990 for the Updated Inventory are 49 percent higher than the estimate in the July 1997 Report, due largely to the fact that fuel consumption estimates are 31 percent higher.

The updated commercial consumption estimates varied by fuel type as shown in Table 9. Consumption of all fuel types are higher.

Table 9. Differences in Commercial Consumption from July 1997 Report and Updated Inventory (BBtu)

Commercial	July 1997 Report[1]	Updated Inventory[2]
Distillate	61	274

Propane/SNG	4,418	5,159
Residual	19	73
Gasoline	0	412
Total	**4,499**	**5,874**

[1]Data from Table 3.3 of the July 1997 Report.
[2]Data from DBEDT Records (2008).

Key Differences in 1990 Industrial Consumption/Emissions (from July 1997 Report)

Industrial CO_2 emissions for the Updated Inventory are 19 percent lower than the estimate in the July 1997 Report, due largely to the fact that fuel consumption estimates are 14 percent lower.

The updated industrial consumption estimates varied by fuel type as shown in Table 10. Coal and gasoline were reported higher, residual was reported lower, and distillate fuel and propane was no longer reported as being consumed in the industrial sector in the updated DBEDT data.

Table 10. Differences in Industrial Consumption from July 1997 Report and Updated Inventory (BBtu)

Industrial	**July 1997 Report[1]**	**Updated Inventory[2]**
Coal	527	701
Distillate/Diesel	3,353	3,759
Gasoline	180	404
Propane	1,020	0
Residual	5,328	4,130
Total	**10,407**	**8,993**

[1]Data from Table 3.3 of the July 1997 Report.
[2]Data from DBEDT Records (2008).

Key Differences in 1990 Electric Power Consumption/Emissions (from July 1997 Report)

Excluding landfill methane and MSW combustion, which are now reported in the Waste sector, electric power consumption and resulting CO_2 emissions in 1990 are relatively similar compared with the July 1997 Report.[8] Energy consumption in the electric power sector remained the same, while emissions decreased 2 percent as a result of updated carbon content coefficients.

The updated electric power consumption estimates varied by fuel type as shown in Table 11. The distillate and residual fuel consumption estimates in the Updated Inventory matched the July 1997 Report estimates.

[8] Methane and MSW combustion were reported in this sector in the July 1997 Report, as shown in Table 3.3 of the July 1997 Report.

Table 11. Differences in Electric Power Consumption from July 1997 Report and Updated Inventory (BBtu)

Electric Power	July 1997 Report[1]	Updated Inventory[2]
Distillate	9,712	9,712
Residual	77,019	77,019
Total	**86,731**	**86,731**

[1]Data from Table 3.3 of the July 1997 Report.
[2]Data from DBEDT Records (2008).

Mobile Combustion

Emissions from mobile combustion result from highway and non-highway (i.e., off-road) vehicles. Over 98 percent of emissions from mobile combustion are CO_2, while the remainder is CH_4 and N_2O. While estimating CO_2 emissions is straightforward, estimating CH_4 and N_2O emissions is more complex because of variations in the engine type. In addition, highway versus non-highway fuel consumption was not disaggregated in fuel consumption estimates obtained for this sector, and as a result off-road consumption was apportioned to calculate CH_4 and N_2O emissions. Mobile fuel combustion by the military is also included in the mobile combustion sector in the final emission estimates.

Methodology

IPCC methodologies, specifically the steps presented in the U.S. Inventory, were used to estimate emissions from highway vehicle combustion. The methodologies for estimating CO_2 emissions versus CH_4 and N_2O emissions differ, so they are presented separately below.

Methodology for CO_2 Emissions from Highway Vehicles

Since CO_2 emissions from highway vehicle combustion are not dependent on the vehicle type and model year, emissions were estimated using the following equation:

CO_2 Emissions = Highway Vehicle Fuel Consumption (by fuel type) x Carbon Content Coefficient x Fraction Oxidized

Methodology for Estimating CH_4 and N_2O Emissions from Highway Vehicles

Estimating CH_4 and N_2O emissions from highway vehicles is more complex because emissions are dependent on numerous factors, such as engine type and emissions control technology. The following steps were used for estimating CH_4 and N_2O emissions from highway vehicles:

1) Determined vehicle miles traveled by vehicle type, fuel type, and model year,
2) Allocated vehicle miles traveled (VMT) data to control technology type,
3) Applied CH_4 and N_2O emission factors by vehicle, fuel, and control technology type to estimate emissions

Methodology for Estimating CO_2, CH_4, and N_2O Emissions from Off-Road Vehicles

Emissions of CO_2 from off-road mobile sources were calculated by applying the carbon content coefficient and fraction oxidized for each fuel type. Off-road consumption was calculated by determining the ratio of off-road gasoline and diesel fuel consumed compared to highway vehicle consumption. Using this fuel consumption amount, CH_4 and N_2O emissions were calculated from off-road mobile sources using U.S. default emission factors in the IPCC 1996 Guidelines.

Data

DBEDT Records (2008) provided 1990 and 2007 fuel consumption data for mobile combustion, which included consumption by fuel type, by county. The 1990 and 2007 data were categorized into the transportation sector based on the consumption activity, and the sector specified in the consumption data on the recommended categorization. The definition for the transportation sector was based on EIA sector definitions.

Fuel consumed for international transport was then subtracted from the fuel consumption totals, as emissions from these fuels are not counted in Hawaii totals. See the section on International Bunker fuels for a description of how this data was obtained.
The Hawaii Department of Transportation provided vehicle miles traveled (VMT) estimates by vehicle type, by county for 1990 and 2007 (Hawaii DOT 2008). These estimates of VMT by vehicle type were used to develop the CH_4 and N_2O emission estimates for highway vehicles.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

The differences between the revised estimates of consumption and CO_2 emissions and the estimates from the July 1997 Report are larger in the transportation sector than in any other sector. CO_2 emissions from transportation are 126 percent higher in the Updated Inventory than in the July 1997 Inventory due to an increase in consumption of about the same magnitude (104 percent).

The updated transportation consumption estimates varied by fuel type as shown in Table 12. Dramatic increases in the amount of jet fuel, residual fuel, and diesel fuel are the main reason for these differences. Most of this consumption was simply not reported in the July 1997 report, due to the fact that DBEDT received guidance from U.S. EPA not to include travel from the Hawaii to the mainland, Alaska, or U.S. territories. This guidance from the EPA was cited on page 5-5 in Section 5.2.1.4 of the July 1997 Report. Updated estimates reflect current EPA guidance on this issue, which states that emissions should be counted in the inventory of the State from where marine and aviation travel originate.

Table 12. Differences in Transportation Consumption from July 1997 Report and Updated Inventory (BBtu)

Transportation	July 1997 Report[1]	Updated Inventory[2]
Avgas	218	226
Diesel	4,571	16,650
Gasoline	46,442	46,353
Jet Fuel	23,089	102,869
Propane	80	329
Residual	43	13,559
Total	**74,443**	**179,987**

[1]Data from Table 3.3 of the July 1997 Report. Does not include military fuels and travel outside Hawaii.
[2]Data from DBEDT Records (2008). Does not include international bunker fuels.

Military Combustion

Military combustion emissions in 1990 and 2007 were estimated for: (1) residual fuel consumed for electricity generation; (2) aviation gasoline and jet fuel consumed for military aviation, distillate, gasoline; (3) residual fuel consumed for military marine; and (4) distillate and gasoline fuel consumed in military vehicles. The emissions for electricity generation from the military were a direct result of the combustion of residual fuel. These emission estimates are included in the commercial sector. Gasoline and residual fuel consumption data were not available for 2007.

In the Updated Inventory, the stationary and mobile emissions were calculated separately, and the residual fuel consumed for electricity generation was aggregated into the draft commercial estimates, while the remaining fuels consumed by the military were aggregated into the transportation sector estimates.

Table 13 below shows total emissions from the military by fuel type.

Table 13. Emissions from Military Fuel Combustion ($MMTCO_2$)

Fuel Type	1990	2007
Diesel Fuel Oil	0.36	0.39
Gasoline	0.34	-
Jet Fuel	0.62	0.62
Propane	0.00	0.01
Residual Fuel Oil	0.06	-
TOTAL	**1.38**	**1.02**

Note: Gasoline and residual fuel consumption data were not available for 2007.

Methodology

The same methodologies described in the sections above were used to estimate emissions from combustion of military fuels.

Data

DBEDT Records (2008) provided 1990 and 2007 fuel consumption data for military combustion, which included stationary and mobile consumption by fuel type, by county.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Military emission estimates are not included in the July 1997 Report totals. Emission estimates for the military in the Updated Inventory are included in the commercial and transportation sectors.

International Bunker Fuel Combustion

International bunker fuels are defined for Hawaii as marine and aviation travel originating in Hawaii and ending in a foreign country.[9] IPCC 2006 Guidelines were followed by estimating emissions from bunker fuels, and reporting bunker fuel estimates separately from totals. Fuel consumption data was available for marine bunker fuels in Honolulu from the U.S. Department of Commerce (US DOC 2007). Consumption of aviation international bunker fuel was calculated

[9] Travel originating in a foreign county and ending in Hawaii is not estimated or included, per IPCC convention.

based on data international and domestic flight data from the Bureau of Transportation Transtats Database (US BTS 2007).

Methodology

The methodology for estimating emissions from marine international bunker fuels was the same as described above.

For aviation bunker fuels, miles traveled by aircraft for domestic and international destinations were calculated. The Bureau of Transportation Transtats Database provided the miles traveled by aircraft for domestic versus international flights. This estimate of domestic versus international flights was converted into a percentage for both 1990 and 2007. This percentage was applied to consumption estimates to determine the amount of fuel consumed for international flights. The fuel consumption was determined by multiplying the international percentage by the jet fuel consumed in the transportation sector on Maui, Oahu, and Hawaii.

Data

Data for marine international bunker fuels was obtained from the Department of Commerce, which provided the amount of diesel and residual fuel consumed in marine vessels leaving Honolulu with an international destination for 2006. For 1990, only the total United States marine bunker fuel consumption was available. Hawaii's portion of the 1990 U.S. consumption was calculated by assuming Hawaii represented the same proportion of the total U.S. consumption as 2006.

The Bureau of Transportation Statistics Transtats database was used to obtain domestic and international flight mileage for aviation bunkers.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

International Bunker emission estimates for aviation and marine fuels were not included in the July 1997 Report for the energy sector.

Since the July 1997 Report, data for flights with an international destination and domestic flights from Hawaii were obtained, as well as international bunker fuels for marine operations. Both aviation and marine bunker fuel emissions were estimated in the Updated Inventory, but not reported in state totals.

Oil and Gas Operations

The most emissive activities from this source include oil and gas transportation, distribution, and refinery operations. Since the release of the July 1997 Report, a significant amount of research has been conducted on the emissions resulting from these systems for the U.S. Inventory and for EPA's State Inventory Tool. Using emission factors and information resulting from this research, the estimates of this source were improved for the Updated Inventory.

Methodology

The methodology and emission factors presented in the U.S. Inventory and EPA's State Inventory Tool were used to estimate CH_4 emissions from Oil and Gas operations. This methodology is based on various EPA reports[10] and includes the following steps:

[10] *Estimates of Methane Emissions from the U.S. Oil Industry (Draft Report).* Prepared by ICF-Kaiser, Office of Air and Radiation, U.S. Environmental Protection Agency. October 1999.

1) Determine the oil and gas operations that occur on each island,
2) Determine the activity levels for each year (i.e., the levels of production, transportation, refining and distribution), and
3) Estimate emissions for the production, transportation, refining and distribution for each year.

Data

Data on the amount of crude oil refined was obtained from DBEDT Records (2008) for both 1990 and 2007 estimates in Oahu. It was also assumed that products were transported by either ships or trucks.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

In the July 1997 Report, fugitive CH_4 emissions from Oil and Gas operations were included in the industrial processes sector. To maintain consistency with the U.S. Inventory and the IPCC 2006 Guidelines, Oil and Gas emissions were moved to the energy sector.

In addition, in the July 1997 Report, emissions from SNG processing were submitted to DBEDT by the BHP Gas Company. Estimates of the amount of SNG processed were not readily available for this Updated Inventory. This is an area of further research as DBEDT Records (2008) does not indicate the amount of SNG processed.

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Industrial Processes

A summary of the industrial processes sector emissions appears in Table 14 below.

Table 14. Emissions from the Industrial Processes Sector ($MMTCO_2$ Eq)

Source	1990	2007
Cement Manufacture	0.10	-
Electricity T&D	0.08	0.04
Substitutes of ODS	-	0.50
Total	**0.18**	**0.54**

- No emissions occurring/estimated

Sources and Gases Covered:

- Cement Manufacture (CO_2)
- Electricity Transmission and Distribution (SF_6)
- Substitution of Ozone Depleting Substances (HFCs, PFCs)

Cement Manufacture

Methodology

CO_2 emissions are released as a by-product of the clinker production process, an intermediate product used primarily to make portland cement. Process-related CO_2 emissions from cement production are estimated using IPCC (2006) Tier 2 methodology, using plant-specific clinker production and default factors for calcium oxide content and cement kiln dust. Emissions are calculated using the following equation:

$$CO_2 \text{ Emissions} = Mcl \bullet EFcl \bullet CFckd$$

Where:
Mcl = weight (mass) of clinker produced, tonnes
EFcl = emission factor for clinker, 0.51 tonnes CO_2/tonne clinker
CFckd = emissions correction factor for cement kiln dust, 1.02

Data

The activity data required to calculate CO_2 emissions from cement production is the quantity of clinker produced. Clinker production data and other information pertinent to the Hawaiian cement industry were provided by Hawaiian Cement. Clinker production ceased in 1996, thus no emissions are estimated for 2007 (Wurlitzer 2008).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

The Updated Inventory estimates the emissions associated with cement kiln dust (CKD) produced during clinker manufacture, which increases the cement manufacture estimate by 2 percent. In addition, the Updated Inventory does not estimate emissions from masonry cement production (which was estimated in the July 1997 Report).[11] As per IPCC 2006 methodology, no emissions are associated with the production of masonry cement. Thus, the Updated

[11] Pg 7-1 of the July 1997 Report. Chapter 7: Greenhouse Gas Emissions from Industrial Processes.

Inventory does not estimate emissions from this component. Hawaiian Cement produced masonry cement through 2003 by adding ground limestone to portland cement, and more recently by adding imported flyash. Producing cement using these methods does not result in process-related CO_2 emissions. Any energy-related emissions associated with these activities are captured in the energy sector of this inventory.

These changes resulted in an increase in 1990 CO_2 emissions from cement manufacture of less than 0.01 $MMTCO_2$ (2 percent) relative to the July 1997 Report.

Electrical Transmission and Distribution

Methodology

SF_6 emissions from electrical transmission and distribution (ET&D) systems result from leaks in transmission equipment. Direct estimates are not available because Hawaiian utilities do not report SF_6 purchases or emissions. Emissions are calculated by apportioning U.S. emissions from this source to the island level based on the ratio of island electricity sales to U.S. electricity sales. The apportionment method chosen for HI is consistent with the California Energy Commission's approach for California.

Data

1990 through 2006 U.S. SF_6 emissions data used to estimate emissions in 1990 and 2007 are from the *U.S. Inventory of Greenhouse Gas Emissions and Sinks* (EPA 2008). U.S. electricity sales data come from the U.S. Department of Energy, Energy Information Administration (EIA 2007). Hawaii island-level electricity sales data come from the State of Hawaii Data Book (DBEDT 1990; 2007).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

SF_6 emissions from ET&D were not included in the July 1997 Report. [12]

Substitution of Ozone Depleting Substances

Substitutes of ozone depleting substances (ODSs) include hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs), which serve as alternatives to ODSs being phased out under the Montreal Protocol. HFCs and PFCs are potent greenhouse gasses. Nationally, emissions from ODS substitutes have risen dramatically since 1990, and now constitute one of the largest industrial sources of GHG emissions. The chemicals that these substances replace—ozone depleting substances (ODSs)—are a family of man-made compounds that includes chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs). These compounds have been shown to deplete stratospheric ozone, and therefore are typically referred to as ODSs. ODSs are regulated under the Montreal Protocol; while they also are greenhouse gases, they are not included in greenhouse gas inventories, per IPCC and EPA guidance.

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

[12] Pg 7-1 of the July 1997 Report. Chapter 7: Greenhouse Gas Emissions from Industrial Processes.

occur from thousands of types of equipment from millions of sources, including refrigeration and air-conditioning units, aerosols, and solvents.

On the national level, these emissions are estimated using a complex "Vintaging Model", which tracks the use characteristics of equipment currently in use for more than 50 different end-use categories, and applies HFC and PFC leak rates to estimate annual emissions.

Hawaii island-level estimates are calculated for the following sub-categories:

- Car and truck air-conditioning
- Other refrigeration and air-conditioning
- Aerosols
- Foams
- Solvents
- Fire extinguishing

HFC and PFC emissions from car and truck air-conditioning systems are estimated by apportioning national emissions to the island level based on the ratio of island vehicle registrations to U.S. vehicle registrations. For the remaining sub-categories, national emissions are apportioned to the island level based on the ratio of de facto island population to U.S. population.

Data

U.S. emissions data were obtained from the *U.S. Inventory of Greenhouse Gas Emissions and Sinks* (EPA 2008). U.S. population numbers were obtained from the U.S. Census Bureau (2007). U.S. vehicle registration data were obtained from the U.S. Department of Transportation, Federal Highway Administration (FHWA 2007). Hawaii vehicle registration data were obtained from the State of Hawaii Data Book (DBEDT 1990; 2007).

Hawaii de facto population numbers by island were developed using data from Department of Business, Economic Development and Tourism (DBEDT). De facto population per island statistics are only available for the years 1990 and 2000. However, state total de facto population and resident population is available for years 1960-2006 (State of Hawaii 2007). To determine the historical de facto population per island the total state difference between de facto and resident population was allocated to each island. This state difference percentage per island was calculated from year 1990 data for each island and used to historically calculate de facto population statistics for each island back to 1960. De facto population statistics per island for years 2000 through 2006 were calculated using the state difference percentage per island from year 2000 data.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

HFC and PFC emissions from the substitution of ozone depleting substances were not included in the July 1997 Report.[13] This source category is included in the Updated Inventory; however, 1990 emissions from this source are negligible because HFCs and PFCs as substitutes to ODS were not widely used until 1992. Thus, there is effectively no difference in 1990 emissions from this source in the current estimate relative to the July 1997 Report.

[13] Page 2-1. July 1997 Report. Chapter 2: 1990 Hawaii Greenhouse Gas Emissions.

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Waste

A summary of the waste sector emissions appears in Table 15 below.

Table 15. Emissions from the Waste Sector ($MMTCO_2$ Eq)

Source	1990	2007
Municipal Solid Waste - Landfills	0.54	0.77
Municipal Solid Waste - Combustion	0.18	0.15
Wastewater	0.13	0.15
Total	**0.85**	**1.07**

Sources and Gases Covered:

- CH_4 from Municipal Solid Waste Landfills
- CO_2 and N_2O from Municipal Solid Waste Combustion
- CH_4 and N_2O from Municipal Wastewater

Municipal Solid Waste Landfills

Methodology

Correspondence with the Solid and Hazardous Waste Branch (SHWB) at the Department of Health (DOH) indicated that volume and density information on individual landfills was not available (Ichinotsubo 2008). According to the IPCC Guidelines, waste disposal may be estimated from population and per-capita waste disposal rates if individual landfill waste characteristics are uncertain or unknown (IPCC 2006). Thus, landfill methane emissions estimates were developed using information on waste disposal per capita which was used to calculate waste in place (WIP) for each island in Hawaii.

De facto population per island statistics are only available for the years 1990 and 2000. However, state total de facto population and resident population is available for years 1960-2006 (State of Hawaii 2007). To determine the historical de facto population per island the total state difference between de facto and resident population was allocated to each island. This

state difference percentage per island was calculated from year 1990 data for each island and used to historically calculate de facto population statistics for each island back to 1960. De facto population statistics per island for years 2000 through 2006 were calculated using the state difference percentage per island from year 2000 data.

Waste disposal data per island from 1994 to 2006 were obtained. The one exception is the island of Niihau, which does not have a landfill facility and was assumed to dispose of waste on its neighboring island Kauai.

The calculated potential emissions were adjusted by taking into account landfill gas flaring, oxidation in the landfill soil layer, and landfill gas recovery systems in place on some of Hawaii's landfills (Hihara 2008).

A soil oxidation factor of 10 percent for all landfill generated methane was assumed to account for the amount of landfill methane oxidized by landfill covers at municipal landfills (U.S. EPA 2008). This amount was subtracted from the total potential methane emissions that were calculated as described above.

