

Energy and Greenhouse Gas Solutions
Hawai'i Greenhouse Gas Emissions Profile
1990 and 2005

January 30, 2009

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Executive Summary

Global climate change is among the most monumental environmental issues facing our planet and the Hawaiian Islands. To address this issue, scientists are calling for a sharp reduction in greenhouse gas (GHG) emissions.

Lawmakers have been responding to the call by scientists to take action. In 2007, Governor Lingle enacted the Global Warming Act, which requires Hawai'i to return its greenhouse gas emissions to 1990 levels by 2020. On the campaign trail, President Obama pledged to adopt similar targets and enact strong Federal legislation on energy and climate change. International negotiations are scheduled to proceed in Copenhagen this spring with the intent of revamping Kyoto Protocol commitments.

- Hawai'i's greenhouse gas (GHG) emissions have increased by 23.0 percent in the past 15 years.¹
- 91.4 percent of Hawai'i's GHG emissions result from the combustion of fossil fuels.
- On a per-dollar basis, Hawai'i's GHG emissions have gone up by 7.6 percent since 1990, excluding air transportation and non-domestic maritime activities.
- Hawai'i emissions per capita are approximately 15.0 metric tons of CO₂ equivalent, an increase of 8.1 percent above 1990 levels, excluding air and international maritime transportation.
- Electrical power production is the largest source of GHG emissions in the state at 8.4 million metric tons of CO₂ equivalent in 2005.
- Ground transportation activities are the most significant source of GHG emissions growth, with an increase of 53 percent since 1990.
- GHG emissions from air transportation activities are estimated to have decreased significantly even as the number of passenger miles grew. Aircraft fuel efficiency, capacity management, improved air traffic control practices, and direct neighbor island flights from the U.S. mainland explain the decrease in Hawai'i jet fuel and aviation gasoline consumption.
- Depending on assumptions about the growth in Hawai'i's economy, vehicle fuel efficiency, and the electric sector's conversion to cleaner fuels, Hawai'i's 2020 GHG emissions are projected to only change slightly from 2005 levels. Based on these estimates, the state would need to reduce its GHG emissions by 13% to 23% from baseline levels to comply with Act 234.²

¹ The Hawai'i Global Warming Act of 2007, Act 234, and international protocols restrict regional emissions to the gases emitted within borders. Air transportation and international marine transportation are specifically excluded. If these sources are included, Hawai'i's emissions would have increased by only 7.1 percent.

² Hawai'i Emissions Forecasts and Their Implications for Complying with Act 234, EGGs, 2009

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Introduction

Over the past several decades, the concentration of greenhouse gases (GHGs) has been rising at an unprecedented rate.³ Most atmospheric scientists and climatologists believe that these elevated GHG concentrations are responsible for increases in temperatures and changes in climate, including extreme weather. The leading scientific authority on climate change states that there is over 90 percent certainty that the net effect of human activity is one of warming since 1750.³ Anthropogenic, or from human activity, emissions has driven atmospheric carbon dioxide concentrations to their highest in over six hundred fifty thousand years.^{3,4} The likely effects of climate change place Hawai'i's ecosystem and economy in a precarious position.

In an effort to effect national and global climate change policy to address the increase in greenhouse gas emissions, the Hawai'i legislature passed the Global Warming Solutions Act of 2007, Act 234. Act 234 calls for Hawai'i to return its greenhouse gas (GHG) emissions to 1990 levels by 2020. The law provides for a 10-member task force to create a work plan by the end of 2009 to reduce emissions to targeted levels.

To understand the impact of these required emissions reductions on Hawai'i's economy in terms of its energy usage and industrial output, one needs to know what 1990 GHG emissions were and how emissions have grown since 1990 to today and how much emissions are likely to grow by 2020 if Act 234 were not in place. To do this, we have undertaken two analyses: first, we developed an emissions inventory for the state for the years 1990 and 2005; second, we forecasted emissions growth out to 2020 – this forecast makes use of the trends resulting from this analysis to provide projections of future emissions for the state of Hawai'i. This paper covers the first analysis. The second analysis is described in a separate paper.

In this report, we examine Hawai'i's GHG emissions profile in 1990 and 2005 using Hawai'i-specific data. We find that carbon dioxide (CO₂) is, by far, the most significant greenhouse gas emitted, largely due to the combustion of fossil fuels. The most significant source of growth is ground transportation, which experienced a 53 percent increase in GHG emissions from 1990 to 2005. Electric power generation resulted in 22 percent higher emissions levels in 2005. Non-energy sources of emissions, such as industrial processes, agriculture and municipal solid waste, also grew rapidly but beginning from a relatively small base. Air transportation emissions declined even as the number of passengers grew. Residential, commercial and industrial direct emissions also contracted.

³ Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007 Synthesis Report*, Cambridge University Press.

⁴ Siegenthaler, U., T. F. Stocker, et al. (2005). "Stable Carbon Cycle-Climate Relationship During the Late Pleistocene." *Science* **310**(5752): 1313-1317.