In addition to methane not emitted through oxidation, additional methane was diverted from the atmosphere through landfill gas flaring at a number of landfills. For the Olowalu, Makani, and Halehaka landfills, data from the July 1997 Report[14] on the actual amount of WIP in 1990 was used, since the data on actual flared methane was not available (Hihara 2008). The percentage of the islands' total WIP represented by each of these landfills was calculated. This percentage was multiplied by the previously calculated total methane emissions for the island to estimate the quantity of methane released by each landfill that flared methane in 1990. Finally, a landfill gas collection efficiency of 75 percent was assumed (U.S. EPA 1993). This yielded a total amount of methane flared which was subtracted from the total potential methane emissions that were calculated in 1990 as described above.

Data were obtained on the amount of landfill gas that was recovered for energy at Kapaa Landfill on Oahu in 1990 (Serikaku 2008). Landfill gas recovery was converted into a quantity of methane recovered assuming a 50 percent methane composition of landfill gas (U.S. EPA 2008). Again, this total amount of methane recovered was subtracted from the potential methane emissions in 1990 calculated as described above.

Data were obtained on the flow rate of landfill gas collected and flared at Waimanalo Gulch landfill by the Clean Air Branch of DOH in 2007 (Hihara 2008). This flow rate was converted into a yearly quantity of methane collected, again assuming a 50 percent methane composition of landfill gas (U.S. EPA 2008). Again, this total amount of methane recovered was subtracted from the potential methane emissions calculated in 2007 as described above.

Data

Waste disposal data submitted by SHWB was representative of fiscal year data from 1994 – 2007 (Otsu 2008). The state's fiscal year begins on July 1 and ends June 30. This data excludes construction and demolition (C&D) waste and is representative of each island's Municipal Solid Waste (MSW) disposal. For years prior to 1994, data from the State Inventory Tool (which uses data from BioCycle and the U.S. Census Bureau) was used to historically back cast based on weighted de facto population for each island. Using this waste disposal data, the First Order

[14] Page 8-5. July 1997 Report. Chapter 8: Greenhouse Gas Emissions from Municipal Waste Management.

Decay approach presented in Environmental Protection Agency's (EPA) AP-42 guidance was applied and implemented in the U.S. Inventory and EPA's State Inventory Tool to calculate methane generation potential per island from landfills (EPA 2008).

In order to account for landfill methane that is flared or recovered for energy, data from the July 1997 Report[15] and correspondence with the Honolulu County Refuse Division were used (Serikaku 2008). For 2006, landfill gas flow rates were obtained from the Clean Air Branch at DOH for the Waimanalo Gulch Landfill on Oahu, which is the only landfill that currently has a landfill gas collection system with measured flow rates. The Central Maui Landfill on Maui recently installed a landfill gas collection system but it has yet to perform a performance test; thus information regarding its landfill gas flow rates is unavailable (Hihara 2008).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Total emissions from landfills were estimated in 1990 to be 0.54 million metric tons of carbon dioxide equivalents ($MMTCO_2Eq$), which is 55 percent lower than the estimate reported in the July 1997 Report.[16]

There are four main reasons for the large change in estimated emissions from landfills.

- An updated methodology was used which incorporates the First Order Decay method per the IPCC 2006 Guidelines. This method produces more accurate estimates of annual emissions from landfills, whereas the July 1997 Report relied on a now obsolete methodology for calculating emissions from landfills.[17]
- The emissions estimates from landfills in the revised report use island-specific waste disposal information which was used to calculate total WIP for each island. In contrast, the July 1997 Report used Oahu-specific waste generation per capita values as a proxy for the entire state and applied a default value for the percentage of waste landfilled.[18]
- The July 1997 Report applied average waste generation numbers from 1980-1990 to backcast WIP values to 1960, likely overestimating historical WIP in Hawaii since waste generation per capita in Hawaii generally increases with time.[19]
- The July 1997 Report included CO_2 emissions from landfills which, according to IPCC guidelines, are considered biogenic and should not be counted in an inventory.[20]

Municipal Solid Waste (MSW) Combustion

Methodology

In 1990, MSW was combusted at two facilities. At the H-POWER plant, waste was burned to generate electricity, while the Waipahu Incinerator burned waste simply as a waste management strategy. Emissions were calculated for each facility using two different methods because of the differing levels of data obtained for each facility.

For the Waipahu Incinerator, emissions were calculated associated with the combustion of plastic and synthetic materials in the MSW waste stream using the IPCC methodology. This approach uses waste composition data (i.e., the percent of plastics and synthetic materials) and

[15] Page 8-10. Ibid.
[16] Page 8-2. July 1997 Report. Chapter 8: Greenhouse Gas Emissions from Municipal Waste Management.
[17] Page 8-6. Ibid.
[18] Pages 8-6 to 8-7. Ibid.
[19] Page 8-7. Ibid.
[20] Page 8-2. Ibid.

their respective carbon content to determine the anthropogenic emissions from the combustion of these materials. This facility closed in the early 1990s, and thus no longer generates emissions.

For the H-POWER plant, emissions were calculated using a newly-developed methodology that is currently used in the California Air Resources Board (CARB) Mandatory Greenhouse Gas Emissions Reporting guidelines. This approach utilizes facility-specific steam output data to estimate emissions from the combustion of refuse-derived fuel (RDF) which is processed from MSW. 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.

Data

Data were obtained on the amount of MSW combusted at Waipahu in 1990 from the Honolulu County Refuse Division (Serikaku 2008). Waste composition data in Hawaii, specifically the amount of plastics, synthetic rubber and synthetic fibers in MSW, was assumed to be representative of the national average as described in the U.S. Inventory.

Facility-specific information for the H-POWER plant was obtained directly from Covanta Energy, which operates H-POWER. This data included steam generation, RDF combustion, biogenic carbon ratios and fuel consumption data (Hahn 2008).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Total emissions from waste combustion in 1990 were estimated to be 0.18 $MMTCO_2Eq$, which is more than 4 times larger than the estimate in the July 1997 Report.[21] This difference is largely due to the fact that emissions from waste to energy plants are accounted for in the Waste sector in the Updated Inventory, as opposed to the Energy sector. When comparing emissions from all MSW combustion, the updated emissions estimate is actually 31 percent lower than the July 1997 Report.

There are two main reasons for the decrease in estimates of emissions from waste combustion for 1990 in the Updated Inventory:

(1) For Waipahu, a more accurate methodology based on waste composition data is used to calculate emissions from MSW combustion. This revised methodology differs from the estimate compiled in the July 1997 Report which only looked at the assumed carbon content of the entire MSW stream, rather than specific proportion of materials within the MSW stream.[22]

(2) The revised CARB methodology that is used to calculate emissions from H-POWER is also more accurate in that emissions are being calculated from raw facility operation data including steam output and carbon isotope measurements.

[21] Page 8-2. July 1997 Report. Chapter 8: Greenhouse Gas Emissions from Municipal Waste Management.
[22] Pages 8-6 to 8-7. Ibid.

Municipal Wastewater

Methodology

Estimates have been developed of emissions from wastewater based on IPCC 2006 Guidelines methodology. CH_4 emissions and direct and effluent N_2O emissions from municipal wastewater were calculated.

Data

De facto population data was based on information in the State of Hawaii Databook and calculated as previously described in the Municipal Solid Waste Landfills section. A Biochemical Oxygen Demand (BOD) generation rate factor specific to Hawaii was used, which was provided by DOH and used in the July 1997 Report[23] and originally came from DOH. Updated statistics on total BOD loading were requested from the Wastewater and Clean Water Branches at DOH, but this data was ultimately not available (Teruya 2008).

Data on the number of households per island that are using septic tanks for their wastewater were obtained from the Wastewater Branch at DOH and used in calculations (Pruder 2008). The number of households not using septic tanks is based on the total number of households per island (U.S. Census Bureau 2006 and U.S. Census Bureau 1990).

Other parameters used to calculate emissions from wastewater, including the percentage of wastewater treated anaerobically, were assumed to be the same as those used in the U.S. Inventory.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Total emissions were estimated from municipal wastewater to be 0.13 $MMTCO_2Eq$, which is more than 5 times greater than the estimate in the July 1997 Report.[24] There are two main reasons behind this difference.

N_2O emissions are estimated from wastewater in the Updated Inventory, but were not estimated in the July 1997 Report.[25]

An updated emission factor from the IPCC 2006 Guidelines for the amount of CH_4 emitted per pound of BOD treated is used, which significantly increases the emission estimates.

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[23] Page 8-13. July 1997 Report. Chapter 8: Greenhouse Gas Emissions from Municipal Waste Management.
[24] Page 8-1. July 1997 Report. Chapter 8: Greenhouse Gas Emissions from Municipal Waste Management.
[25] Ibid.

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Agriculture, Forestry, and Other Land Uses (AFOLU)

A summary of the AFOLU sector emissions appears in Table 16 below.

Table 16. Emissions from the Agriculture, Forestry and Other Land Use (AFOLU) Sector ($MMTCO_2$ Eq)

Source/Sink	1990	2007
Enteric Fermentation	0.27	0.25
Manure Management	0.12	0.05
Agricultural Soil Management	0.19	0.17
Field Burning of Agricultural Residues	0.03	0.01
Urea Application	+	+
Agricultural Soil C	0.22	0.24
Landfilled Yard Trimmings and Food Scraps	(0.11)	(0.03)
Urban Trees	(0.11)	(0.13)
Forest C	(2.45)	(2.59)
Forest Fires	0.16	0.12
Total (Sources)	**0.98**	**0.83**
Total (Sinks)	***(2.67)***	***(2.75)***

+ Less than 0.01 $MMTCO_2Eq$
Note: Parentheses indicate negative values or net sequestration.

Sources and Gases Covered:

- Enteric fermentation (CH_4)
  - *Dairy and beef cattle, sheep, goats, swine, horses*
- Manure management (CH_4, N_2O)
  - *Dairy and beef cattle, sheep, goats, swine, horses, chickens*
- Agricultural soil management (N_2O)
  - *Synthetic fertilizer, organic fertilizer, manure N, and crop residue inputs*
- Field burning of agricultural residues (CH_4, N_2O)
  - *Sugarcane*
- Urea application (CO_2)
- Agricultural soil management (CO_2)
- Landfilled yard trimmings and food scraps (CO_2)
- Carbon flux in urban trees (CO_2)
- Carbon flux in forests (CO_2)
- Forest fires (CO_2, CH_4, N_2O)

Information about specific sources is outlined below.

Enteric Fermentation (CH_4)

Methodology

The IPCC (2006) Tier 1 methodology was used, which consists of multiplying an animal's population by an emission factor.

Data

Animal population data are the primary data needed to estimate emissions from enteric fermentation, manure management, and manure nitrogen (N) additions to agricultural soils. Animal population data were obtained from the U.S. Department of Agriculture's (USDA) National Agriculture Statistics Service (NASS), which was identified by the Hawaii Department of Agriculture as the best source of this data (USDA 2008a,b,c). NASS had annual population data by county for cattle and swine. Population data by county for Hawaii for 1987, 1992, 1997, and 2002 were obtained for sheep, goats, and horses from the USDA Census of Agriculture, taken every five years (the 2007 Census is not yet available) (USDA 2004, 2002). Data for the available years were interpolated and extrapolated in order to estimate populations for the years 1990 and 2007.

It was necessary to downscale county data to the island level for two counties, Kauai and Maui. In order to determine the distribution of animal populations on the islands of Kauai, Lanai, Maui, Molokai, and Niihau, agricultural area data by land-use type were obtained from a GIS dataset available from DBEDT, the Agricultural Land Use Maps (ALUM 2008). The ALUM dataset has areas of various agricultural land uses for all islands except Niihau. The dataset was based on data collected in 1978-1980, the same relative percentages of various land use types were assumed for 1990 and 2007.

Estimates of animal population were obtained for beef cattle, sheep, goats, and swine for the islands of Lanai, Molokai, and Niihau via personal communication with the Hawaii Department of Agriculture (HDOA 2008). HDOA (2008) was the only information source for livestock on Niihau, and as a consequence the island was assumed to have only beef cattle and sheep livestock. For other islands, ALUM (2008) data were used to estimate livestock populations, based on the relative percentage of areas of specific types of animal operation (e.g., hog farming) on the islands.

Yearly emission factors were used for the several cattle types (U.S. EPA 2007, 2008) available for the "West" region from 1990 through 2005. 2005 cattle emission factors were used for 2007. Emission factors for bulls, sheep, goats, horses, and swine were obtained from the U.S. Inventory (U.S. EPA 2008).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Estimates from the Updated Inventory were slightly higher for 1990 than estimated in the July 1997 Report.[26] The Updated Inventory uses an identical method and similar emission factors to calculate emissions. However, the Updated Inventory includes additional animal types (goats and horses), which accounts for the difference.

Manure Management (CH_4, N_2O)

Methodology

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

[26] Page 2-1. July 1997 Report. Chapter 2: 1990 Hawaii Greenhouse Gas Emissions.

CH_4 emissions = animal population × typical animal mass × volatile solids excretion per kilogram animal mass × maximum potential emissions × weighted methane conversion factor

N_2O emissions = [∑ (for each waste management system) typical animal mass × N excretion per kg animal mass per day × 365 × (1 - percent N volatilized) × % of manure managed in that system × EF for that system] × conversion from N_2O-N to N_2O

Data

Animal population data were obtained and distributed as described in the Enteric Fermentation section, with the addition of chickens. Annual chicken population data by county were available from USDA (2008d). All factors were obtained from the U.S. Inventory (U.S. EPA 2008), except for weighted methane conversion factors (MCFs), which were taken from U.S. EPA (2007), and originally based on the U.S. Inventory. Weighted MCFs take into account the percent of manure for each animal type managed in different waste management systems (WMS). Hawaii-specific values were available for weighted MCFs and distribution of waste by animal in different WMS. Regional data ("West") were available for volatile solids excretion rates, from U.S. EPA (2007, 2008).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Methane emissions for 1990 from manure management were about 18 percent lower in the Updated Inventory compared with the July 1997 Report.[27] There were several changes in the estimation methodology, including the addition of goats and horses in the updated report, and also the inclusion of more cattle subtypes, more specific emission factors, and a different assumed distribution of manure among manure management system types in the Updated Inventory. N_2O emissions from manure management were not included in the July 1997 Report.[28]

Agricultural Soil Management (N_2O)

Methodology

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

N_2O emissions = direct N_2O emissions + indirect N_2O emissions

Within that overall equation, we used the following equations to calculate direct emissions:

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

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_{PRP1} = N inputs to agricultural soils from pasture, range, and paddock manure from cattle, swine, and poultry

[27] Ibid.
[28] Page 9-1. July 1997 Report. Chapter 9: Greenhouse Gas Emissions from Agricultural Activities.

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 (0.01 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 (0.02 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 (0.01 kg N_2O-N/kg N input)
44/28 = conversion from N_2O-N to N_2O

N inputs to agricultural soils from crop residues = above-ground residue dry matter × crop area × [N content of aboveground residues + ratio of belowground residues to harvested yield for crop × N content of belowground residues]

where,

Above-ground residue dry matter =Fresh weight yield (kg fresh weight harvested/ha) × dry matter fraction of harvested crop × slope + intercept

We used the following equations to calculate indirect emissions:

Indirect N_2O emissions = indirect emissions from volatilization + indirect emissions from leaching/runoff

$$\textit{Indirect emissions from volatilization} = [(N_F \times L_{vol\text{-}F}) + (N_O \times L_{vol\text{-}O}) + (N_{PRP} \times L_{vol\text{-}O})] \times EF_{vol} \times 44/28$$

$$\textit{Indirect emissions from leaching/runoff} = (N_F + N_O + N_{CR} + N_{PRP}) \times L_{leach} \times EF_{leach} \times 44/28$$

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
$L_{vol\text{-}F}$ = fraction N lost through volatilization from synthetic fertilizer inputs (0.10)
$L_{vol\text{-}O}$ = fraction N lost through volatilization from organic fertilizer and manure inputs (0.20)
L_{leach} = fraction N lost through leaching/runoff from all N inputs (0.30)
EF_{vol} = emission factor for indirect N_2O emissions from N volatilization (0.010 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 (+75 kg N_2O-N / kg N leached/runoff)
44/28 = conversion from N_2O-N to N_2O

Data

Crop area and crop production data were needed to estimate emissions from crop residue N additions to agricultural soil and field burning of sugarcane residues. Annual sugarcane area and production estimates were obtained from NASS (USDA 2008e). For other crops (pineapples, sweet potatoes, ginger root, taro, and corn for grain), data from the Census of Agriculture were used (USDA 2002, 2004), and then extrapolated and interpolated as described in the Enteric Fermentation section for sheep, goat, and horse populations. Percent distribution to various animal waste management systems (as described in the Manure Management section) was used to estimate manure N additions to pasture, range, and paddock soils.

For distribution of Kauai and Maui county crop area and production data to individual islands, ALUM (2008) data on relative land use area was used, as described in the Enteric Fermentation section. Those crops were disaggregated using relative percentages of sugarcane and pineapple land areas available from ALUM. However, since commercial pineapple production was halted on Lanai in 1992, the ALUM percentages were assumed to apply to that island and crop through 1992, and thereafter were reduced to zero. For other crops, the relative percentages of total cropland from ALUM were used. The relative percentage of total cropland was also used to distribute state-level synthetic fertilizer application data from the American Association of Plant Food Control Officials (AAPFCO 1995-2007, TVA 1991-1994).

Synthetic and organic fertilizer N application data were obtained from AAPFCO (AAPFCO 1995-2007, TVA 1991-1994). According to these data, commercial organic fertilizer is not applied in Hawaii, and so emissions from this source of N were estimated at zero.

Crop residue factors for corn were obtained from IPCC (2006). Crop residue factors for tubers[29] were used for sweet potatoes, ginger root, and taro. No 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 Hawaii, there would be little crop residue N input from sugarcane. All emission and other factors are IPCC defaults.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

The overall emissions estimate for agricultural soil management is nearly 3.5 times higher than in the July 1997 Report.[30] This is because the July 1997 Report included only direct N_2O emissions from synthetic fertilizer application.[31] In the Updated Inventory, in addition to direct fertilizer emissions, direct emissions from crop residue and manure inputs and indirect emissions from fertilizer, crop residues, and manure were estimated.

Field Burning of Agricultural Residues (CH_4, N_2O)

Methodology

An 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 only crop evaluated was sugarcane because it

[29] Tuber: "An underground stem which has been modified for storage of nutrients, such as a potato." (University of California Museum of Paleontology Botany Glossary: http://www.ucmp.berkeley.edu/glossary/glossary_8.html.)
[30] Page 9-1. July 1997 Report. Chapter 9: Greenhouse Gas Emissions from Agricultural Activities.
[31] Ibid.

appears to be the only major crop in Hawaii whose residues are regularly burned (Hudson 2008).

Emissions = crop production × residue-crop ratio × dry matter fraction × fraction of crop burned × burning efficiency × combustion efficiency × C or N content of residue × emissions ratio × conversion factor

where,

Crop production	= annual weight of crop produced
Residue/crop ratio	= amount of residue produced per unit of crop production (0.19)
Fraction of residue burned	= amount of residue which is burned per unit of total residue (95%)
Dry matter fraction	= amount of dry matter per unit of biomass (62%)
Fraction of C or N	= amount of C or N per unit of dry matter (42.4% and 0.4%, respectively)
Burning efficiency	= the proportion of prefire fuel biomass consumed (0.81)
Combustion efficiency	= the proportion of C or N released with respect to the total amount of C or N available in the burned material, respectively (0.68)
Emissions ratio	= g CH_4-C/g C released or g N_2O-N/g N release (+5 and +7, respectively)
Conversion factor	= conversion of CH_4-C to C or N_2O-N to N (16/12 and 44/28, respectively)

Data

Crop area and production data were obtained and distributed as described in the Agricultural Soil Management section. The residue/crop ratio and burning efficiency were taken from Kinoshita (1988). Dry matter fraction, fraction of carbon and N, and combustion efficiency were taken from Turn et al. (1997). Fraction of residue burned was from Ashman (2008).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Emissions estimates in the Updated Inventory are 90 percent higher for CH_4 and 101 percent higher for N_2O from sugarcane burning, compared to the July 1997 Report.[32] Overall, $MMTCO_2Eq$ reported from the Updated Inventory were 108 percent larger for field burning of agricultural residues when compared to the July 1997 Report. Although the methods and data used in the July 1997 Report and the Updated Inventory were similar, there were two key exceptions.[33]

First, the July 1997 Report did not use a conversion factor (converting CH_4-C to CH_4 and N_2O-N to N_2O), which led to artificially low estimates. This correction was responsible for the bulk of the increase in estimates seen in the updated report, in addition to smaller increases due to an update to the emissions ratio (grams of CH_4-C per gram of carbon released), and an increase in the estimate of the percent of sugarcane area burned from 10 percent to 95 percent. In addition, other revised factors for sugarcane burning were employed based on Hawaii-specific

[32] Page 9-1. July 1997 Report. Chapter 9: Greenhouse Gas Emissions from Agricultural Activities.
[33] Page 9-15. Ibid.

information provided by the Hawaii Agricultural Research Center, although these had the tendency to reduce emission estimates compared to those in the July 1997 Report.

Urea Application (CO_2)

Methodology

The EPA State Inventory Tool, which provides estimates of state-level emissions from urea, was used to estimate emissions from urea application in Hawaii. Data on urea fertilizer sales are available by state for each fertilizer year (July through June).[34] Historical usage patterns are used to apportion these sales to the appropriate calendar years (January through December). An emission factor of 0.2 MT C/MT urea was used to estimate the carbon emissions, in the form of CO_2, that result from urea application. This emission factor is based on the carbon content of urea by mass; it is assumed that all carbon contained in the urea is eventually emitted to the atmosphere. Data on cropland area by island were used to apportion emissions to each island.

Data

Fertilizer sales data is from the EPA State Inventory Tool, which sources it from the annual publications of Association of American Plant Food Control Officials (AAPFCO) (AAPFCO 1995-2007, TVA 1991-1994). The emission factor of 0.2 is MT C/MT urea was obtained from the EPA State Inventory Tool as well, which sources it from IPCC (2006).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

The carbon flux from urea application was not estimated in July 1997 Report.[35]

Agricultural Soil Management (CO_2)

Agricultural soils – either in cropland or grasslands – that have been converted from other land uses in the past can be sources and sinks of carbon. These 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 1 to 6 percent organic carbon by weight (EPA 2008). 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, sequestration of carbon by agricultural soils is largely due to enrollment in the Conservation Reserve Program, conservation tillage practices, increased hay production, and intensified crop production.

Methodology

Data for the flux from Hawaii's mineral and organic soils was available for the year 1997 in the USDA's U.S. Agriculture and Forestry Greenhouse Gas Inventory (USDA 2008f). Values for 2006 were available from the U.S. Inventory. These estimates were developed by Dr. Stephen Ogle of Colorado State University using the Century biogeochemical model, which simulates changes in soil carbon nationwide based on weather patterns, land use, management activities, and water dynamics. Land-use history data for this modeling was obtained from the USDA National

[34] Fertilizer sales are reported by fertilizer year, corresponding to the growing season. The 2007 fertilizer year, for example, runs from July 2006 to June 2007.
[35] Page 9-1. July 1997 Report. Chapter 9: Greenhouse Gas Emissions from Agricultural Activities.

Resources Inventory, which tracks approximately 400,000 points on agricultural land in the U.S., with data collected for each point on a five-year cycle. 1990 values were assumed to be the same as 1997. Data on cropland area by island was used to apportion flux to each island (ALUM 2008).

Data

The land use history for Hawaii's agricultural lands was obtained from USDA's National Resources Inventory database for use in Century modeling. Additional inputs to the Century model included weather, manure amendments, fertilizer use, and tillage practices (EPA 2008). The model results for Hawaii are reported in the U.S. Inventory. Cropland area data for each island from ALUM (2008) were used for apportioning the flux estimates between islands.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

While carbon flux from a known pool of abandoned lands was estimated in the July 1997 report, this methodology did not account for all agricultural lands. The methodology used in the Updated Inventory accounts for all changes in cropland and grassland tracked by the National Resources Inventory.

Landfilled Yard Trimmings and Food Scraps (CO_2)

Methodology

For this source, estimates of the carbon sequestration in landfilled yard trimmings and food scraps for Hawaii were generated by the EPA State Inventory Tool. The EPA State Inventory Tool is centered around data on the generation of food scraps and yard trimmings for the entire US. Additionally, it uses data on the amounts of organic waste composted, incinerated, and landfilled each year. This information is used to develop an estimate of the yard trimmings and food scraps added to landfills each year nationwide.

State and national population data is 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. Given these estimates for the state of Hawaii, island population data was used to apportion sequestration by island.

Data

Default values from the EPA State Inventory Tool for the composition of yard trimmings and their carbon content were used to calculate carbon inputs into landfills. Waste generation data for each year (available on 10 year intervals between 1960 and 1990), also obtained from the EPA State Inventory Tool, were used to calculate the national-level estimates. Annual state population data from the U.S. Census, contained within the EPA State Inventory Tool, were used to calculate state-level estimates. Island populations within Hawaii were obtained from the 2007 Hawaii Databook (DBEDT 1990 to 2007) and used to apportion carbon sequestration by island.

Key Differences in 1990 Emission Estimate (from July 1997 Report)

The carbon flux of landfilled yard trimmings and food scraps was not estimated in the July 1997 Report.[36]

Urban Trees (CO_2)

Methodology

Carbon flux by urban trees was calculated using Hawaii-specific data where available and the methodology from the U.S. Inventory. Honolulu's "Municipal Forest Resource Analysis" (Vargas *et al.* 2007) provided data on Honolulu's urban tree cover and carbon sequestration rates for these trees. Using this Honolulu-specific data, a rate of annual carbon sequestration per square meter of tree canopy (kg C/m^2 tree cover) was calculated.

Urbanized area for the state of Hawaii was determined from the U.S. Census of 1990 and 2000 (U.S. Census Bureau 1990, 2000). The U.S. Census defines urbanized areas as places that have a minimum of 50,000 people and is a contiguous or connected area with a density of at least 1,000 people per square mile[37]. Under these definitions, the U.S. Census identified only 2 urbanized areas in Hawaii, both of which are on Oahu (Honolulu and Kailua-Kaneohe). A linear trend was fitted to the 1990 and 2000 data to establish a time series from 1990 to 2007. The Honolulu study did not provide an estimate of how much of Honolulu's urban area was tree cover; this data was not found for Hawaii as a whole, either. As a result, the national average urban tree cover (27.1 percent) was used to estimate how much of Hawaii's urbanized area is covered by tree canopy. With an estimate of total urban tree cover for Hawaii, the Hawaii-specific sequestration factor (kg C/m^2 tree cover) was applied to this area to calculate total C sequestration by urban trees (MT C/yr).

Data

The City and County of Honolulu's "Municipal Forest Resource Analysis" was used to determine carbon sequestration rates. Census-defined urbanized area values were used to calculate urbanized area in Hawaii. The percent of this urbanized area that is tree canopy was estimated from the national average, as provided in the 1990-2006 U.S. Inventory (EPA 2008).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

Carbon flux in urban trees was not estimated in the July 1997 Report.

Forest Carbon (CO_2)

Methodology

The Tier 1 Gain Loss Method as outlined by the 2006 IPCC Guidelines (IPCC 2006) was used to calculate carbon flux in managed Hawaii forests.[38] This method requires forestland acreage

[36] Page 2-1. July 1997 Report. Chapter 2: 1990 Hawaii Greenhouse Gas Emissions.

[37] Definitions for urbanized area changed between 1990 and 2000. The 1990 U.S. Census defined urban land as "urbanized areas," which included land with a population density greater than 1,000 people per square mile, and adjacent "urban places," which had predefined political boundaries and a population total greater than 2,500. In 2000, the U.S. Census replaced the "urban places" category with a new category of urban land called an "urban cluster," which included areas with more than 500 people per square mile. (EPA 2008)

[38] Managed forests, under IPCC guidelines, are deemed to be a human-influenced greenhouse gas sink and, accordingly, included here. This encompasses any forest that is under any sort of human intervention, alteration,

time series data as well as aboveground biomass growth rate, the ratio of below ground biomass to aboveground biomass, and the carbon fraction. The Gain Loss method calculates annual increase in biomass carbon stocks by multiplying forest land area by mean biomass growth and the percent of biomass that is carbon. Mean biomass growth is derived by multiplying the average annual above-ground biomass growth by 1 added to the ratio of below ground biomass to above ground biomass. This biomass growth was then multiplied by a carbon factor to determine the net addition of carbon. In obtaining these factors, the tropical Asia Insular IPCC default values were chosen as default factors for forest and shrubland.[39]

Managed forestland acreage time series data were obtained from the Hawaii Databook. 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 Hawaii for each year between 1990 and 2007. According to a National Oceanic and Atmospheric Administration Coastal Services Center (NOAA-CCAP) 2000 study (NOAA-CCAP 2000), roughly half of Hawaii's forestland is shrub/scrubland, defined as land with vegetation less than 20 feet tall. Forestland was divided into two sub-categories: forest and shrub/scrubland using the island-specific forestland:shrubland ratios derived from the NOAA-CCAP study. Different carbon factors were used for each of these subcategories.

Data

Managed forest area estimates were calculated from private forestland in Conservation Districts, forest reserve land in Conservation Districts, forested natural areas, and wooded farmland. The time series for this calculation for 1990-2007 was obtained from the Hawaii Databook. Tropical Asia Insular biomass growth and carbon fraction data were obtained from the 2006 IPCC Guidelines (IPCC 2006).

Key Differences in 1990 Emission Estimate (from July 1997 Report)

The July 1997 Report cited a total of 1.99 million acres of forestland in Hawaii.[40] This number came from discussions with forestry personnel at the time. The July 1997 Report only calculated carbon sequestration from forest plantations, which represented 2 percent of the total reported 1.99 million acres. Managed forest land estimates in the Updated Inventory were found in this effort, however, to comprise around 1.2 million acres of Hawaii's forests. Conversations with the Hawaii Department of Forestry and Wildlife and Hawaii forest experts (Mann and Cannarella 2008) as well as comparison to recent NOAA and USGS Hawaii GAP Analysis Program forest studies confirmed that this updated estimate is a more accurate assessment of managed forest acreage. Unlike the July 1997 Report, the revised inventory thus calculated carbon sequestration for the entire 1.2 million acres of managed forest. It also applied a forest:shrubland ratio in order to more accurately capture the character of Hawaiian forests.

maintenance, or legal protection. Unmanaged forests are not under human influence and thus out of the purview of this inventory.

[39] Extensive research was conducted to find Hawaii-specific carbon factors, during the course of which many Hawaii forest experts were contacted (Cole, Giardina, Litton, Bennet, Friday, and Ostertag 2008). However, the results of this research indicated that the IPCC defaults for tropical Asia insular land would be best suited for the revised estimates.

[40] Page 9-11. July 1997 Report. Chapter 9: Greenhouse Gas Emissions from Agricultural Activities.

Forest Fires (CO_2, CH_4, N_2O)

Methodology

Dividing the total forest land acreage for Hawaii by the wildland acreage under protection resulted in a "forest land to total wildland under protection" ratio. Next, data on the acreage burned each year were obtained from the Hawaii Department of Land and Natural Resources (DLNR) (Dept. of Land Natural Resources 2008) and the Hawaii Databook (DBEDT 1990 to 2007). The acreage data was apportioned to each island based on the known forest acreage of each island (see the "Forest Carbon" section of this memo). The acreage burned was multiplied by the "forest land to wildland under protection" ratio to obtain, for each year, the acres of forest burned in Hawaii by island.

The acres of forest burned were multiplied by the IPCC default value to determine the fraction of biomass that is burned and by the U.S. default value for the carbon content of that biomass. This calculation yielded an estimate of the carbon released from forest fires by island for each year, and use of the appropriate conversion factors for each gas resulted in estimates of CH_4 and N_2O emissions. The conversion equations used were as follows (EPA 2008):

$$CH_4 \text{ Emissions} = (\text{C released}) \times (\text{emission ratio}) \times 16/12$$
$$N_2O \text{ Emissions} = (\text{C released}) \times (\text{N/C ratio}) \times (\text{emission ratio}) \times 44/28$$

The N/C ratio was taken to be 0.01, as recommended by the IPCC Good Practice Guidelines (2003).

Data

Data for years 1994 to 2006 on acres burned by wildfire was obtained from the Annual Wildfire Summary Report, published by the Fire Management Program of the DLNR. Data found in the Hawaii Databook (which contains data for years 1998 to 2006) are identical to the data provided by the Fire Management Program. Due to limited data availability, 1994 data were used as proxy data for 1990.

Because acres burned data is for wildland, it was necessary to develop a forestland to wildland ratio to estimate area of forestland burned. "Wildland under Protection" data, in million hectares, were obtained for years 1998 and 2002 from the National Association of State Foresters (1998, 2002). 1998 data was used for 1990 and 2002 data was used for 2007. Forestland data were obtained from the same sources as the Forest Carbon estimates of this inventory (see "Forest Carbon" section of this memo). The average carbon density was provided by Linda Heath, U.S. Forest Service, for the lower 48 states for the 1990-2006 U.S. Inventory[41] (Heath 2007). The general amount burned by wildfire factor (0.4) is an IPCC default factor.

Key Differences in 1990 Emission Estimate (from July 1997 Report)
Emissions from forest fires were not estimated in the July 1997 Report.

[41] Extensive research was conducted to find a Hawaii-specific factor for average carbon density. Due to a lack of such a factor, we used the one for the lower 48 states, as provided by Linda Heath.

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USDA (2008b) *Cattle on Feed*, Hawaii. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington, DC. Available online at: http://www.nass.usda.gov/QuickStats.

USDA (2008c) *Hogs and Pigs*, Hawaii. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington, DC. Available online at: http://www.nass.usda.gov/QuickStats.

USDA (2008d) *Chicken Inventory*, Hawaii. National Agricultural Statistics Service, U.S. Department of Agriculture, Washington, DC. Available online at: http://www.nass.usda.gov/QuickStats.

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Glossary of Key Terms

Above-ground residue: Organic residue remaining above the ground after the harvesting and processing of a crop. Includes residues left over from harvesting, such as plant stubble. Crop residues can enhance the organic carbon content of the soil.[42]

Agriculture, Forestry and Other Land Use (AFOLU): The IPCC 2006 Guidelines introduced this sector, which addresses emissions due to agriculture, forestry, and other land uses.

Agricultural soil management: Microbial processes in the soil naturally produce nitrous oxide, a greenhouse gas. A number of agricultural activities increase mineral nitrogen availability in soils, thereby increasing the amount available for the microbial activities of nitrification and denitrification, and ultimately the amount of nitrous oxide emitted. Management practices such as fertilization, application of managed livestock manure, production of nitrogen fixing crops, retention of crop residues, cultivation of organic soils, irrigation, tillage practices, and drainage can all influence the amount of nitrous oxide which agricultural soils emit.

Anaerobic: Describes chemical processes which occur in the absence of oxygen. In anaerobic or anoxic conditions, a distinct set of microbes dominate the breakdown of organic materials, often resulting in the production of methane gas.

Anthropogenic: Made by people or resulting from human activities. This term is usually used in the context of emissions that are produced as a result of human activities.[43]

Below-ground residue: Organic crop residues that remain or are plowed back into the field after the harvesting of a crop.[44]

Biogenic: Produced by living organisms. The combustion of biogenic materials (such as biofuels or organic waste) is considered carbon neutral, since this carbon was sequestered from the atmosphere.

Biomass: The total mass of living organisms in a given area or volume; recently dead plant material is often included as dead biomass. Biomass can be used for fuel directly by burning it (e.g., wood), or indirectly by fermentation to alcohol (e.g., sugar) or extraction of combustible oils (e.g., soybeans).[45]

Biochemical oxygen demand (BOD): The amount of oxygen that would be required to completely consume the organic matter contained in wastewater through aerobic decomposition processes. BOD serves as a measure of the organic content of the wastewater. [46]

[42] Follett, R. F. Soil Management concepts and carbon sequestration in cropland soils. Soil & Tillage Research 61 (2001):77-92.
[43] Environmental Protection Agency (EPA). 2008. Glossary of Key Terms. Climate Change. http://www.epa.gov/climatechange/glossary.html
[44] Environmental Protection Agency (EPA). 2006. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004.
[45] Intergovernmental Panel on Climate Change (IPCC). 2001. "Appendix II: Glossary." In Climate Change 2001: Mitigation. Third Assessment Report.
[46] Environmental Protection Agency (EPA). 2006. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2004.

Calcium oxide content: Calcium oxide (CaO or quicklime) is formed by heating limestone to decompose its carbonates. This is usually done in shaft or rotary kilns at high temperatures and the process releases carbon dioxide. The calcium oxide content of industrial products is used to estimate carbon dioxide emissions.[47]

Cement kiln dust (CKD): Cement kiln dust is dust generated during the production of clinker, and is either recycled into the kiln or disposed of in landfills or elsewhere. Since emissions associated with clinker production are based on clinker weight, if non-recycled CKD is not accounted for, then a portion of carbon dioxide emissions associated with clinker production are not accounted for.[48]

Carbon content coefficient: A value used to calculate the amount of carbon contained in fuels, and therefore, the amount of carbon dioxide emitted as the result of fuel combustion. Carbon content coefficients are specific to fuel type.

Carbon dioxide (CO_2): A naturally occurring gas, which also is emitted from human activities such as burning fossil fuels and biomass, land-use changes, and industrial processes. It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a global warming potential of 1.[49]

Carbon dioxide equivalent: A measure used to compare the emissions of the different greenhouse gases based upon their global warming potential (GWP). Greenhouse gas emissions in the United States are most commonly expressed in million metric tons of carbon dioxide equivalents ($MMTCO_2Eq$).[50]

Carbon factor: Used in the AFOLU section to calculate the amount of carbon contained in living biomass and dead organic matter pools, which in turn is used to calculate the amount of carbon dioxide emitted or absorbed by biomass.[51]

Carbon flux: The rate of exchange of carbon between pools (i.e., reservoirs).[52]

Carbon sequestration: The uptake and storage of carbon. Trees and plants, for example, absorb carbon dioxide as part of their process of growth, releasing the oxygen portion and storing the carbon. Carbon can also be sequestered by geological or other processes. For example, unburned fossil fuels, which are mostly composed of ancient biomass, are reservoirs for carbon sequestration.[53]

Clinker: One of the major inputs to cement, produced by heating a properly proportioned mixture of finely ground raw materials (calcium carbonate, silica, alumina, and iron oxide) in a kiln to a temperature of about 2,700°F.[54] Clinker is an intermediate product that is finely ground after production, and mixed with a small proportion of calcium sulfate and other ingredients to form hydraulic (typically portland) cement.[55]

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[47] Intergovernmental Panel on Climate Change. 2006. Eggelston, S., Buendia, L., Miwa, K., Ngara, T. and K.Tanabe, eds. Chapters 1-5 In: 2006 IPCC Guidelines for National Greenhouse Gas Inventories. NGGIP Publications.
[48] Ibid.
[49] EPA. 2008.
[50] United Nations Framework Convention on Climate Change (UNFCCC). 2008. Glossary. Available online at: http://unfccc.int/resource/cd_roms/na1/ghg_inventories/english/8_glossary/Glossary.htm
[51] IPCC. 2006. Chapter 1.
[52] UNFCCC. 2008.
[53] UNFCCC. 2008.
[54] U.S. Department of Energy. 2008. Glossary. Available online at: http://www.eia.doe.gov/oiaf/1605/archive/gg98rpt/glossary.html
[55] IPCC. 2006. Ch 2.

Conservation Reserve Program: A voluntary program for agricultural landowners run by the USDA Farm Service Agency. CRP participants sign a multi-year contract to establish vegetative ground cover on environmentally sensitive lands; they receive an annual payment for doing so. The CRP aims to reduce soil erosion, improve water quality, and increase wildlife habitat.[56]

Conservation tillage: A planting practice that reduces tilling of the soil. Crop residues are generally not plowed under, or only plowed in thin strips, and the new crop is planted among the stubble of the old crop. This practice reduces soil erosion and is favored on sensitive soils.

De facto population: The number of persons physically present in an area, regardless of military status or usual place of residence. It includes visitors present but excludes residents temporarily absent, both calculated as an average daily census[57].

Diesel fuel oil: A fuel composed of distillates obtained in petroleum refining operation or blends of such distillates with residual oil used in motor vehicles. The boiling point and specific gravity are higher for diesel fuels than for gasoline.[58]

Emissions: In the climate change context, emissions refer to the release of greenhouse gases and/or their precursors and aerosols into the atmosphere over a specified area and period of time.[59]

Emission factor/coefficient: A unique value for scaling emissions to activity data in terms of a standard rate of emissions per unit of activity (e.g., grams of carbon dioxide emitted per barrel of petroleum consumed).[60]

Energy Information Administration (EIA): Independent statistical agency within the U.S. Department of Energy. The EIA provides policy-independent data, forecasts and analyses regarding energy. The agency also collects data on energy reserves, production, consumption, distribution, prices, technology and other aspects. EIA programs cover data on coal, petroleum, natural gas, electric, renewable and nuclear energy.[61]

Enteric fermentation: During digestion, microbes present in an animal's digestive system aid digestion by breaking down food consumed by the animal. This microbial fermentation process, referred to as enteric fermentation, produces methane as a byproduct, which can be exhaled or eructated (i.e., belched) by the animal.[62]

Extrapolate: Method of constructing new data points outside of a discrete set of known data points.