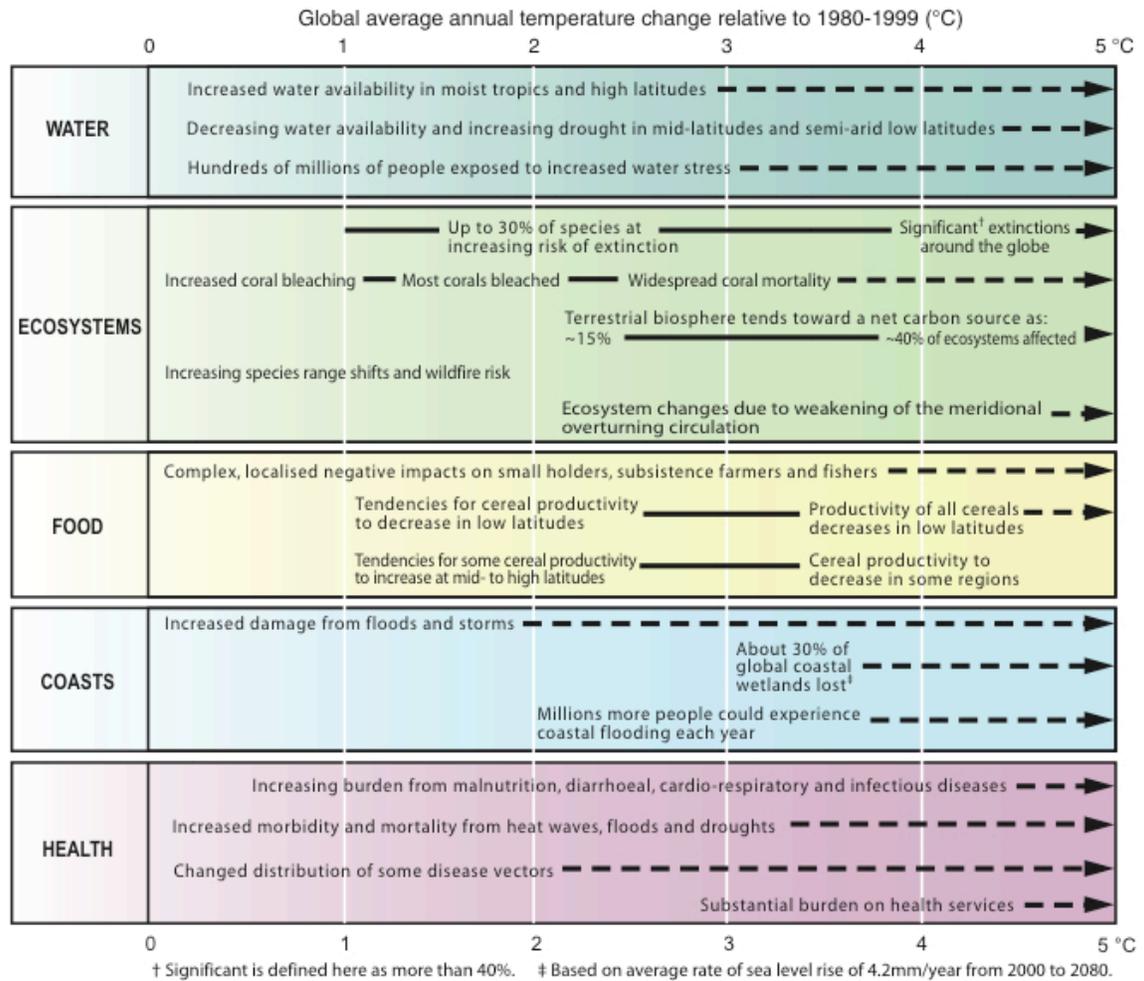
Greenhouse Gases and Global Climate Change

Carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), along with other compounds, are naturally occurring gases in the atmosphere that serve an important function of regulating the Earth's climate. Solar radiation reaches the Earth from the sun and warms the surface. A portion of this energy reflects back to space in the form of infrared, or thermal, radiation. GHGs absorb infrared radiation, and so keep some of the energy from escaping into space, thereby trapping heat in the atmosphere. The resulting "natural greenhouse effect" is the reason why the planet is some 30°C warmer than it would be without these natural greenhouse gases – a condition essential for life as we know it.

Emissions of anthropogenic greenhouse gases (GHG) increase the amount of heat trapped in the atmosphere. To sustain a radiative balance, the Earth must get rid of energy at the same rate at which it receives energy from the sun. Since the human input of GHGs reduces the amount of energy that escapes from the atmosphere to outer space, the Earth's surface must warm to radiate more energy into the atmosphere. This is how the climate adjusts to restore the balance between incoming and outgoing energy, which is known as the "enhanced greenhouse effect".

The climate adjusts in large part through an overall increase in temperature of the Earth's surface and lower atmosphere. This rise in temperature is accompanied by other changes, for example in cloud cover and wind patterns. Some of these changes enhance the warming further (positive feedbacks), while others counteract it (negative feedbacks). Figure 1 lists the best overall estimates of impacts based on global temperature increases.

Figure 1: Projected impacts from global average temperature change (IPCC, 2007⁵)



⁵ Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007 Synthesis Report*, Cambridge University Press.

Table 1: Principal greenhouse gases and their sources

Symbol	Name	Common Source
CO ₂	Carbon Dioxide	Burning fossil fuels, solid waste, and wood; chemical reactions (e.g. cement manufacturing). Can be removed when absorbed by plants as part of the carbon cycle, a process referred to as sequestration.
CH ₄	Methane	Production and transport of coal, oil, and natural gas; livestock and agricultural activities; decay of organic waste, and combustion of fossil fuels.
N ₂ O	Nitrous Oxide	Agricultural and industrial activities; combustion of fossil fuels.
CFCs 11 and 12, HFCs, PFCs, and SF ₆	Chlorofluorocarbons, Hydrofluorocarbons, Perfluorocarbons, and Sulfur Hexafluoride	Industrial processes; refrigeration; air conditioning; aerosols, foam blowing, solvents.