Fossil fuel: A general term for buried combustible geologic deposits of organic materials, formed from decayed plants and animals that have been converted to crude oil, coal, natural gas, or heavy oils by exposure to heat and pressure in the earth's crust over hundreds of millions of years.[63]

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[56] United States Department of Agriculture (USDA), Natural Resources Conservation Service. Conservation Reserve Program Description. Available online at http://www.nrcs.usda.gov/programs/CRP/.
[57] State of Hawaii (2007). *The State of Hawaii Databook, 2007.* Honolulu: Department of Business, Economic Development, and Tourism; Research and Economic Analysis Division.
[58] Energy Information Administration (EIA). 2008. Glossary. Available online at: http://www.eia.doe.gov/glossary/index.html
[59] IPCC. 2001.
[60] UNFCCC. 2008.
[61] Energy Information Administration. 2008. EIA Program Description. Available online at: http://www.eia.doe.gov/neic/aboutEIA/aboutus.html
[62] EPA. 2006.
[63] UNFCCC. 2008.

Fraction oxidized: The fraction of the carbon in a fuel that is oxidized during combustion. Usually 99 to 100 percent of the carbon is oxidized during combustion, therefore the fraction of carbon oxidized is assumed to be 1 (i.e., 100 percent) in deriving default carbon dioxide emission factors.

Gasoline: A light, liquid hydrocarbon oil typically used to fuel internal combustion engines.[64]

Geographic Information System (GIS): A system that stores, analyses, manages and presents geographically oriented data. GIS programs allow users to manipulate spatial data in order to run analyses, edit data, and create maps.

Greenhouse gas (GHG): Any gas that absorbs infrared radiation in the atmosphere. Greenhouse gases include, but are not limited to, water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrochlorofluorocarbons (HCFCs), stratospheric ozone (O_3), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). See *carbon dioxide, methane, nitrous oxide, hydrochlorofluorocarbon, hydrofluorocarbon, perfluorocarbon, sulfur hexafluoride.*[65]

Heat Content: The amount of heat energy available to be released by the transformation or use of a specified physical unit of an energy form (e.g., a ton of coal, a barrel of oil, a kilowatt-hour of electricity, a cubic foot of natural gas, or a pound of steam). The amount of heat energy is commonly expressed in British thermal units (Btu). Note: Heat content of combustible energy forms can be expressed in terms of either gross heat content (higher or upper heating value) or net heat content (lower heating value), depending upon whether or not the available heat energy includes or excludes the energy used to vaporize water (water may be present in the original energy form and is created during the combustion process).[66]

Hydrofluorocarbons (HFCs): Compounds containing only hydrogen, fluorine, and carbon atoms. They were introduced as alternatives to ozone depleting substances in serving many industrial, commercial, and personal needs. HFCs are emitted as by-products of industrial processes and are also used in manufacturing. They do not significantly deplete the stratospheric ozone layer, but they are powerful greenhouse gases with high global warming potentials.[67]

Industrial Processes: In the Industrial Processes sector, emissions are produced as a by-product of many non-energy related industrial process activities. For example, industrial processes can chemically transform raw materials which often release waste gases such as carbon dioxide, methane, and nitrous oxide. The processes include iron and steel production, cement manufacture, ammonia manufacture and urea application, lime manufacture, limestone and dolomite use, and others.[68]

[64] IPCC. 2006. Chapter 1.
[65] UNFCCC. 2008.
[66] EIA. 2008.
[67] UNFCCC. 2008.
[68] EPA. 2006.

Intergovernmental Panel on Climate Change (IPCC): The IPCC was established jointly by the United Nations Environment Programme and the World Meteorological Organization in 1988. The purpose of the IPCC is to assess information in the scientific and technical literature related to all significant components of the issue of climate change. The IPCC draws upon hundreds of the world's expert scientists as authors and thousands as expert reviewers. Leading experts on climate change and environmental, social, and economic sciences from some 60 nations have helped the IPCC to prepare periodic assessments of the scientific underpinnings for understanding global climate change and its consequences. With its capacity for reporting on climate change, its consequences, and the viability of adaptation and mitigation measures, the IPCC is also looked to as the official advisory body to the world's governments on the state of the science of the climate change issue. For example, the IPCC organized the development of internationally accepted methods for conducting national greenhouse gas emission inventories.[69]

Interpolation: Method of constructing new data points within the range of a discrete set of known data points.

Intergovernmental Panel on Climate Change 2006 Guidelines: Most recent version of emission estimation methodologies published by the IPCC for each sector, including a large number of default emissions factors.

International bunker fuel: Fuel supplied to ships and aircraft for international transportation, irrespective of the flag of the carrier, consisting primarily of residual and distillate fuel oil for ships and jet fuel for aircraft.[70]

Kerosene: A petroleum distillate that has a maximum distillation temperature of 401 degrees Fahrenheit at the 10 percent recovery point, a final boiling point of 572 degrees Fahrenheit, and a minimum flash point of 100 degrees Fahrenheit. Used in space heaters, cookstoves, water heaters, and wick lamps. It is also the primary ingredient of commercial jet fuel.[71]

Landfill: A landfill is a solid waste disposal site where waste is deposited below, at or above ground level. The definition is limited to engineered sites with cover materials, controlled placement of waste and management of liquids and gases.[72] Organic wastes placed in landfills decompose anaerobically and release methane gas. Landfills are one of the largest anthropogenic sources of methane emissions in the United States.[73]

Landfill gas flaring: Open air burning of landfill waste gases and volatile liquids through a chimney in order to control landfill gas emissions.[74]

Landfill gas recovery systems: Landfills generate gases continuously due to decomposition processes. Instead of allowing LFG to escape into the air, landfill gas recovery systems capture the gas and convert it into a usable form.[75]

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[69] EPA. 2006.
[70] UNFCCC. 2008.
[71] UNFCCC. 2008.
[72] IPCC. 2007: *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
[73] Energy Information Administration (EIA). 2006. Landfill Gas. Available online at: http://www.eia.doe.gov/cneaf/solar.renewables/page/landfillgas/landfillgas.html
[74] IPCC. 2007.
[75] EPA. 2008. Landfill Methane Outreach Program (LMOP).Available online at: http://www.epa.gov/landfill/overview.htm

Leaching/runoff: Leaching and runoff are processes through which indirect emissions of nitrous oxide occur. Nitrogen compounds in the soil are leached by rainfall or irrigation, and carried offsite, where nitrous oxide emissions eventually take place.[76]

Liquefied petroleum gas (LPG): Gas containing ethane, ethylene, propane, propylene, normal butane, butylene, and isobutene that is stored under pressure so that it is in liquid form.[77]

Manure management: The management of livestock manure can produce anthropogenic methane and nitrous oxide emissions. Methane is produced by the anaerobic decomposition of manure. Nitrous oxide is produced as part of the nitrogen cycle through the nitrification and denitrification of nitrogen in livestock manure and urine. When livestock or poultry manure is stored or treated in systems that promote anaerobic conditions (e.g. as a liquid/slurry in lagoons, ponds, tanks or pits), the decomposition of materials in the manure tends to produce methane. When manure is handled as a solid (e.g. in stacks or drylots), or deposited on a pasture, range or paddock lands, it tends to decompose aerobically and produce little or no methane.[78]

Methane (CH_4): A hydrocarbon that is a greenhouse gas with a global warming potential estimated at 21. Methane is produced through anaerobic (without oxygen) decomposition of waste in landfills, decomposition of animal wastes, animal digestion (enteric fermentation), production and distribution of natural gas and petroleum, coal production, and incomplete fuel combustion.[79]

Military combustion: Includes fuels combusted by the military for electricity generation, aviation, marine operations and vehicles.

$MMTCO_2Eq$: Million metric tons of carbon dioxide equivalents. $MMTCO_2Eq$ = (million metric tons of a gas) × (GWP of the gas).[80]

Municipal solid waste (MSW): Residential solid waste and some non-hazardous commercial, institutional, and industrial wastes. This material is generally sent to municipal landfills for disposal.[81]

National Resources Inventory: Statistical survey of natural resource conditions and trends on non-Federal land in the United States. Non-Federal land includes privately owned lands, tribal and trust lands and lands controlled by state and local governments.[82]

Natural gas: Underground deposits of gases consisting of 50 to 90 percent methane and small amounts of heavier gaseous hydrocarbon compounds such as propane and butane.[83]

Nitrous oxide (N_2O): A powerful greenhouse gas with a global warming potential estimated at 310. Major sources of nitrous oxide include soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.[84]

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[76] IPCC. 2006.
[77] UNFCCC. 2008.
[78] EPA. 2006.
[79] UNFCCC. 2008.
[80] EPA. 2008.
[81] UNFCCC. 2008.
[82] United States Department of Agriculture, Natural Resources Conservation Service. 2008. National Resources Inventory. Available at: http://www.nrcs.usda.gov/technical/NRI/
[83] UNFCCC. 2008.
[84] Ibid.

Organic fertilizer: Organic material such as manure or compost, applied to cropland as a source of plant nutrients.[85] This material could include animal manure, sewage sludge, compost, or other organic materials.[86]

Ozone depleting substances (ODSs): A family of man-made compounds that includes, but is not limited to, chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs). These compounds have been shown to deplete stratospheric ozone, and therefore are typically referred to as ODSs.[87]

Pasture, range and paddock manure: Unmanaged manure deposited by grazing animals on ground in pastures, rangeland, or paddocks.

Perfluorocarbons (PFCs): A group of human-made chemicals composed of carbon and fluorine only. These chemicals (predominantly CF_4 and C_2F_6) were introduced as alternatives, along with hydrofluorocarbons, to the ozone depleting substances. In addition, PFCs are emitted as by-products of some industrial processes and are also used in manufacturing. PFCs do not harm the stratospheric ozone layer, but they are powerful greenhouse gases: the global warming potential of CF_4 is 6,500 and that of C_2F_6 is 9,200.[88]

Petroleum: A broadly defined class of liquid hydrocarbon mixtures. Included are crude oil, lease condensate, unfinished oils, refined products obtained from the processing of crude oil, and natural gas plant liquids. *Note:* Volumes of finished petroleum products include non-hydrocarbon compounds, such as additives and detergents, after they have been blended into the products.[89]

Petroleum Coke: A residue high in carbon content and low in hydrogen that is the final product of thermal decomposition in the condensation process in petroleum refining. It is used as a fuel and in some metals refining processes.[90]

Petroleum Industry Monitoring, Analysis and Reporting (PIMAR) program: The Hawaii Public Utilities Commission administers the PIMAR program in order to provide greater petroleum market transparency and useful information to the public through a variety of data.[91]

Portland cement: Type of hydraulic cement made from clinker and calcium sulfate or anhydrite. Often used in the production of concrete.[92]

Residual fuel oil: The heavier oils that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. Includes Bunker C fuel oil and is used for commercial and industrial heating, electricity generation, and to power ships. Imports of residual fuel oil include imported crude oil burned as fuel.[93]

[85] Ibid.
[86] IPCC. 2006.
[87] UNFCCC. 2008.
[88] Ibid.
[89] EIA. 2008.
[90] Ibid.
[91] Public Utilities Commission, State of Hawaii. 2008. Petroleum Industry Monitoring, Analysis and Reporting Program. Program description available online at: http://www.puc.hawaii.gov/pimar.html
[92] IPCC. 2006.
[93] UNFCCC. 2008.

Sector: Division, most commonly used to denote type of energy consumer (e.g., residential) or according to the Intergovernmental Panel on Climate Change, the type of greenhouse gas emitter (e.g. industrial process, agriculture/forestry, energy or waste).[94]

Sink: A reservoir that uptakes a pollutant from another part of its cycle. Soil and trees tend to act as natural sinks for carbon.[95]

Soil carbon: A major component of the terrestrial biosphere pool in the carbon cycle. The amount of carbon in the soil is a function of the historical vegetative cover and productivity, which in turn is dependent in part upon climatic variables.[96]

Source: Any process or activity that releases a greenhouse gas, an aerosol, or a precursor of a greenhouse gas into the atmosphere.[97]

Substitutes of ozone depleting substances (ODSs): Hydrofluorocarbons (HFCs) and, to a very limited extent, perfluorocarbons (PFCs), serving as alternatives to ozone depleting substances (ODS) being phased out under the Montreal Protocol.[98]

Sulfur hexafluoride (SF_6): A colorless gas soluble in alcohol and ether, slightly soluble in water. A very powerful greenhouse gas used primarily in electrical transmission and distribution systems and as a dielectric in electronics.[99]

Synthetic fertilizer: Commercially prepared mixtures of plant nutrients such as nitrates, phosphates, and potassium applied to the soil to restore fertility and increase crop yields.[100] In this document, this term refers exclusively to synthetic nitrogen fertilizers, such as urea or ammonium phosphate.

Synthetic natural gas (SNG): A manufactured product chemically similar in most respects to natural gas, resulting from the conversion or reforming of petroleum hydrocarbons. It may easily be substituted for, or interchanged with, pipeline quality natural gas.

United Nations Framework Convention on Climate Change (UNFCCC): An international agreement adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Economic Community. Its ultimate objective is the 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. It contains commitments for all parties. Under the Convention parties included in Annex I (developed countries) aimed to return greenhouse gas emission not controlled by the Montreal Protocol to 1990 levels by the year 2000. The convention came into force in March 1994. The Kyoto Protocol is an addition to the UNFCCC that contains additional commitments for those countries that ratify it.[101]

Urea: A common nitrogen fertilizer used in agriculture, with the formula $(NH_2)_2CO$.

Vehicle miles traveled: The number of miles traveled nationally by vehicles for a period of 1 year. VMT is either calculated using two odometer readings or, for vehicles with less than two odometer readings, imputed using a regression estimate.

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[94] Ibid.
[95] Ibid.
[96] Ibid.
[97] Ibid.
[98] IPCC. 2006. Chapter 7.
[99] UNFCCC. 2008.
[100] Ibid.
[101] IPCC. 2007.

Volatile solids: The portion of the carbon content of manure that can be converted to methane.

Volatilization: Volatilization is a process through which indirect emissions of nitrous oxide occur. Non-nitrous-oxide nitrogen compounds are vaporized from soils and carried offsite, where they are redeposited and eventually converted to nitrous oxide.

Waste in place (WIP): The total amount of municipal solid waste physically present in a landfill in any given year. This amount includes municipal solid waste that was deposited in previous years and represents the total accumulation of waste in a landfill.

Wastewater: Water containing waste that has been discharged from residential, industrial, and commercial areas. Wastewater from domestic (municipal sewage) and industrial sources is treated to remove soluble organic matter, suspended solids, pathogenic organisms, and chemical contaminants.[102]

Wildland under protection: An area of land which is undeveloped and unmanaged, but protected from wildfires by state and federal personnel.

Yard trimmings and food scraps: Items such as grass clippings, leaves, branches and food scraps which are discarded in landfills.

[102] EPA. 2006.

Appendix: Sector-specific exhibits

Fig 1. Energy Emissions by Source, 1990 (MMTCO2Eq)

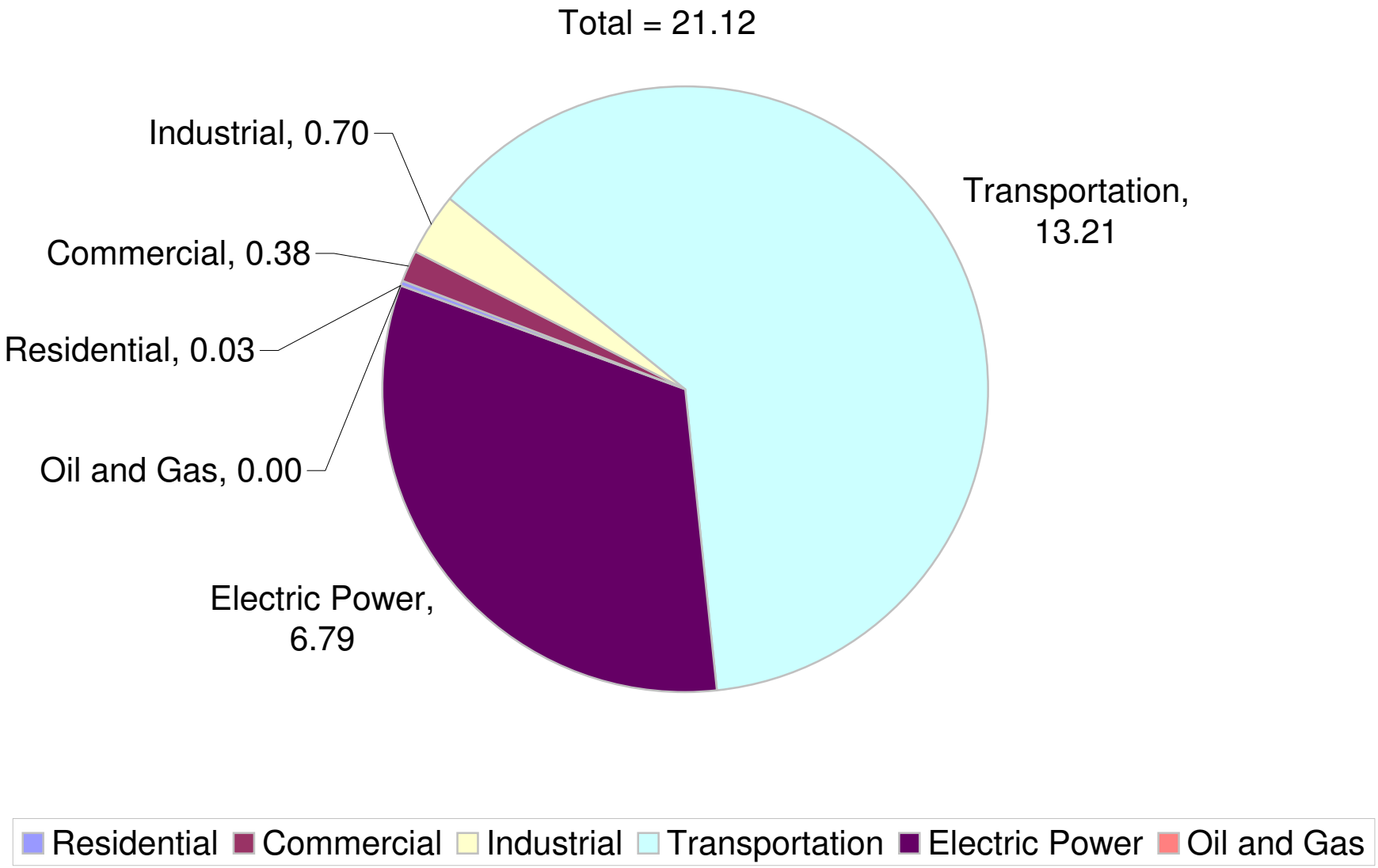

Fig 2. Energy Emissions by Source, 2007 (MMTCO2Eq)

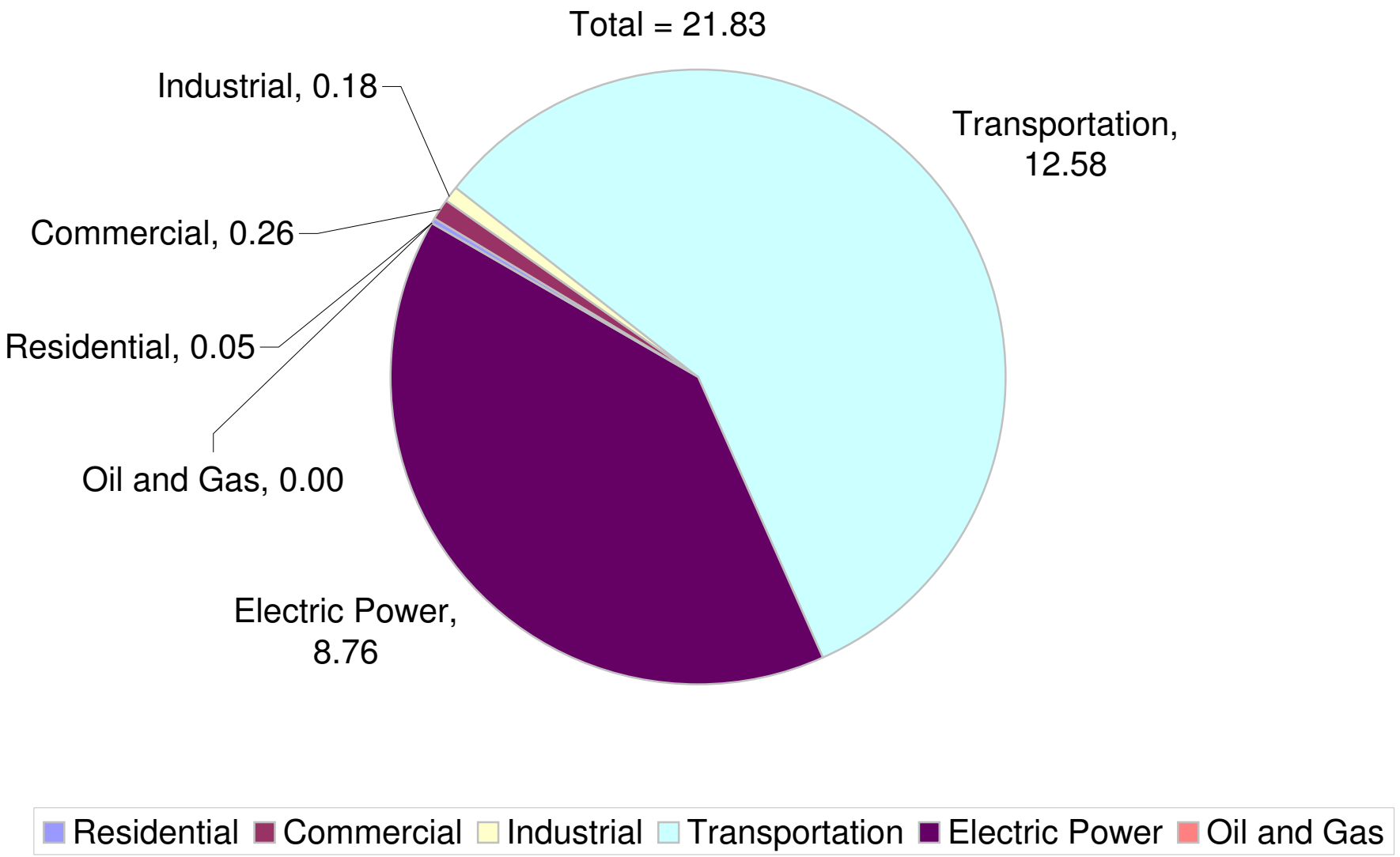

Fig 3. Energy Emissions by Sector, 1990 & 2007 (MMTCO2Eq)

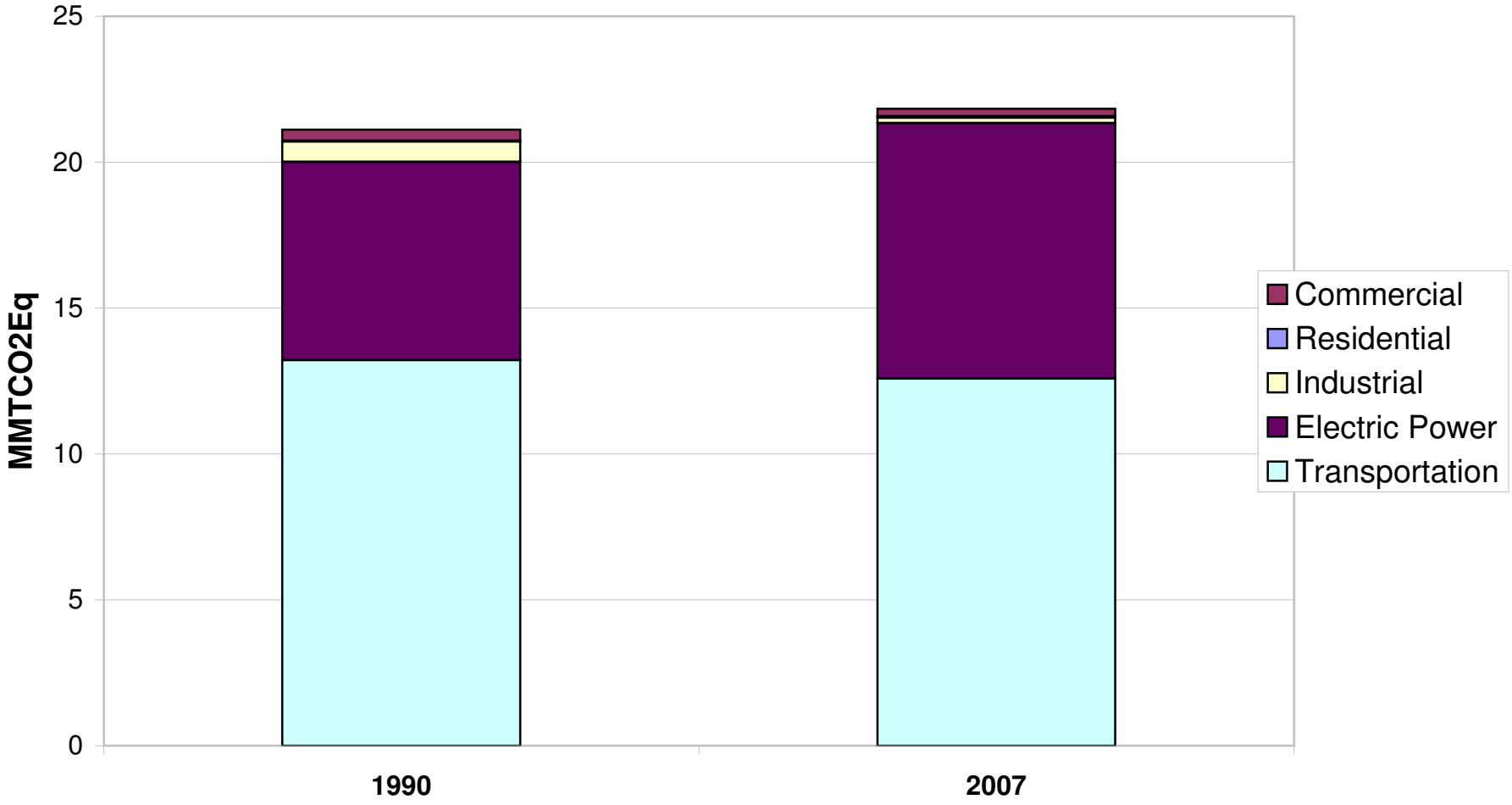

Fig 4. Energy Emissions by Fuel Type, 1990 & 2007 (MMTCO2Eq)

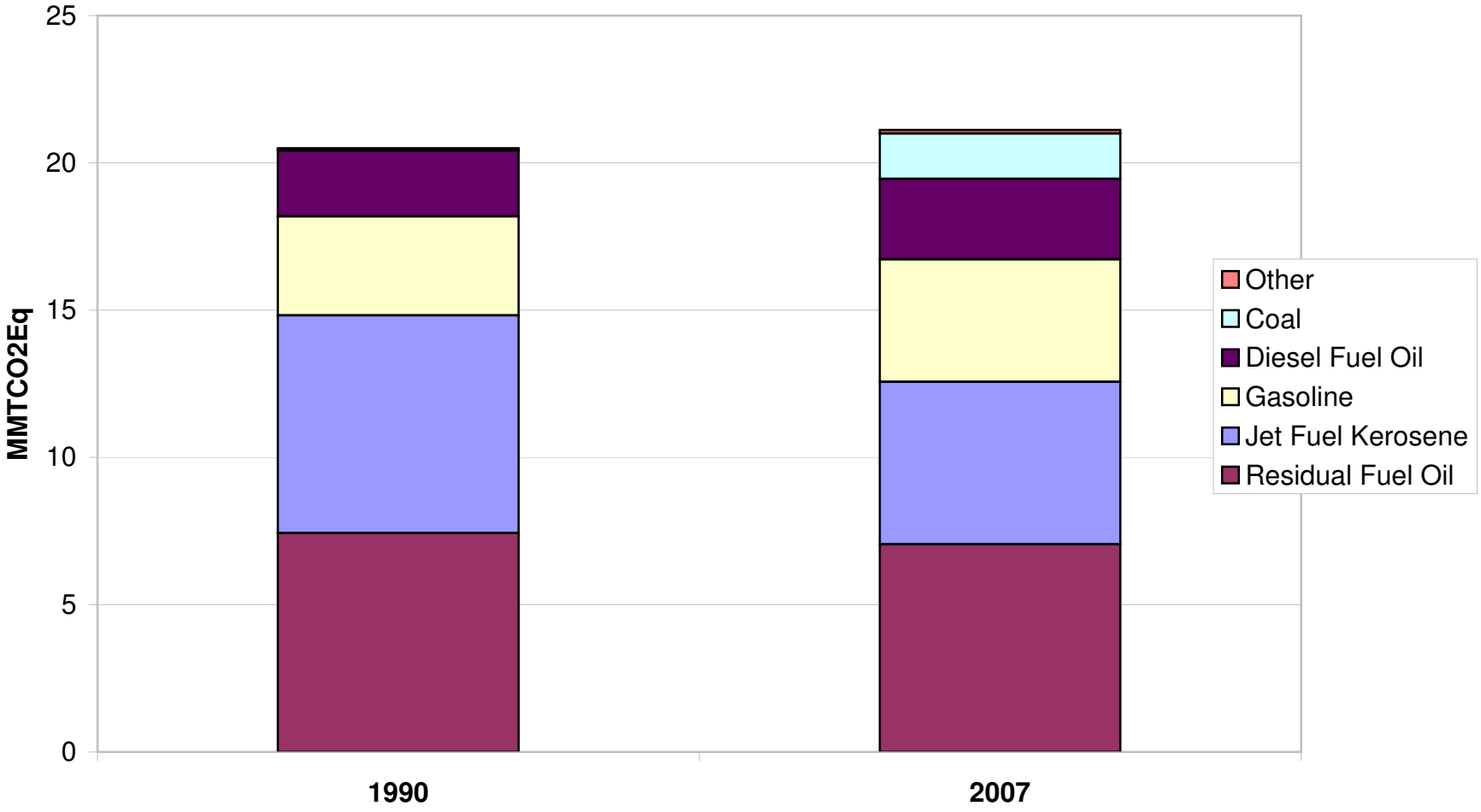

Fig 5. Energy Emissions by Island and Source, 1990 (MMTCO2Eq)

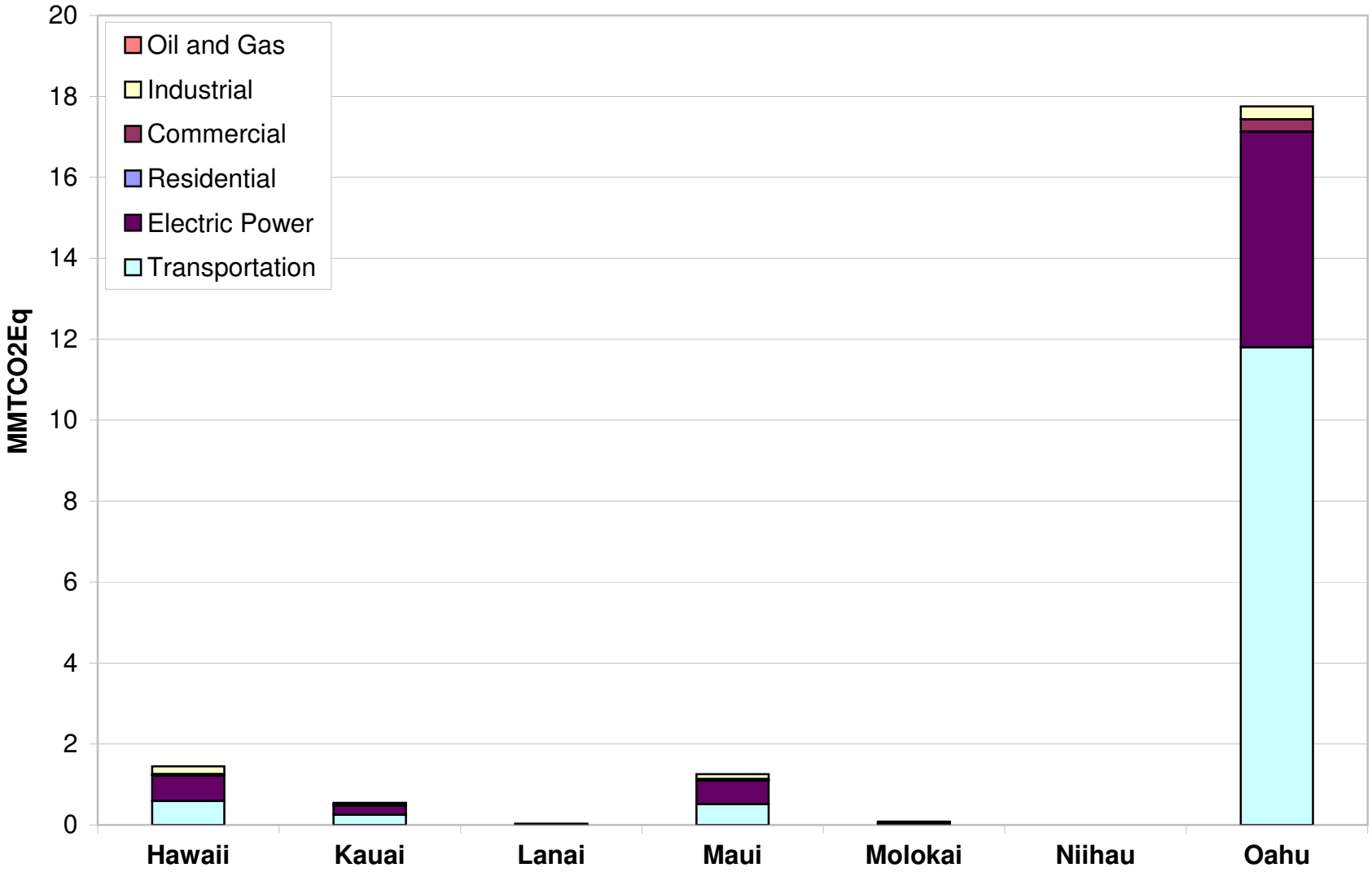

Fig 6. Energy Emissions by Island and Source, 2007 (MMTCO2Eq)

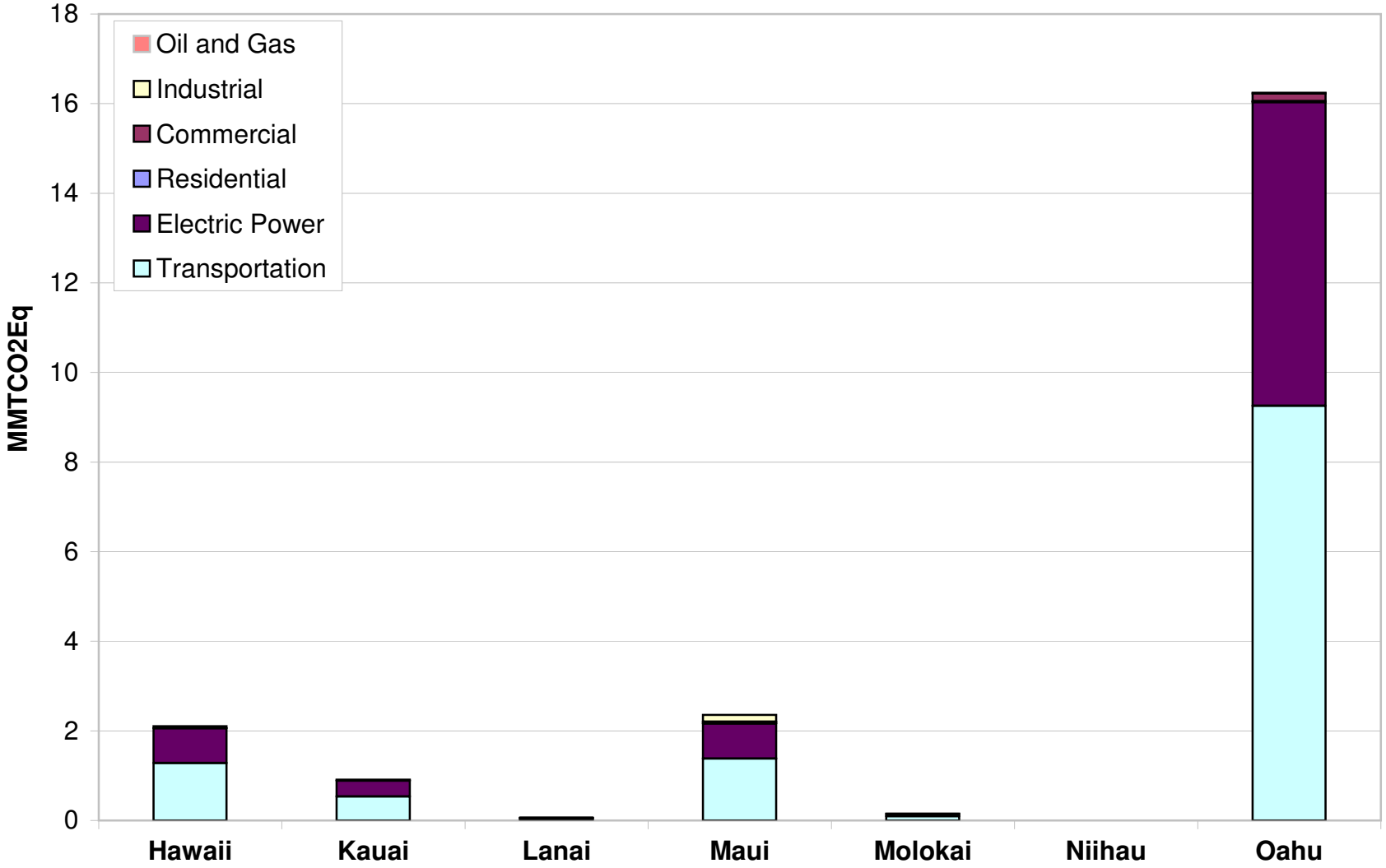

Fig 7. Hawaii GHG Transportation Emissions, 1990 & 2007 (MMTCO2Eq)

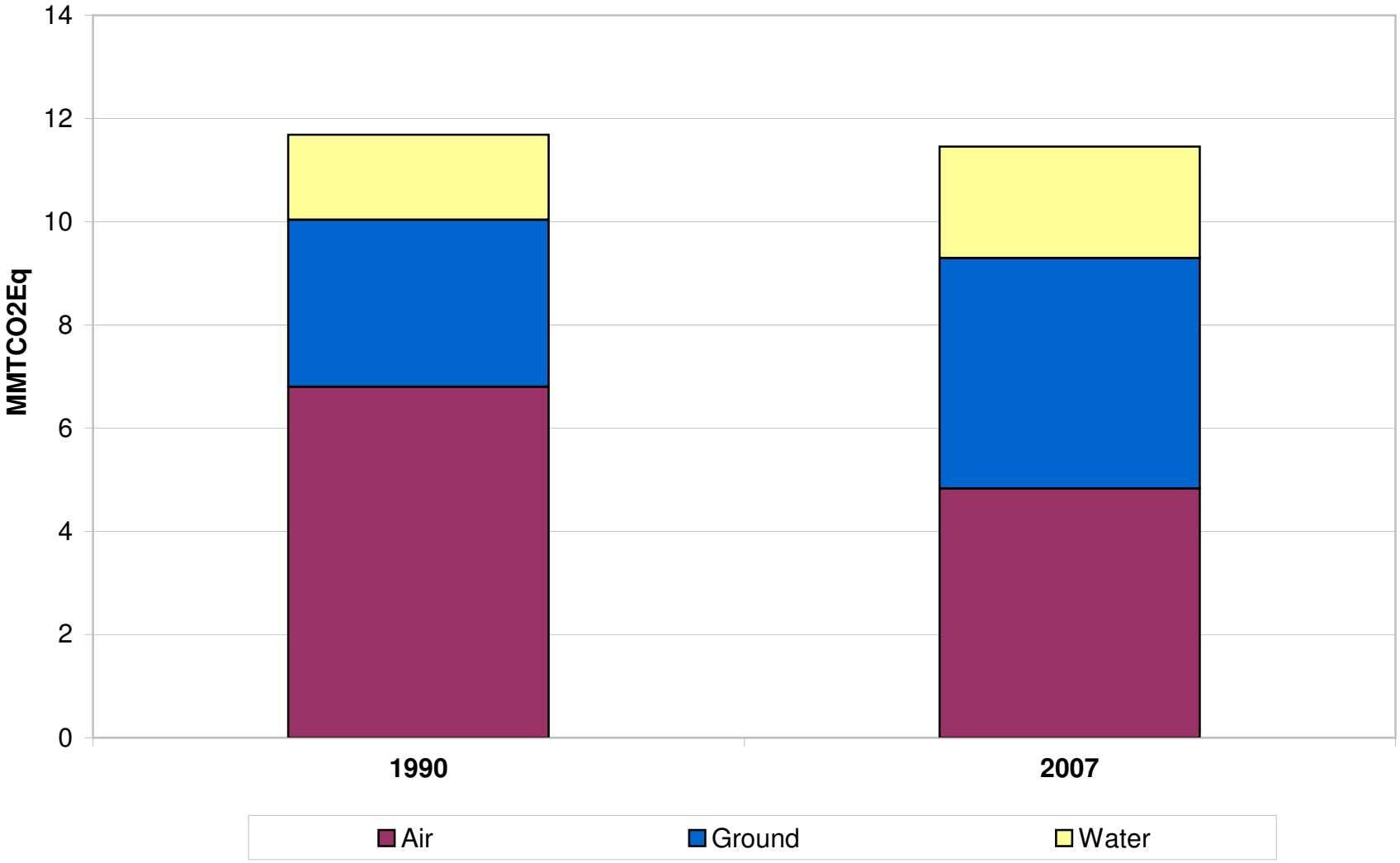

Fig 8. Hawaii GHG Transportation Emissions by Fuel Type, 1990 (MMTCO2Eq)