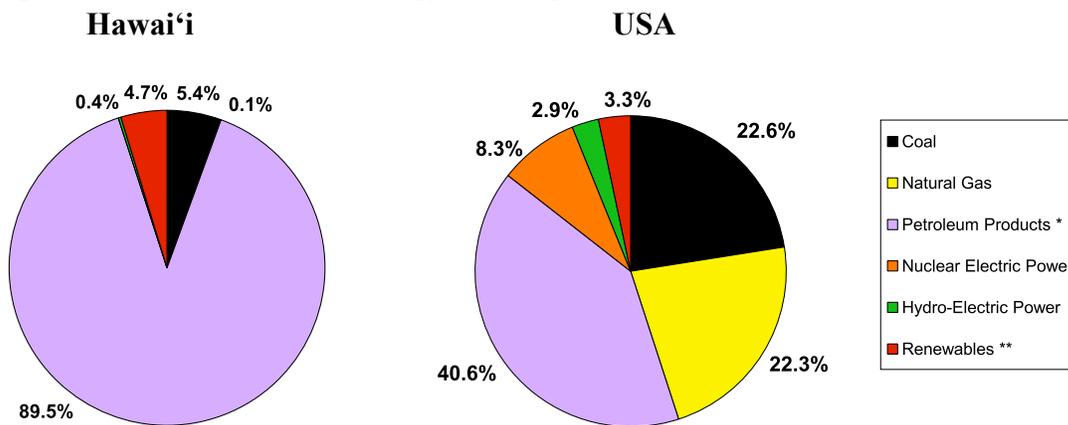
Of the main atmospheric greenhouse gases, carbon dioxide is the most important in terms of global warming. Carbon dioxide absorbs less energy per molecule than other GHGs such as methane and nitrous oxide, but the amount of CO₂ emissions are far greater than any of the other GHGs.

Energy and Greenhouse Gas Emissions in Hawai‘i

The energy and greenhouse gas emissions profile for the State of Hawai‘i is distinguished from that of the Continental USA.

Energy use in Hawai‘i is amongst the lowest in America. Out of 50 states and the District of Columbia, Hawai‘i ranks 47 in electricity use per capita, 43 for total energy use and 1 for energy prices.⁶ Due to a mild climate, many Hawai‘i households do not require home heating or air conditioning. Driving distances are shorter leading to fewer vehicle miles traveled per vehicle. Hawai‘i’s primary civilian industries are tourism and residential services (health, financial, education, etc). There are few manufacturing activities, and a small agricultural sector. Mobile energy sources account for over half of Hawai‘i’s greenhouse gas emissions. Air and maritime transportation are particularly important because of the long distances to ship goods to Hawai‘i and the large tourism industry. This contrasts with the U.S. where mobile sources account for only one-third of total GHG emissions.

⁶ Annual Energy Review 2007, Department of Energy, Energy Information Agency

Figure 2: Hawai'i and U.S. energy consumption 2007

*Petroleum Products: Av. gasoline, motor gasoline, residual fuel oil, distillate fuel oil, jet fuel, kerosene, LPG and other petroleum products.

** Renewables: biomass, geothermal, wind, photovoltaic, solar thermal energy, and net imports of electricity (mainland USA only).

Hawai'i's energy infrastructure is unique. Petroleum products fuel approximately nine-tenths of all energy use in Hawai'i as opposed to 40.6 percent for the U.S. as a whole. Two local oil refineries, Chevron and Tesoro, provide most petroleum products used in Hawai'i. Petroleum fired power plants supply about 75 percent of Hawai'i's electricity. Coal provides 18 percent, and renewable sources provide about 6 percent. For the U.S., coal and natural gas are the main fossil fuels used to generate electricity accounting for 51.4 and 17 percent, respectively, of generation.⁷

Table 2 provides the major sources of Hawai'i GHG emissions for 1990 and 2005. The data and methodology used by UHERO-EGGS to compile the GHG emissions listed in Table 2 are summarized in an appendix to this report. GHG emissions are reported in millions of metric tons of carbon dioxide equivalence (MMTCO₂e) and include the six main greenhouse gases: carbon dioxide, methane, nitrous oxide, and HFCs, PFCs, and SF₆. Emissions of non-CO₂ are converted to CO₂ equivalent by multiplying each gas by its global warming potential (GWP).⁸ In this study, potential carbon sinks are excluded. The table aggregates emissions from almost all activities into major categories. Emissions are reported to the nearest one hundred thousand metric tons. Because Act 234 excludes emissions from air transport and non-domestic marine transport, Table 2 reports total Hawai'i emissions inclusive and exclusive of emissions from these two categories. The composition of Hawai'i's GHG emissions in 2005 is given in Figure 3.

⁷ Annual Energy Review 2007, Department of Energy, Energy Information Agency

⁸ **Global warming potential (GWP)** is a measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is a relative scale, which compares the gas to that of the same mass of carbon dioxide (whose GWP is by definition 1). The GWP are taken for 100 years. For example, methane is taken to be 25, and nitrous oxide is taken to be 298.

Table 2: Hawai'i's greenhouse gas emissions sources (MMTCO₂E)

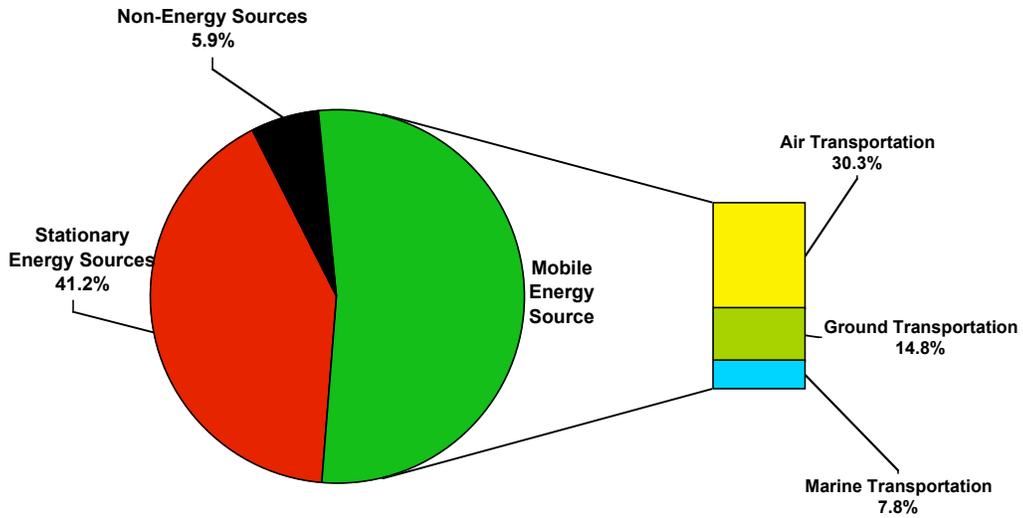
Emission Source	1990	2005
Energy Sources	23.2	24.2
Stationary Energy Sources	10.2	10.9
Electric Power Sector	6.8	8.4
Residential Energy Sector	0.4	0.3
Commercial Energy Sector	0.8	0.3
Industrial Energy Sector	2.2	1.9
Mobile Energy Sources	13.1	13.3
Air Transportation Sector	7.5	6.0
Ground Transportation Sector	3.7	5.6
Marine Transportation Sector	1.9	1.7
Non-Energy Sources	1.5	2.3
Industrial Processes Sector	0.2	0.8
Agriculture Sector	0.6	0.5
Waste	0.6	1.0
Municipal Solid Waste	0.5	0.8
Wastewater Sector	0.1	0.1
Total without Air and International Marine	15.4	19.0
Grand Total	24.7	26.4

Several major trends are evident.

- Total Hawai'i GHG emissions covered by Act 234 increased by 23 percent from 1990 to 2005, excluding air transport and non-state maritime transport.
- Electric power production contributes 6.8 and 8.4 MMTCO₂e in 1990 and 2005 respectively and is the largest contributing sector to Hawai'i's total GHG emissions.
- Combined, the power and transportation sectors are responsible for about 82 percent of total Hawai'i GHG emissions and about 75 percent of emissions covered by Act 234. Mobile energy sources comprise more than half of all GHG emissions in Hawai'i. Air transportation contributes 22.7 percent and ground transport 21.2 percent.
- Air transportation emissions are estimated to have decreased from 7.5 to 6.0 MMTCO₂e from 1990 to 2005, a 20 percent decline.
- Ground transportation emissions have surged from 3.7 to 5.6 MMTCO₂e in the span of 15 years.
- Non-energy sources of emissions are estimated to be a source of small but rapidly growing GHG emissions.
- If emissions from air transport and non-domestic marine are excluded the electric and remaining transport sector still account for almost 70% and 75% of total Hawai'i GHG emissions in 1990 and 2005, respectively.

Figure 3: Share of GHG emissions by major categories for 1990 and 2005

1990



2005

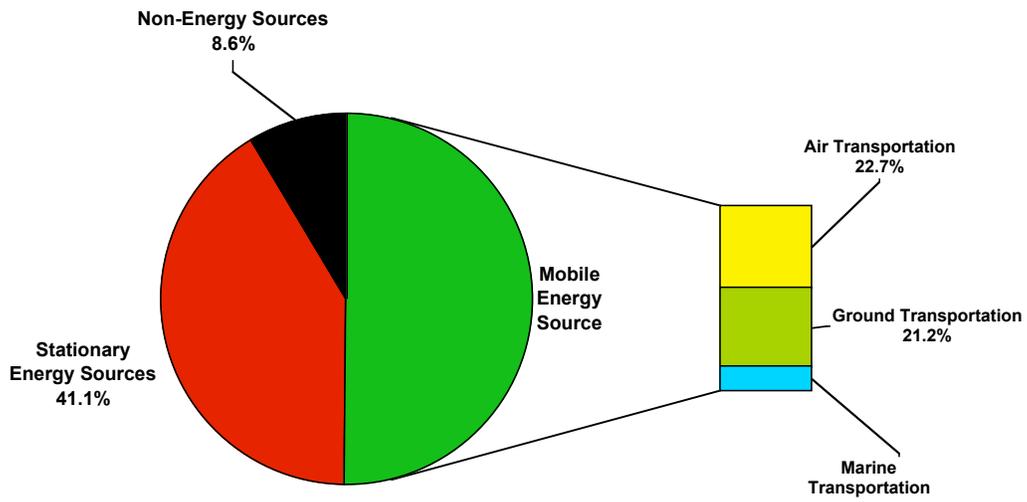
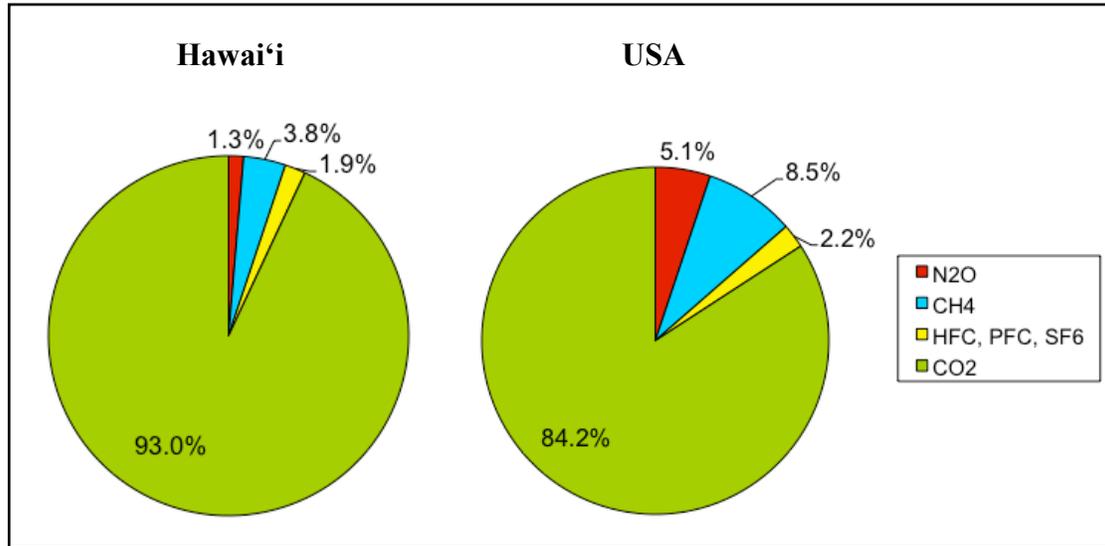