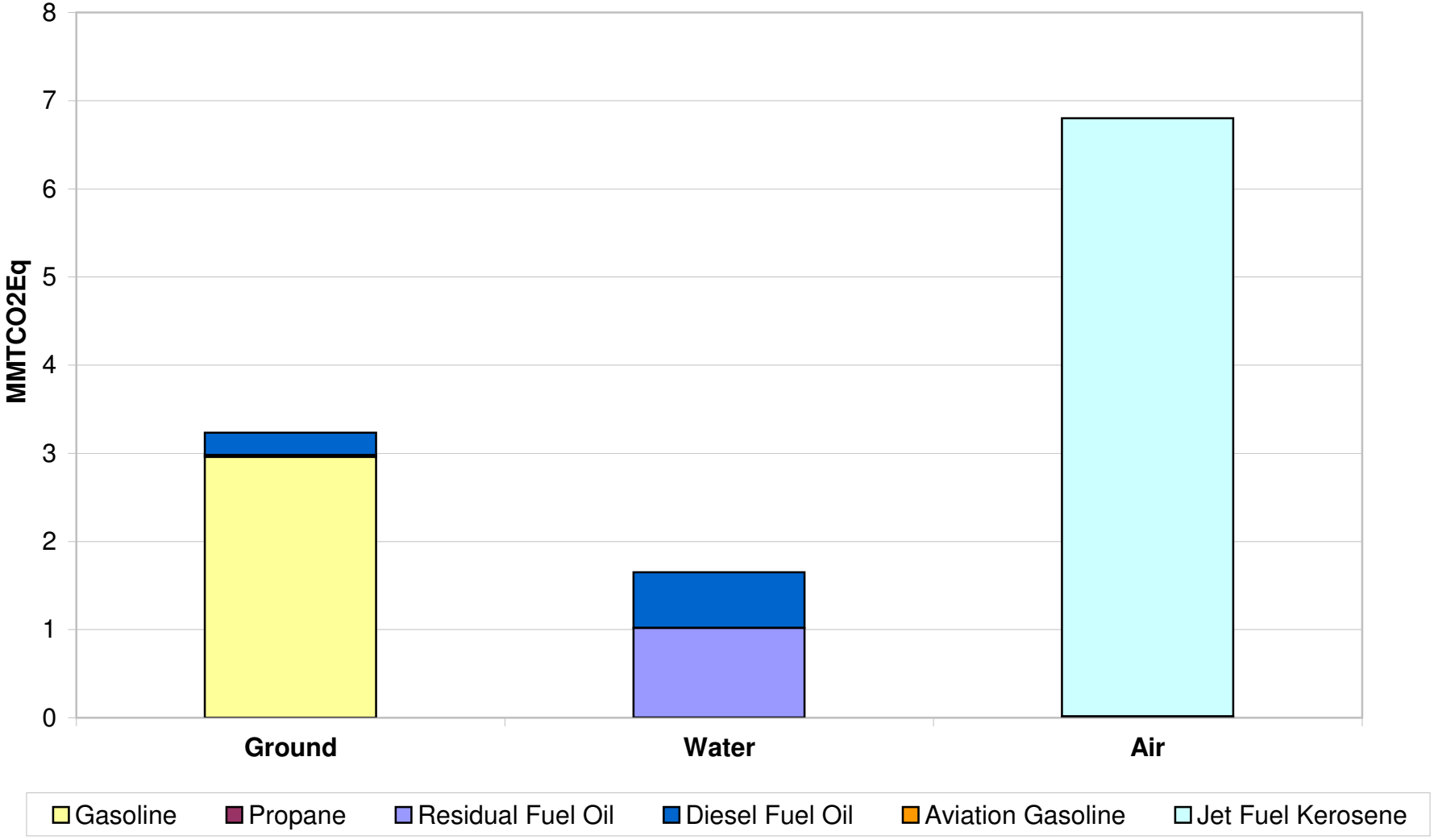

Fig 9. Hawaii GHG Transportation Emissions by Fuel Type, 2007 (MMTCO2Eq)

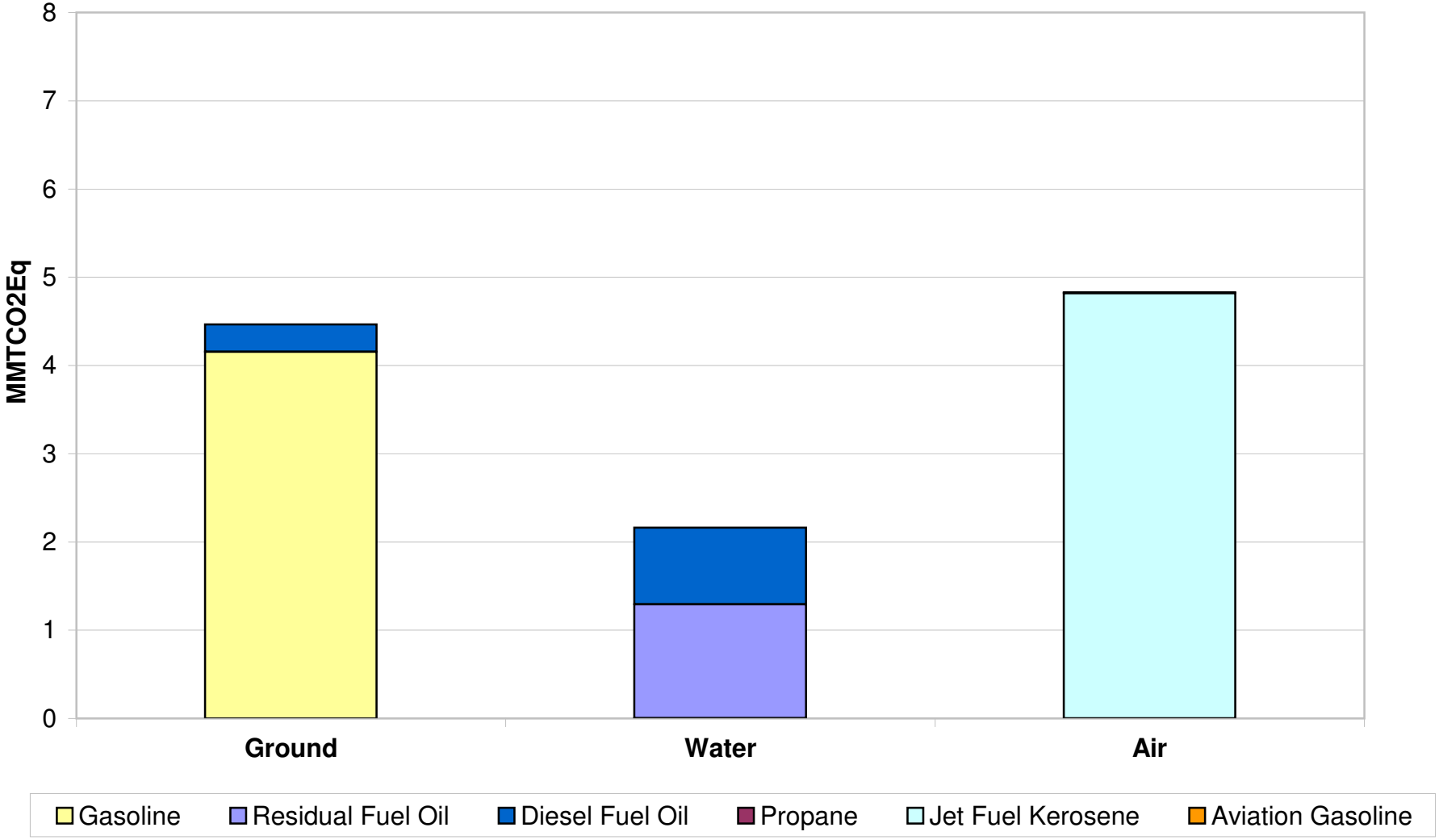

Fig 10. Emissions from Military Fuel Combustion, 1990

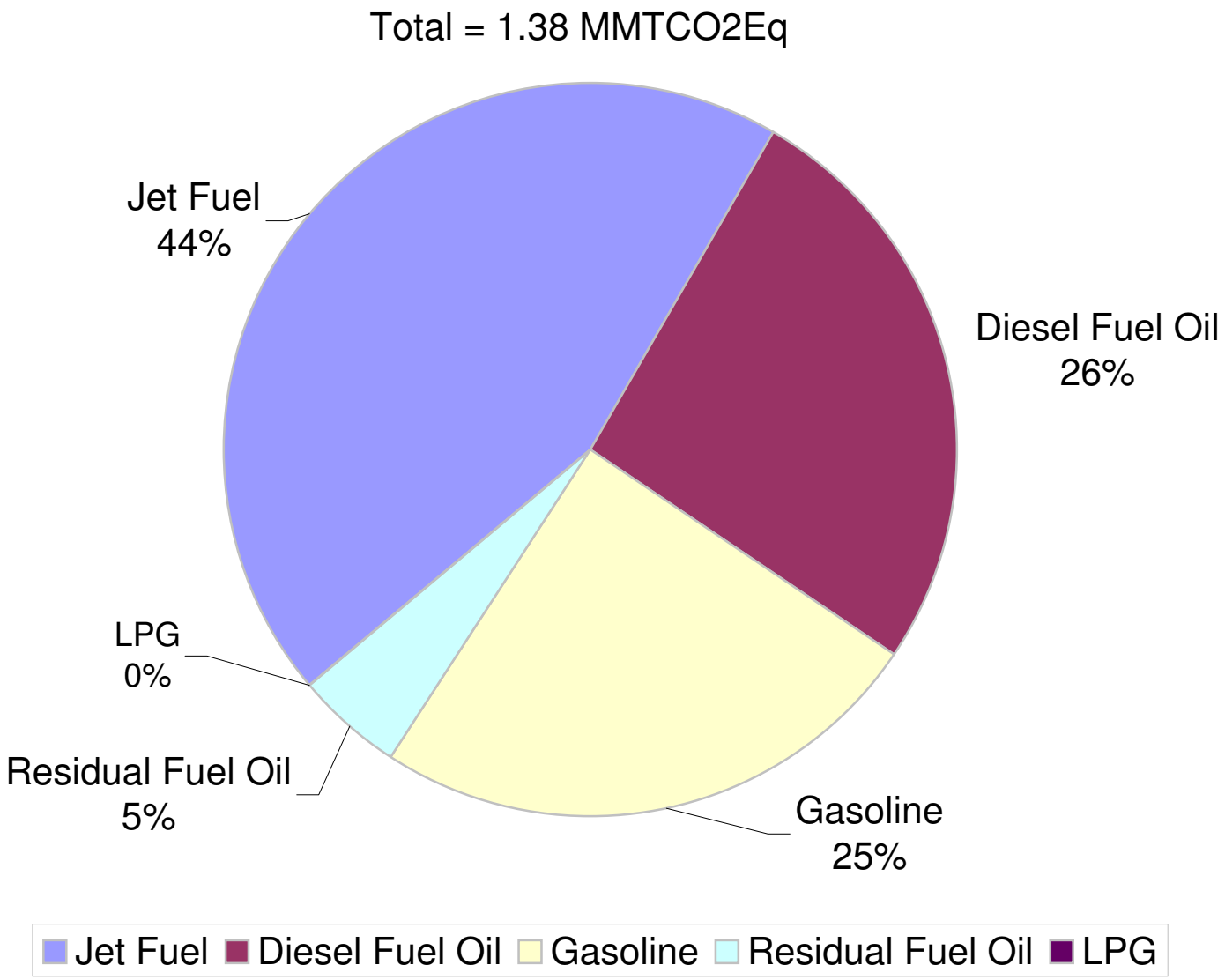

Fig 11. Industrial Processes Emissions by Source, 1990

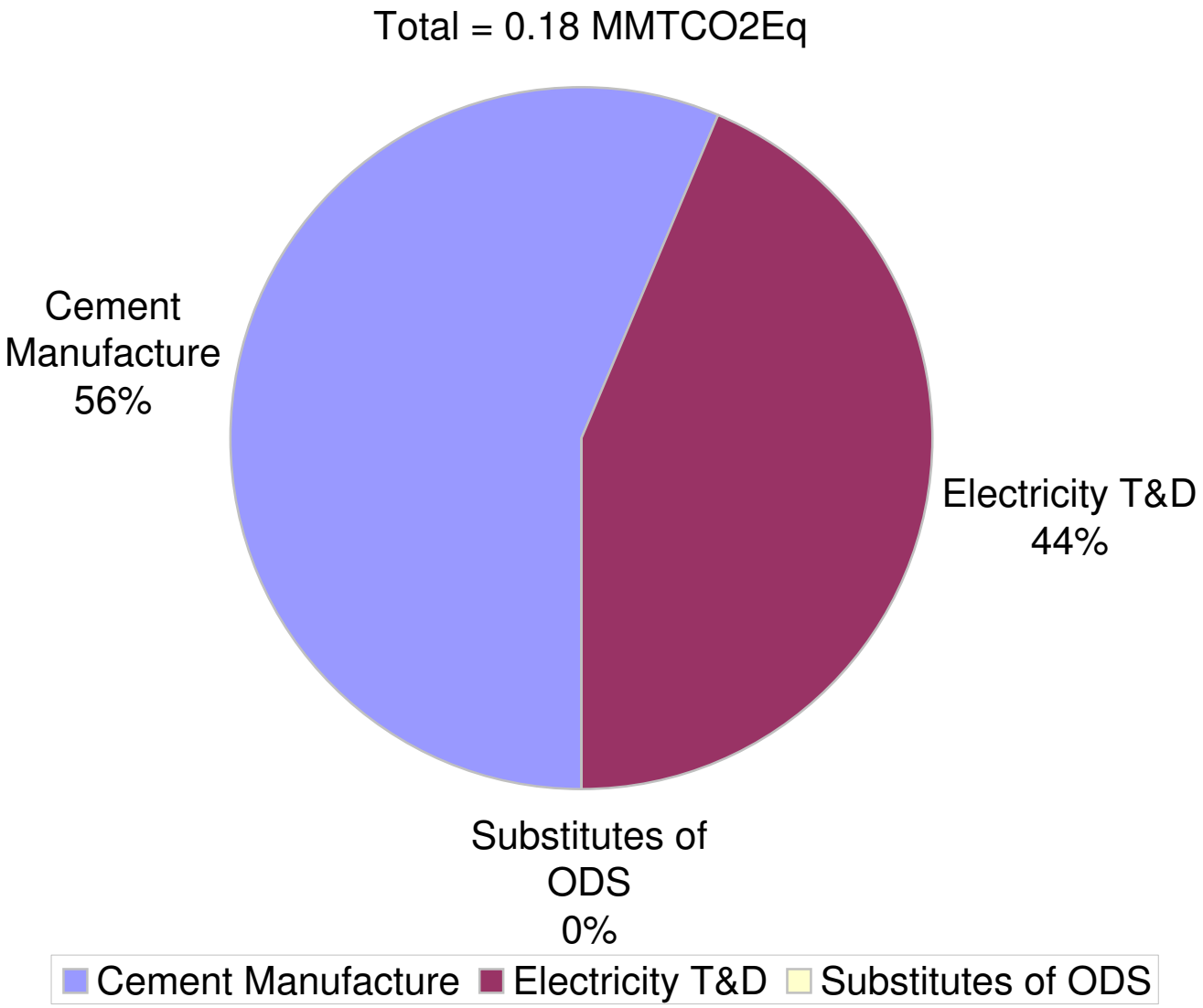

Fig 12. Industrial Processes Emissions by Source, 2007

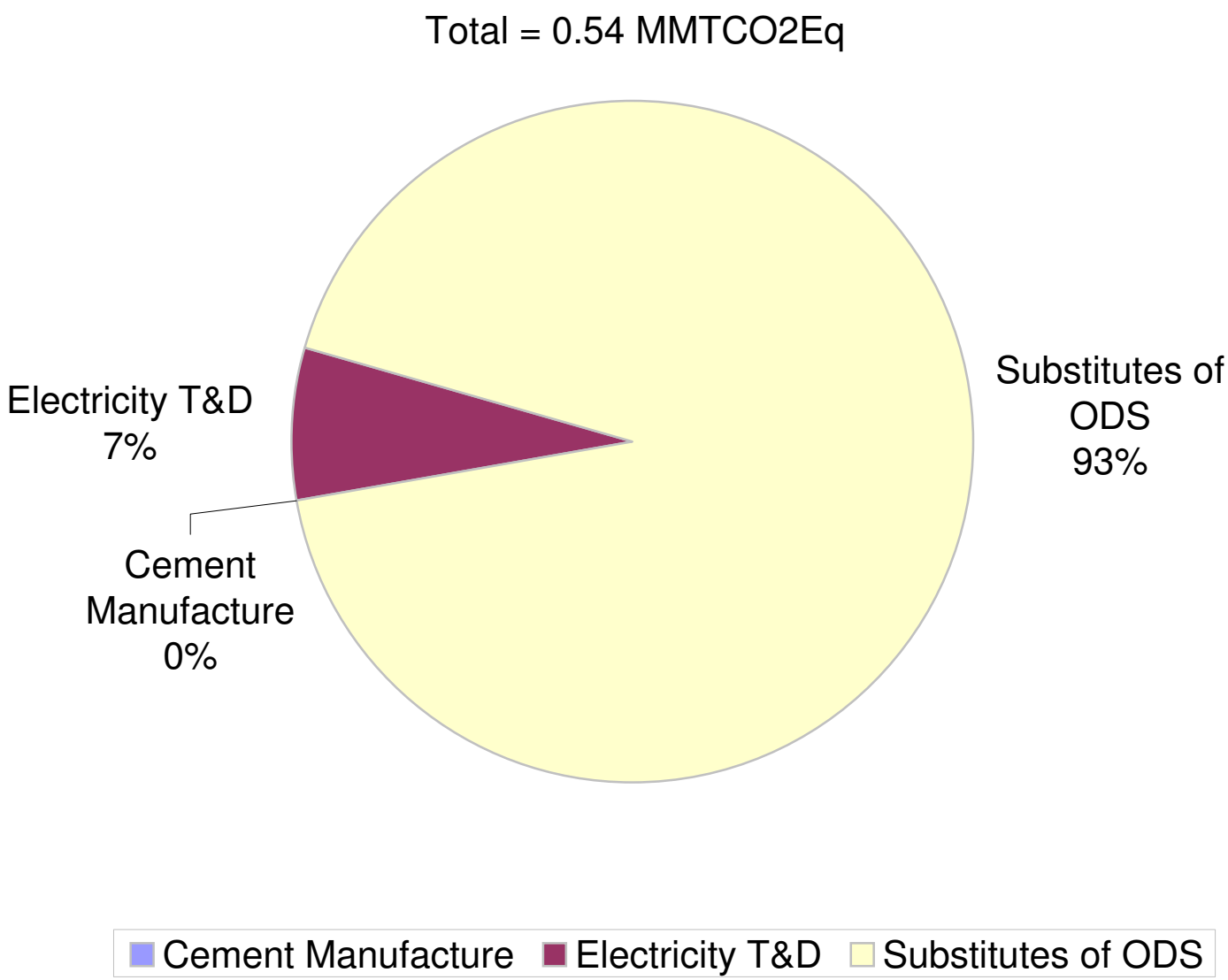

Fig 13. Waste Emissions by Source, 1990

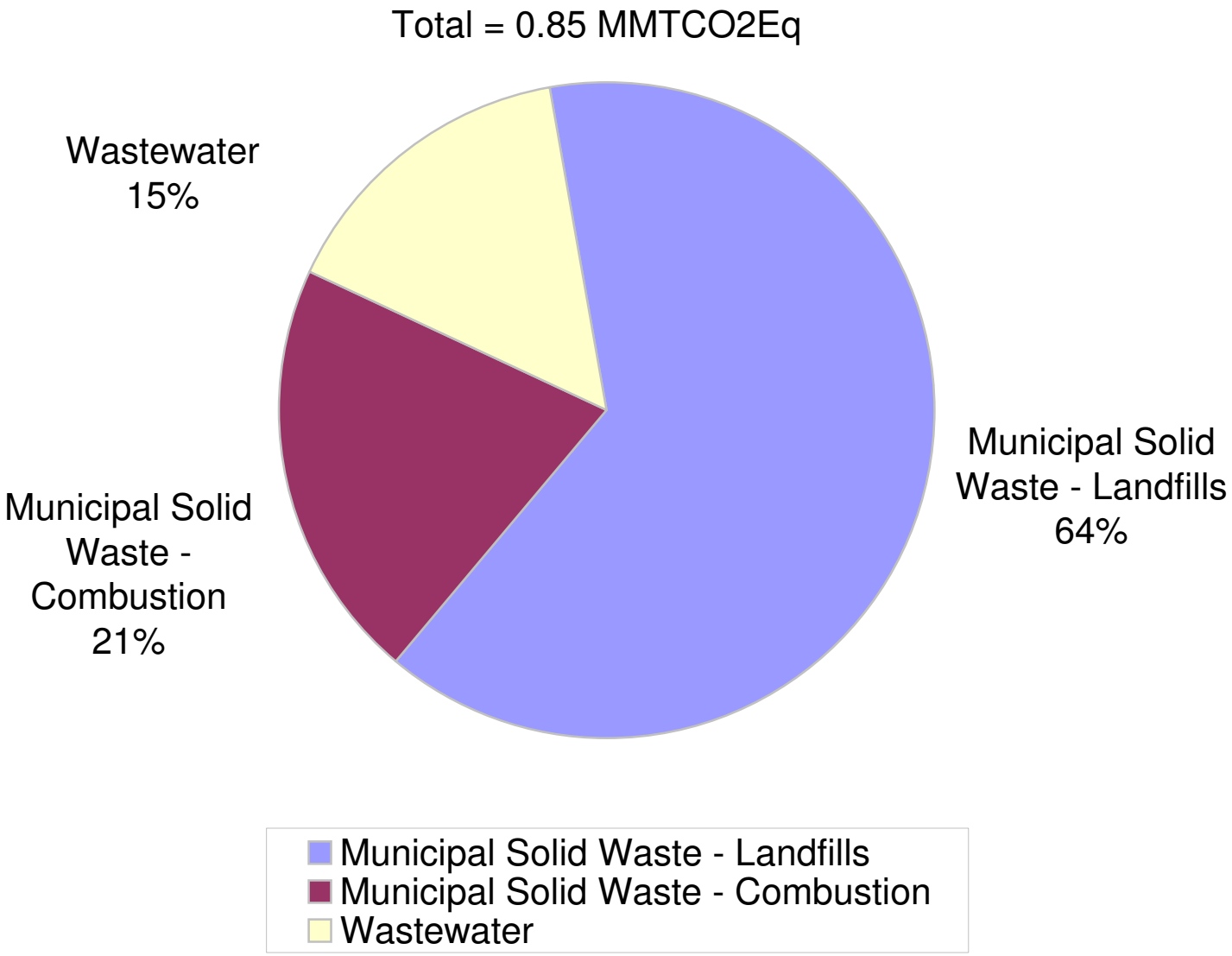

Fig 14. Waste Emissions by Source, 2007

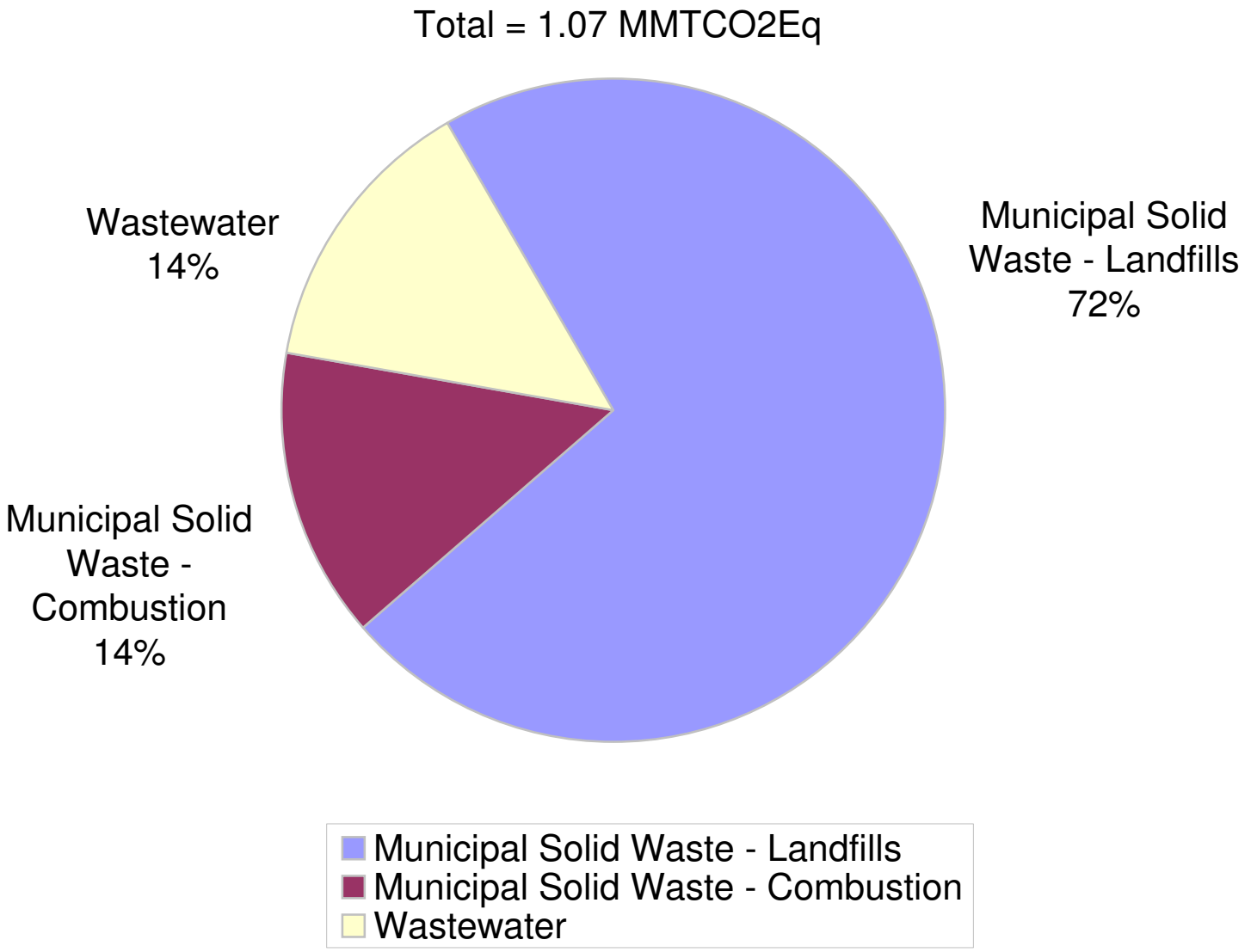

Fig 15. Agriculture, Forestry, and Other Land Use: Emission Sources, 1990

Total = 0.98 MMTCO2Eq

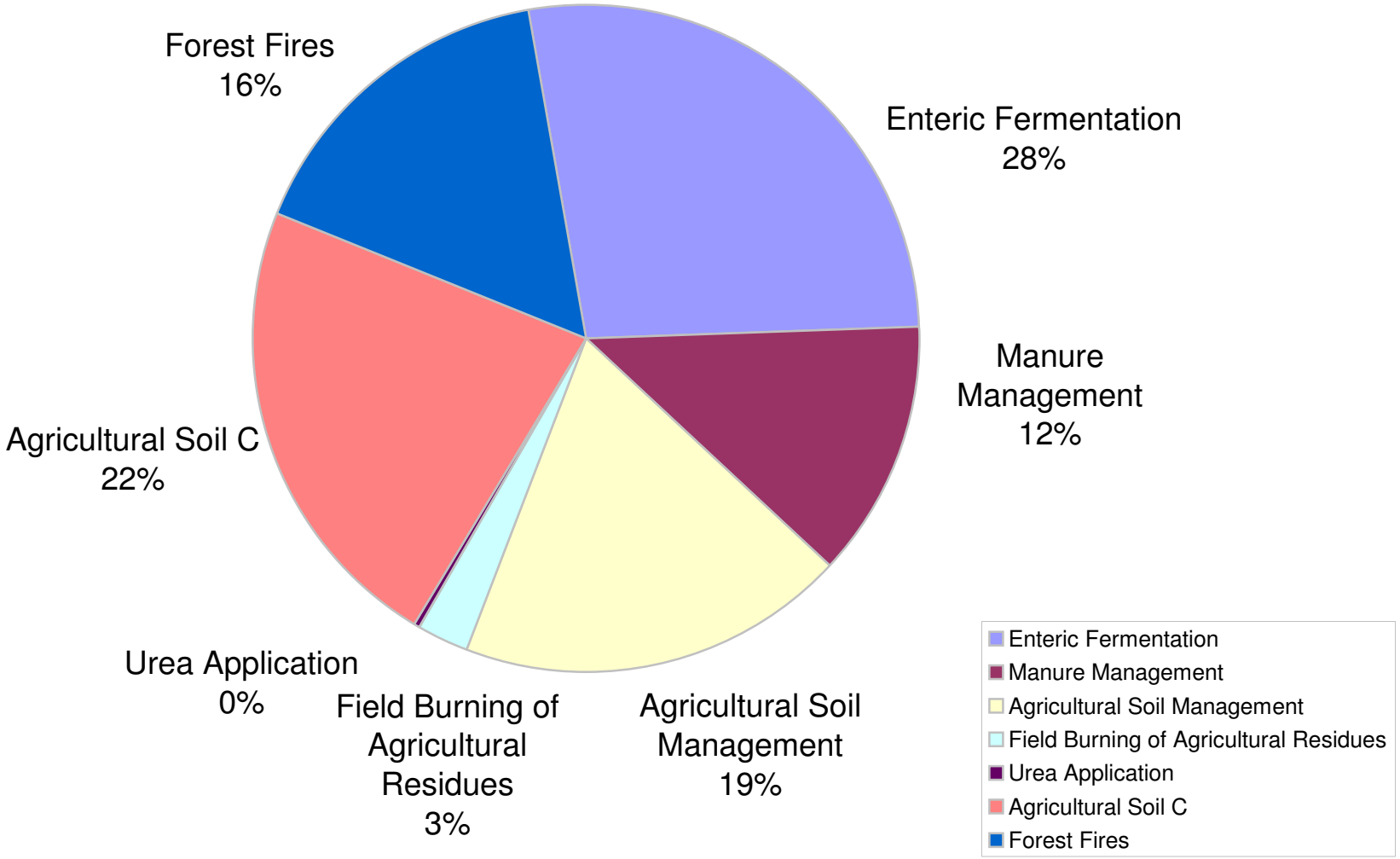

Fig 16. Agriculture, Forestry, and Other Land Use: Emission Sources, 2007

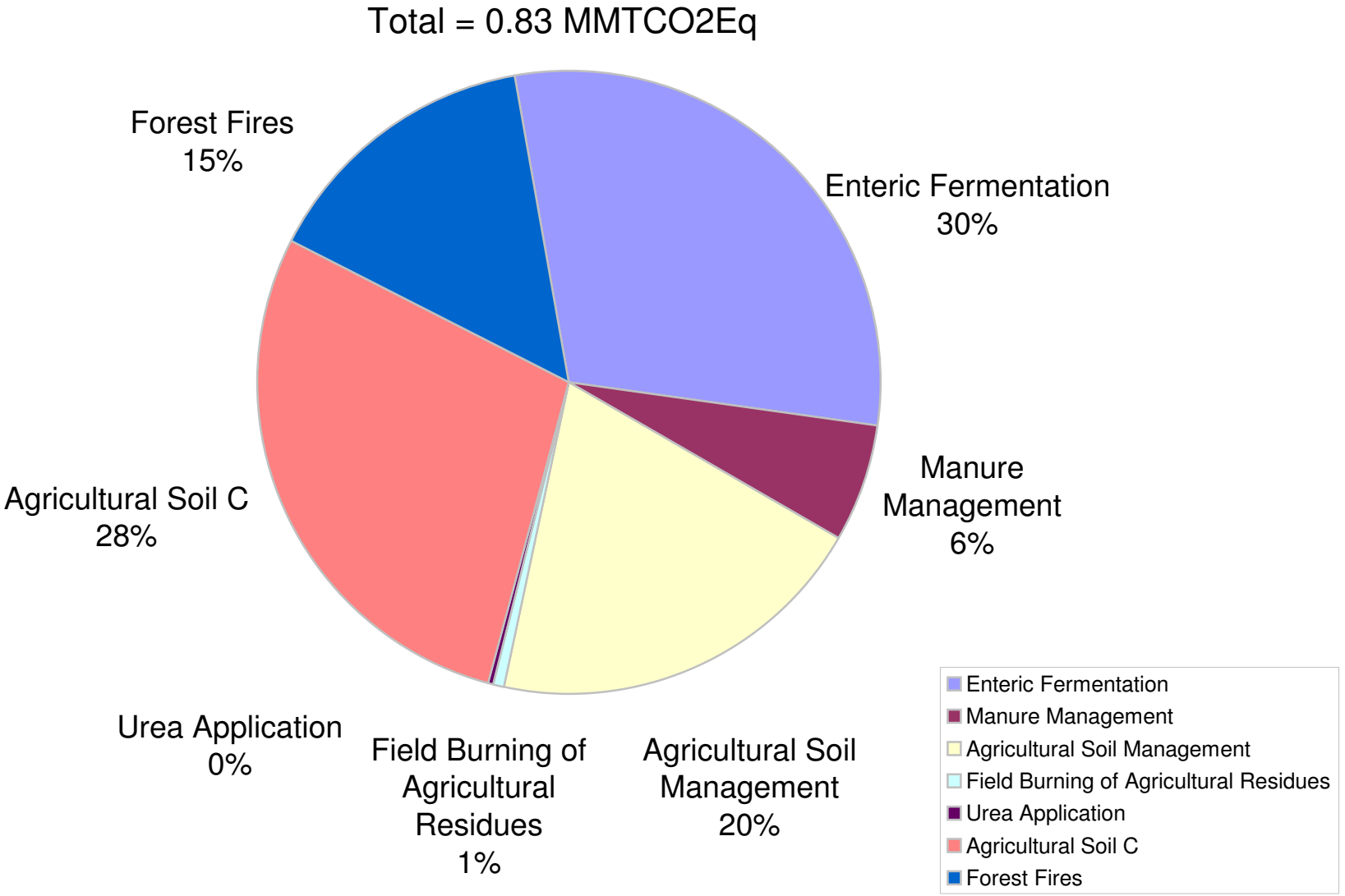

Fig 17. Agriculture, Forestry, and Other Land Use: Sinks, 1990

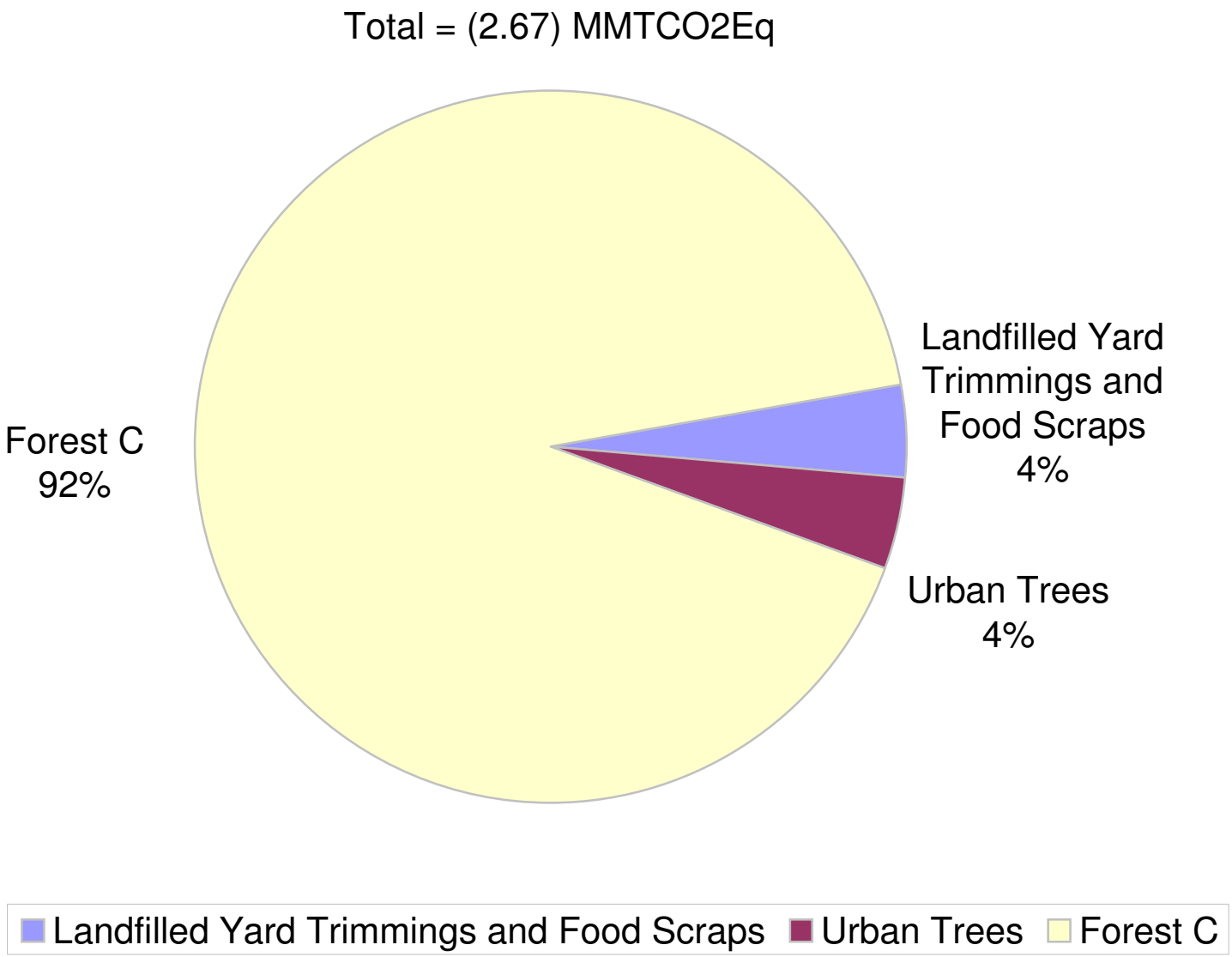

Fig 18. Agriculture, Forestry, and Other Land Use: Sinks, 2007

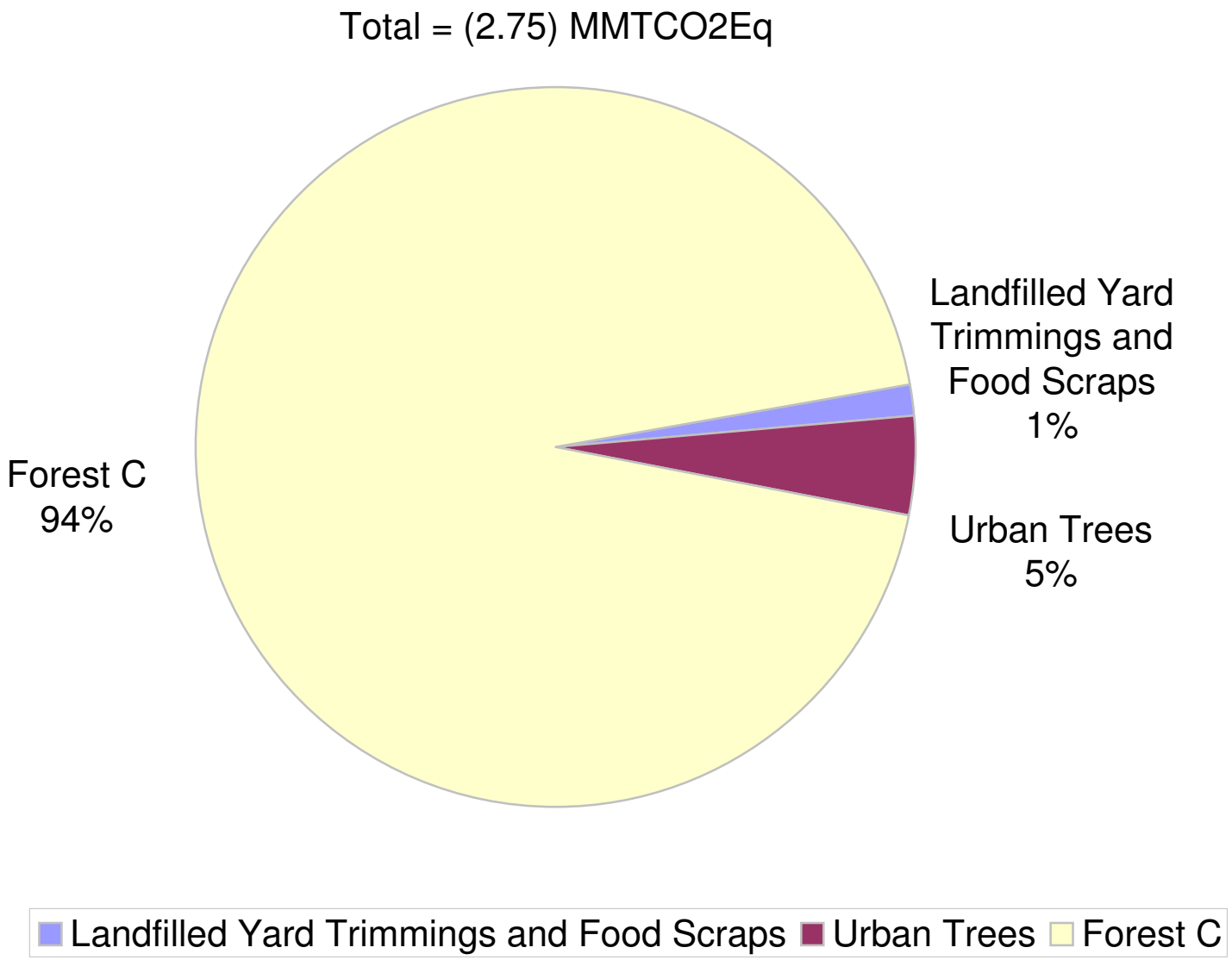

Table A1: Hawaii Sector and Source Category, by Island (1990, 2007)