Figure 4: Share of GHG emissions by gas for Hawai‘i and the USA, 2005

Source: UHERO; Annual Energy Review, Department of Energy, Energy Information Agency, Report Number DOE/EIA-0384(2007) <http://www.eia.doe.gov/emeu/aer>

Act 234 calls for reducing total GHG emissions, not merely CO₂ emissions. Therefore, in addressing emission sources, regulators must know which GHGs are the biggest contributors. Figure 4 compares the composition of Hawai‘i’s greenhouse gas profile with that of the United States for the year 2005. Emission shares are denoted in tons of carbon dioxide (CO₂) equivalent. As shown, 93 percent of Hawai‘i and 84 percent of US GHG emissions are in the form of CO₂. The relatively high share of carbon dioxide emissions is attributable to Hawai‘i’s and the U.S.’s reliance on fossil fuels for energy. Methane (CH₄) and nitrous oxide (N₂O) are a relatively small component of Hawai‘i’s GHG emissions profile at 3.8 and 1.3 percent respectively.

- In addressing emissions sources, regulators must focus on CO₂ emissions from combustion of fossil fuels since almost 93 percent of total emissions are from CO₂. When emissions from air transport are omitted, the share of CO₂ emissions exceeds 90 percent.
- The majority of Hawai‘i’s CO₂ emissions result from the combustion of refined petroleum products. About 6 percent of CO₂ emissions come from the burning of coal at AES Hawai‘i on Oahu and at the Hawai‘i Commercial and Sugar on Maui.
- Therefore, policies aimed at reducing oil consumption for sustainability or energy security reasons will also benefit the state in terms of reducing its GHG emissions.

- Methane is the second-most important GHG in terms of global warming potential. The main sources of methane emissions are related to agricultural practices, land use changes, and waste management activities
- The remaining non-carbon GHGs are less important in terms of their contribution to global warming.

To understand how Hawai'i's economy must adjust to comply with Act 234, we report on GHG emissions Figures 5 and 6 in metric tons of CO₂ per capita. From 1990 to 2005, emissions per capita have remained relatively flat. Since Hawai'i's population has grown, overall state emissions have increased.

Figure 6 includes only GHGs that are covered by Act 234. Act 234 excludes air transport (where there have been GHG emissions reduction efficiency gains) and non-intrastate maritime transport. On a per capita basis, emissions of Act 234 GHGs have increased by about 0.7 metric tons CO₂ equivalent.

Figure 5: Emissions per capita (MTCO₂E/capita)

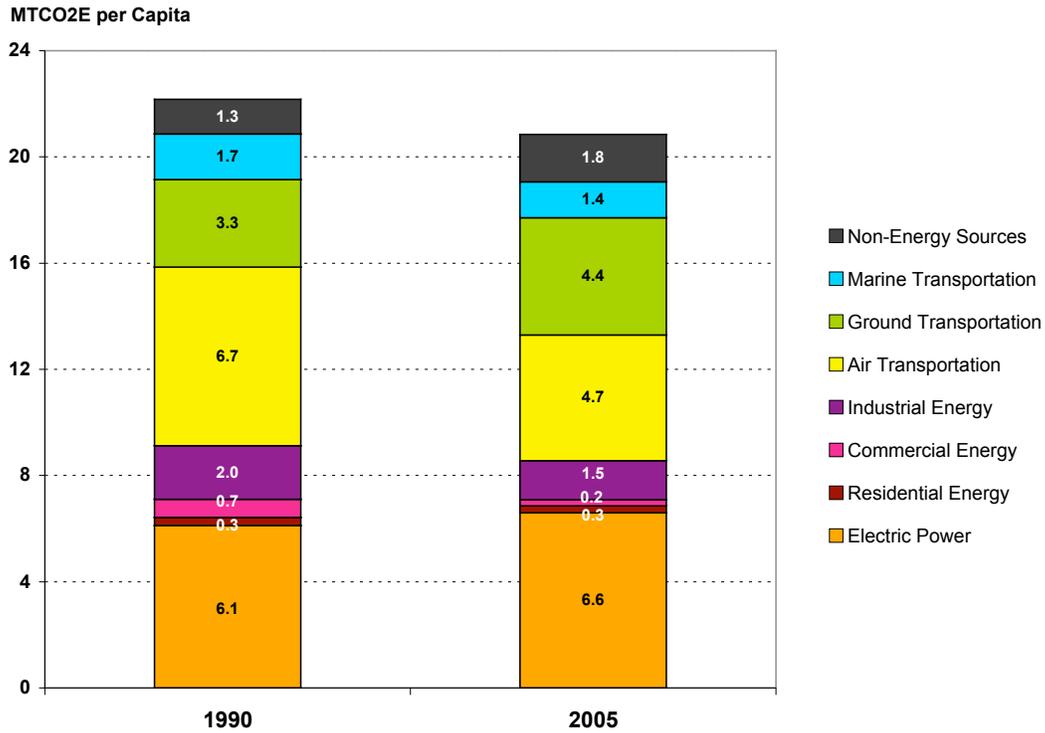
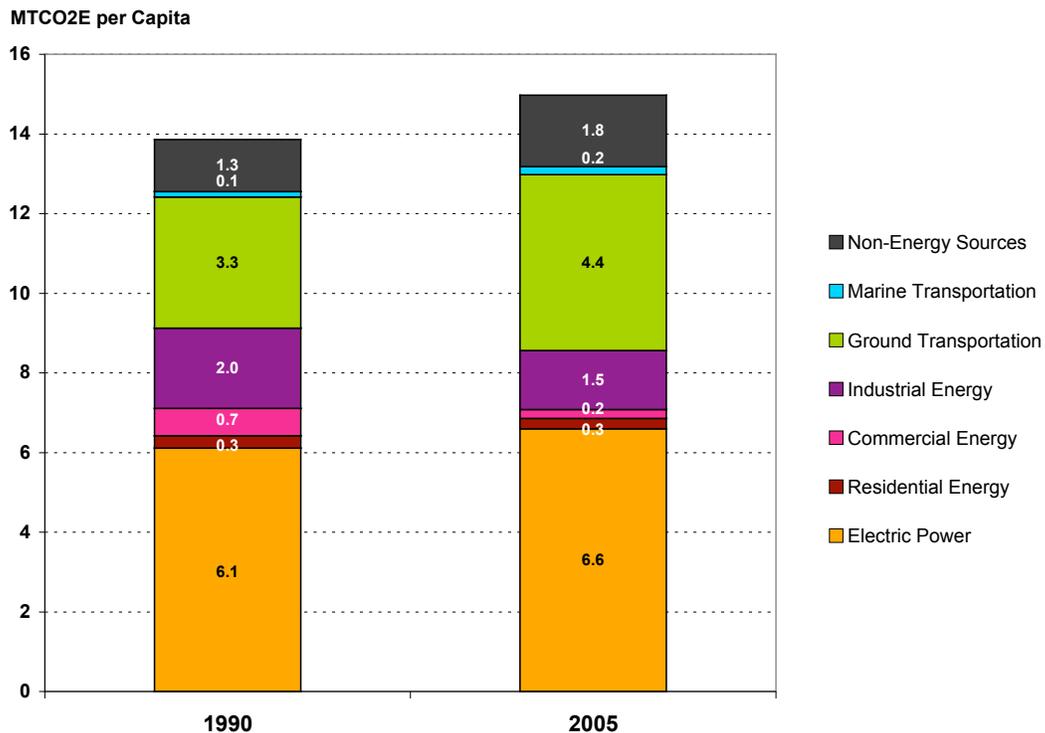


Figure 6: Emissions per capita omitting air transport and non-domestic marine (MTCO₂E/capita)



Figures 7 and 8 show GHG emissions per real dollar of gross state product for all sources and those covered under Act 234 respectively. GHG emissions per real dollar of GSP have declined over time when including Hawai'i's comprehensive GHG profile, Figure 6. However, when air transport and non-domestic maritime activities are omitted, GHG emissions per real dollar of GSP have increased from 1990 to 2005 by 0.016 kilograms CO₂ /\$ of GSP, or almost four percent. Hawai'i's economy has tended to grow in ways that are increasing our carbon footprint.

UHERO is launching a comprehensive evaluation of the drivers of GHG emissions trends. Three possible factors could explain Hawai'i's growing carbon-intensity per dollar of output. First, residential development is expanding in locations further from urban employment centers. This has resulted in increased commuting time and ground transportation emissions. Second, Hawai'i's visitors are heavy energy users of power and transportation services, and the economy continues to focus more on tourism. Finally, Hawai'i relies heavily on fossil fuels for power and has a relatively small component of renewable energy in its power profile. These factors will be included in UHERO's on-going evaluation.

Air transport activities have become less energy and GHG intensive as aircraft have become more fuel efficient, and transportation management techniques have provided higher load factors. GHG emissions per dollar of airline activity (and on a per-passenger basis) have declined over the 15-year span.

Figure 8 reveals an upward relationship between Hawai'i economic activity and GHG emissions when air transport and non-domestic marine are excluded. In other words, each dollar of Hawai'i's economic activity is associated with higher GHG impact in 2005 than 15 years earlier. Electricity emissions increased by 0.01 KG of CO₂ equivalent, or 5.8 percent, per real dollar of Hawai'i output. Ground transportation emissions are increasing by 33.3 percent per real dollar of Hawai'i gross state product. While most per dollar sources of emissions are relatively flat or decreasing, ground transportation emissions are increasing at a rate substantially above the increase in real gross state product.