Emissions (MMTCO2Eq)

	1990						2007					
Source/Island	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**
ENERGY												
Residential	**0.03**	**0.00**	**0.00**	**-**	**-**	***0.03***	**0.05**	**0.00**	**0.00**	**-**	**-**	***0.05***
Hawaii	0.01	0.00	0.00	-	-	***0.01***	0.01	0.00	0.00	-	-	***0.01***
Kauai	0.01	0.00	0.00	-	-	***0.01***	0.00	0.00	0.00	-	-	***0.00***
Lanai	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Maui	0.01	0.00	0.00	-	-	***0.01***	0.00	0.00	0.00	-	-	***0.00***
Molokai	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Niihau	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Oahu	0.01	0.00	0.00	-	-	***0.01***	0.03	0.00	0.00	-	-	***0.03***
Commercial	**0.38**	**0.00**	**0.00**	**-**	**-**	***0.38***	**0.26**	**0.00**	**0.00**	**-**	**-**	***0.26***
Hawaii	0.03	0.00	0.00	-	-	***0.03***	0.04	0.00	0.00	-	-	***0.04***
Kauai	0.02	0.00	0.00	-	-	***0.02***	0.02	0.00	0.00	-	-	***0.02***
Lanai	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Maui	0.03	0.00	0.00	-	-	***0.03***	0.03	0.00	0.00	-	-	***0.03***
Molokai	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Niihau	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Oahu	0.30	0.00	0.00	-	-	***0.30***	0.17	0.00	0.00	-	-	***0.17***
Industrial	**0.69**	**0.00**	**0.00**	**-**	**-**	***0.70***	**0.18**	**0.00**	**0.00**	**-**	**-**	***0.18***
Hawaii	0.19	0.00	0.00	-	-	***0.19***	0.00	0.00	0.00	-	-	***0.00***
Kauai	0.05	0.00	0.00	-	-	***0.05***	0.00	0.00	0.00	-	-	***0.00***
Lanai	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Maui	0.12	0.00	0.00	-	-	***0.12***	0.15	0.00	0.00	-	-	***0.16***
Molokai	0.01	0.00	0.00	-	-	***0.01***	0.01	0.00	0.00	-	-	***0.01***
Niihau	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Oahu	0.33	0.00	0.00	-	-	***0.33***	0.01	0.00	0.00	-	-	***0.01***
Transportation	**12.94**	**0.03**	**0.24**	**-**	**-**	***13.21***	**12.37**	**0.02**	**0.20**	**-**	**-**	***12.58***
Hawaii	0.57	0.00	0.02	-	-	***0.59***	1.25	0.00	0.03	-	-	***1.28***
Kauai	0.24	0.00	0.01	-	-	***0.25***	0.53	0.00	0.01	-	-	***0.54***
Lanai	0.01	0.00	0.00	-	-	***0.02***	0.04	0.00	0.00	-	-	***0.04***
Maui	0.50	0.00	0.02	-	-	***0.52***	1.35	0.00	0.03	-	-	***1.38***
Molokai	0.03	0.00	0.00	-	-	***0.04***	0.09	0.00	0.00	-	-	***0.09***
Niihau	0.00	0.00	0.00	-	-	***0.00***	0.00	0.00	0.00	-	-	***0.00***
Oahu	11.59	0.02	0.19	-	-	***11.80***	9.11	0.01	0.14	-	-	***9.25***
Electric Power	**6.77**	**0.01**	**0.02**	**-**	**-**	***6.79***	**8.72**	**0.01**	**0.02**	**-**	**-**	***8.76***
Hawaii	0.62	0.00	0.00	-	-	***0.62***	0.77	0.00	0.00	-	-	***0.77***
Kauai	0.22	0.00	0.00	-	-	***0.22***	0.35	0.00	0.00	-	-	***0.35***
Lanai	0.02	0.00	0.00	-	-	***0.02***	0.02	0.00	0.00	-	-	***0.02***
Maui	0.58	0.00	0.00	-	-	***0.58***	0.78	0.00	0.00	-	-	***0.78***

	1990						2007					
Source/Island	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**
Molokai	0.04	0.00	0.00	-	-	***0.04***	0.05	0.00	0.00	-	-	***0.05***
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	5.30	0.00	0.01	-	-	***5.32***	6.75	0.00	0.02	-	-	***6.77***
Oil and Gas	**-**	**0.00**	**-**	**-**	**-**	***0.00***	**-**	**0.00**	**-**	**-**	**-**	***0.00***
Hawaii	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Kauai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Lanai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Maui	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Molokai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	-	0.00	-	-	-	***0.00***	-	0.00	-	-	-	***0.00***
International Bunker Fuels	**1.00**	***0.00***	***0.01***	**-**	**-**	***1.01***	**1.31**	***0.00***	***0.01***	**-**	**-**	***1.32***
Hawaii	*0.03*	*0.00*	*0.00*	-	-	***0.03***	*0.04*	*0.00*	*0.00*	-	-	***0.04***
Kauai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Lanai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Maui	*0.05*	*0.00*	*0.00*	-	-	***0.05***	*0.07*	*0.00*	*0.00*	-	-	***0.07***
Molokai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	*0.92*	*0.00*	*0.01*	-	-	***0.93***	*1.20*	*0.00*	*0.01*	-	-	***1.22***
Total (excluding International Bunkers)	***20.82***	**0.04**	**0.26**	**-**	**-**	**21.12**	***21.58***	**0.02**	**0.23**	**-**	**-**	**21.83**
INDUSTRIAL PROCESSES												
Cement Manufacture	**0.10**	**-**	**-**	**-**	**-**	**0.10**	**-**	**-**	**-**	**-**	**-**	**-**
Hawaii	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Kauai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Lanai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Maui	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Molokai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	0.10	-	-	-	-	**0.10**	-	-	-	-	-	**-**
Electricity T&D	**-**	**-**	**-**	**-**	**0.08**	**0.08**	**-**	**-**	**-**	**-**	**0.04**	**0.04**
Hawaii	-	-	-	-	0.01	**0.01**	-	-	-	-	0.00	**0.00**
Kauai	-	-	-	-	0.00	**0.00**	-	-	-	-	0.00	**0.00**
Lanai	-	-	-	-	0.00	**0.00**	-	-	-	-	0.00	**0.00**
Maui	-	-	-	-	0.01	**0.01**	-	-	-	-	0.00	**0.00**
Molokai	-	-	-	-	0.00	**0.00**	-	-	-	-	0.00	**0.00**
Niihau	-	-	-	-	-	-	-	-	-	-	-	**-**
Oahu	-	-	-	-	0.06	**0.06**	-	-	-	-	0.03	**0.03**

	1990						2007					
Source/Island	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**
Substitutes of ODS	-	-	-	-	-	**-**	**-**	**-**	**-**	**0.50**	**-**	**0.50**
Hawaii	-	-	-	-	-	**-**	-	-	-	0.07	-	**0.07**
Kauai	-	-	-	-	-	**-**	-	-	-	0.02	-	**0.02**
Lanai	-	-	-	-	-	**-**	-	-	-	0.00	-	**0.00**
Maui	-	-	-	-	-	**-**	-	-	-	0.07	-	**0.07**
Molokai	-	-	-	-	-	**-**	-	-	-	0.00	-	**0.00**
Niihau	-	-	-	-	-	**-**	-	-	-	0.00	-	**0.00**
Oahu	-	-	-	-	-	**-**	-	-	-	0.34	-	**0.34**
Industrial Processes Total	**0.10**	**-**	**-**	**-**	**0.08**	**0.18**	**-**	**-**	**-**	**0.50**	**0.04**	**0.54**
WASTE												
Municipal Solid Waste - Landfills	**-**	**0.54**	**-**	**-**	**-**	**0.54**	**-**	**0.77**	**-**	**-**	**-**	**0.77**
Hawaii	-	0.06	-	-	-	**0.06**	-	0.12	-	-	-	**0.12**
Kauai	-	0.02	-	-	-	**0.02**	-	0.06	-	-	-	**0.06**
Lanai	-	0.00	-	-	-	**0.00**	-	0.00	-	-	-	**0.00**
Maui	-	0.04	-	-	-	**0.04**	-	0.11	-	-	-	**0.11**
Molokai	-	0.00	-	-	-	**0.00**	-	0.01	-	-	-	**0.01**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	-	0.41	-	-	-	**0.41**	-	0.47	-	-	-	**0.47**
Municipal Solid Waste - Combustion	**0.17**	**-**	**0.00**	**-**	**-**	**0.18**	**0.15**	**-**	**0.00**	**-**	**-**	**0.15**
Hawaii	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Kauai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Lanai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Maui	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Molokai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	0.17	-	0.00	-	-	**0.18**	0.15	-	0.00	-	-	**0.15**
Wastewater	**-**	**0.06**	**0.07**	**-**	**-**	**0.13**	**-**	**0.07**	**0.08**	**-**	**-**	**0.15**
Hawaii	-	0.01	0.01	-	-	**0.01**	-	0.01	0.01	-	-	**0.02**
Kauai	-	0.00	0.00	-	-	**0.01**	-	0.00	0.00	-	-	**0.01**
Lanai	-	0.00	0.00	-	-	**0.00**	-	0.00	0.00	-	-	**0.00**
Maui	-	0.01	0.01	-	-	**0.01**	-	0.01	0.01	-	-	**0.02**
Molokai	-	0.00	0.00	-	-	**0.00**	-	0.00	0.00	-	-	**0.00**
Niihau	-	0.00	0.00	-	-	**0.00**	-	0.00	0.00	-	-	**0.00**
Oahu	-	0.04	0.05	-	-	**0.09**	-	0.04	0.06	-	-	**0.10**
Waste Total	**0.17**	**0.60**	**0.07**	**-**	**-**	**0.85**	**0.15**	**0.83**	**0.08**	**-**	**-**	**1.07**
Agriculture, Forestry and Other Land Use (Agricultural Sources)												
Enteric Fermentation	**-**	**0.27**	**-**	**-**	**-**	**0.27**	**-**	**0.25**	**-**	**-**	**-**	**0.25**

	1990						2007					
Source/Island	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**
Hawaii	-	0.20	-	-	-	**0.20**	-	0.19	-	-	-	**0.19**
Kauai	-	0.02	-	-	-	**0.02**	-	0.02	-	-	-	**0.02**
Lanai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Maui	-	0.05	-	-	-	**0.05**	-	0.03	-	-	-	**0.03**
Molokai	-	0.00	-	-	-	**0.00**	-	0.00	-	-	-	**0.00**
Niihau	-	0.00	-	-	-	**0.00**	-	0.00	-	-	-	**0.00**
Oahu	-	0.00	-	-	-	**0.00**	-	0.00	-	-	-	**0.00**
Manure Management	**-**	**0.10**	**0.02**	**-**	**-**	**0.12**	**-**	**0.04**	**0.01**	**-**	**-**	**0.05**
Hawaii	-	0.02	0.01	-	-	**0.03**	-	0.01	0.01	-	-	**0.02**
Kauai	-	0.00	0.00	-	-	**0.01**	-	0.00	0.00	-	-	**0.00**
Lanai	-	0.00	0.00	-	-	**0.00**	-	0.00	0.00	-	-	**0.00**
Maui	-	0.01	0.00	-	-	**0.01**	-	0.00	0.00	-	-	**0.00**
Molokai	-	0.00	0.00	-	-	**0.00**	-	0.00	0.00	-	-	**0.00**
Niihau	-	0.00	0.00	-	-	**0.00**	-	0.00	0.00	-	-	**0.00**
Oahu	-	0.07	0.00	-	-	**0.07**	-	0.02	0.00	-	-	**0.02**
Agricultural Soil Management	**-**	**-**	**0.19**	**-**	**-**	**0.19**	**-**	**-**	**0.17**	**-**	**-**	**0.17**
Hawaii	-	-	0.10	-	-	**0.10**	-	-	0.10	-	-	**0.10**
Kauai	-	-	0.02	-	-	**0.02**	-	-	0.02	-	-	**0.02**
Lanai	-	-	0.01	-	-	**0.01**	-	-	0.00	-	-	**0.00**
Maui	-	-	0.04	-	-	**0.04**	-	-	0.03	-	-	**0.03**
Molokai	-	-	0.00	-	-	**0.00**	-	-	0.00	-	-	**0.00**
Niihau	-	-	0.00	-	-	**0.00**	-	-	0.00	-	-	**0.00**
Oahu	-	-	0.02	-	-	**0.02**	-	-	0.02	-	-	**0.02**
Field Burning of Agricultural Residues	**-**	**0.02**	**0.00**	**-**	**-**	**0.03**	**-**	**0.00**	**0.00**	**-**	**-**	**0.01**
Hawaii	-	0.01	0.00	-	-	**0.01**	-	-	-	-	-	**-**
Kauai	-	0.01	0.00	-	-	**0.01**	-	0.00	0.00	-	-	**0.00**
Lanai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Maui	-	0.01	0.00	-	-	**0.01**	-	0.00	0.00	-	-	**0.00**
Molokai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	-	0.00	0.00	-	-	**0.00**	-	-	-	-	-	**-**
Agriculture SubTota	-	***0.39***	***0.22***	***-***	***-***	***0.60***	***-***	***0.29***	***0.18***	***-***	***-***	***0.47***
Agriculture, Forestry and Other Land Use (Forestry and Other Land Use Sources/Sinks)												
Urea Application	**0.00**	**-**	**-**	**-**	**-**	**0.00**	**0.00**	**-**	**-**	**-**	**-**	**0.00**
Hawaii	0.00	-	-	-	-	**0.00**	0.00	-	-	-	-	**0.00**
Kauai	0.00	-	-	-	-	**0.00**	0.00	-	-	-	-	**0.00**
Lanai	0.00	-	-	-	-	**0.00**	0.00	-	-	-	-	**0.00**

	1990						2007					
Source/Island	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**
Maui	0.00	-	-	-	-	**0.00**	0.00	-	-	-	-	**0.00**
Molokai	0.00	-	-	-	-	**0.00**	0.00	-	-	-	-	**0.00**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	0.00	-	-	-	-	**0.00**	0.00	-	-	-	-	**0.00**
Agricultural Soil C	**0.22**	**-**	**-**	**-**	**-**	**0.22**	**0.24**	**-**	**-**	**-**	**-**	**0.24**
Hawaii	0.09	-	-	-	-	**0.09**	0.10	-	-	-	-	**0.10**
Kauai	0.04	-	-	-	-	**0.04**	0.04	-	-	-	-	**0.04**
Lanai	0.01	-	-	-	-	**0.01**	0.01	-	-	-	-	**0.01**
Maui	0.05	-	-	-	-	**0.05**	0.05	-	-	-	-	**0.05**
Molokai	0.00	-	-	-	-	**0.00**	0.00	-	-	-	-	**0.00**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	0.04	-	-	-	-	**0.04**	0.04	-	-	-	-	**0.04**
Landfilled Yard Trimmings and Food Scraps	**(0.11)**	**-**	**-**	**-**	**-**	**(0.11)**	**(0.03)**	**-**	**-**	**-**	**-**	**(0.03)**
Hawaii	(0.01)	-	-	-	-	**(0.01)**	(0.00)	-	-	-	-	**(0.00)**
Kauai	(0.01)	-	-	-	-	**(0.01)**	(0.00)	-	-	-	-	**(0.00)**
Lanai	(0.00)	-	-	-	-	**(0.00)**	(0.00)	-	-	-	-	**(0.00)**
Maui	(0.01)	-	-	-	-	**(0.01)**	(0.00)	-	-	-	-	**(0.00)**
Molokai	(0.00)	-	-	-	-	**(0.00)**	(0.00)	-	-	-	-	**(0.00)**
Niihau	(0.00)	-	-	-	-	**(0.00)**	(0.00)	-	-	-	-	**(0.00)**
Oahu	(0.08)	-	-	-	-	**(0.08)**	(0.02)	-	-	-	-	**(0.02)**
Urban Trees	**(0.11)**	**-**	**-**	**-**	**-**	**(0.11)**	**(0.13)**	**-**	**-**	**-**	**-**	**(0.13)**
Hawaii	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Kauai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Lanai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Maui	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Molokai	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	(0.11)	-	-	-	-	**(0.11)**	(0.13)	-	-	-	-	**(0.13)**
Forest C	**(2.45)**	**-**	**-**	**-**	**-**	**(2.45)**	**(2.59)**	**-**	**-**	**-**	**-**	**(2.59)**
Hawaii	(1.53)	-	-	-	-	**(1.53)**	(1.72)	-	-	-	-	**(1.72)**
Kauai	(0.29)	-	-	-	-	**(0.29)**	(0.27)	-	-	-	-	**(0.27)**
Lanai	(0.02)	-	-	-	-	**(0.02)**	(0.02)	-	-	-	-	**(0.02)**
Maui	(0.35)	-	-	-	-	**(0.35)**	(0.34)	-	-	-	-	**(0.34)**
Molokai	(0.03)	-	-	-	-	**(0.03)**	(0.00)	-	-	-	-	**(0.00)**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	(0.22)	-	-	-	-	**(0.22)**	(0.23)	-	-	-	-	**(0.23)**
Forest Fires	**0.15**	**0.01**	**0.00**	**-**	**-**	**0.16**	**0.11**	**0.01**	**0.00**	**-**	**-**	**0.12**
Hawaii	0.08	0.01	0.00	-	-	**0.09**	0.07	0.01	0.00	-	-	**0.08**
Kauai	0.02	0.00	0.00	-	-	**0.03**	0.02	0.00	0.00	-	-	**0.02**

	1990						2007					
Source/Island	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**	**CO2**	**CH4**	**N2O**	**HFCs & PFCs**	**SF6**	**Total**
Lanai	0.00	0.00	0.00	-	-	**0.00**	0.00	0.00	0.00	-	-	**0.00**
Maui	0.02	0.00	0.00	-	-	**0.02**	0.01	0.00	0.00	-	-	**0.02**
Molokai	0.00	0.00	0.00	-	-	**0.00**	0.00	0.00	0.00	-	-	**0.00**
Niihau	-	-	-	-	-	**-**	-	-	-	-	-	**-**
Oahu	0.02	0.00	0.00	-	-	**0.02**	0.01	0.00	0.00	-	-	**0.01**
Forestry and Other Land Use Total	***(2.30)***	***0.01***	***0.00***	***-***	***-***	***(2.29)***	***(2.40)***	***0.01***	***0.00***	***-***	***-***	***(2.39)***
AFOLU (Sources)	**0.37**	**0.40**	**0.22**	**-**	**-**	**0.98**	**0.35**	**0.30**	**0.18**	**-**	**-**	**0.83**
AFOLU (Sinks)	***(2.67)***	***-***	***-***	***-***	***-***	***(2.67)***	***(2.75)***	***-***	***-***	***-***	***-***	***(2.75)***
Agriculture, Forestry and Other Land Use Total	**-2.30**	**0.40**	**0.22**	**0.00**	**0.00**	**-1.69**	**-2.40**	**0.30**	**0.18**	**0.00**	**0.00**	**-1.92**
TOTAL Emissions (Excluding Sinks)	**21.46**	**1.04**	**0.55**	**0.00**	**0.08**	**23.13**	**22.08**	**1.16**	**0.49**	**0.50**	**0.04**	**24.27**
TOTAL Net Emissions (Including Sinks)	**18.79**	**1.04**	**0.55**	**0.00**	**0.08**	**20.46**	**19.33**	**1.16**	**0.49**	**0.50**	**0.04**	**21.52**