Figure 7: Emissions per real dollar of gross state product (KgCO2e/Real \$ GSP)

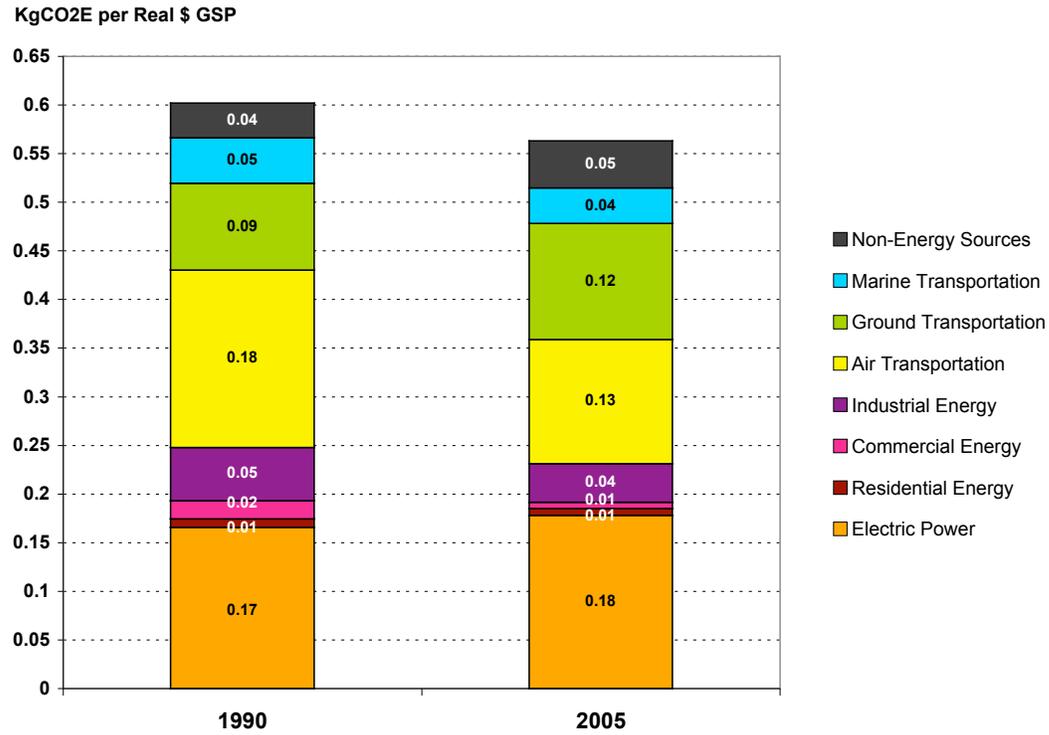


Figure 8: Emissions per real dollar of gross state product omitting air transport and non-domestic marine (KgCO2e/Real \$ GSP)

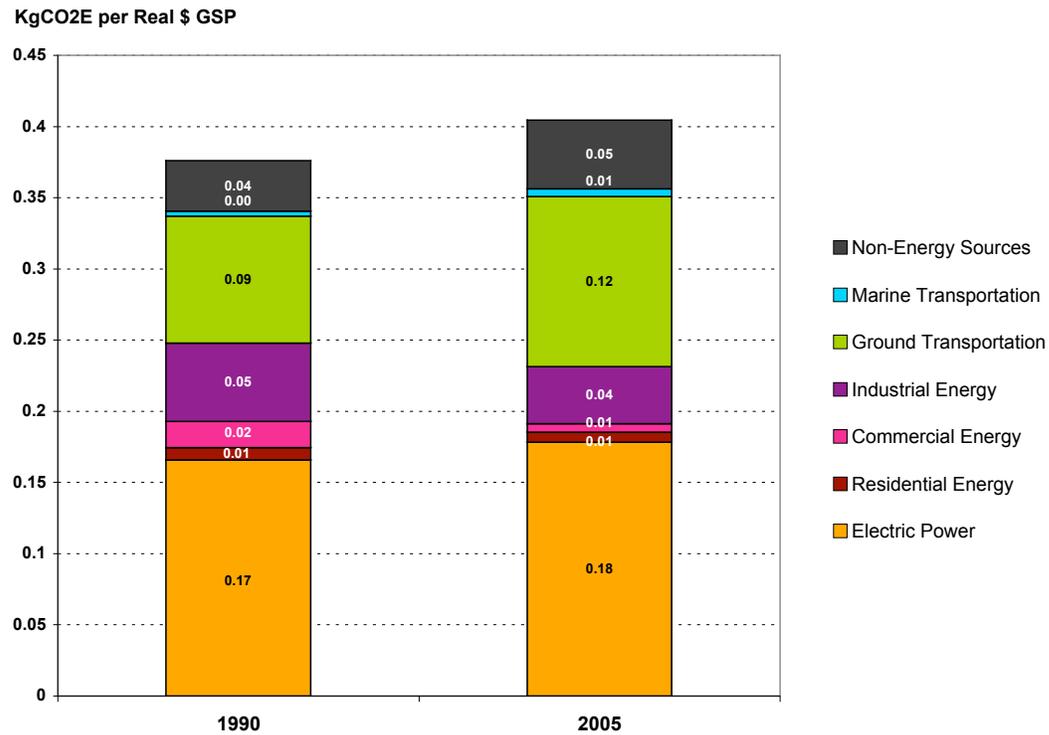
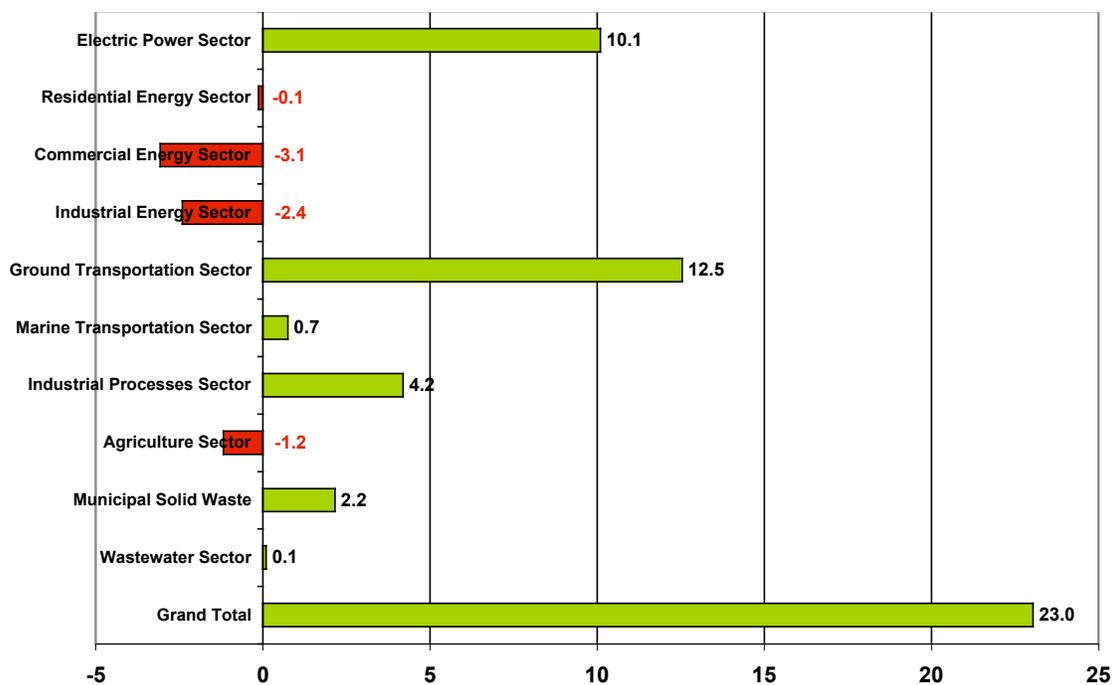


Figure 9 displays the share of total emissions growth from 1990 to 2005 attributable to various sectors when emissions from air and non-domestic marine are excluded. For example, ground transportation accounts for over 50% of the growth which represents a 12.5% increase in statewide emissions from 1990 levels. Emissions growth in the electric power sector contributed over 10 percent of the total growth in emissions, largely attributable to the addition of coal-fired power production. On the other extreme, the residential, commercial and industrial sectors' direct emissions (i.e. excludes indirect emissions from ground transportation and electricity consumption) declined over the study period.

Figure 9: Normalized rate of change with respect to total 1990 emissions under Act 234, 1990 to 2005 (%)



Next Steps

Having identified many of the trends in Hawai'i's GHG emissions profile the next stage for UHERO EGGS is in progress. At present, our group is producing several specialized reports based on our findings and community engagement:

- Concepts in Greenhouse Gas Regulation: A Primer on Meeting Act 234
- An Overview of U.S. Regional & National Climate Change Policy: Lessons for Hawai'i
- Greenhouse Gas Emissions and Hawai'i's Economic Activity
- Greenhouse Gas Emissions in Hawai'i's Transportation Sectors

We encourage an active dialogue with all stakeholders.

APPENDIX: Methods and Data

Following the guidance of national and international efforts, we developed a Hawai'i emissions inventory for the six major greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). The primary guidance tools used were:

- *Guidelines for National Greenhouse Gas Inventories*, produced by the Intergovernmental Panel on Climate Change (IPCC, 2006)
- *Draft State Greenhouse Gas Inventory Tool*, produced by the U.S. Environmental Protection Agency (U.S. EPA, July 2008)
- *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard, Revised Edition*, produced by the World Resources Institute and World Business Council for Sustainable Development (WRI/WBCSD, 2004)

The IPCC (2006) divides GHG emissions into four sectors: 1) Energy, 2) Industrial Processes and Product Use, 3) Agriculture, Forestry and Other Land Use, and 4) Waste. Under United Nations Framework Convention on Climate Change (UNFCCC), reporting guidelines for national GHG inventories of the Parties, international transport fuels are excluded from the national inventory totals, but are to be reported separately. We generally followed this format and developed an inventory with the following structure:

Energy

Stationary Energy Sources

Electric Power

GHG emissions from all fuel combustion in electricity generation from main activity producers.

Commercial

GHG emissions from fuel combustion in commercial and institutional buildings.

Residential

GHG emissions from fuel combustion in households.

Industrial

GHG emissions from combustion of fuels in industry. This includes combustion for the generation of electricity and heat for own use.

Mobile Energy Sources

Ground

GHG emissions resulting from fuel use in road vehicles, including agricultural vehicles on paved roads.

Aviation

GHG emissions resulting from fuel use for take-off, landing and flight of planes (excluding military).

Marine

GHG emissions from fuel used to propel marine vehicles.

Non-Energy Sources

Industrial Processes

GHG emissions released from industrial processes that chemically or physically transform materials.

Agriculture

GHG emissions resulting from enteric fermentation, manure management, agricultural soil management, field burning of agricultural residues, and urea application.

Waste

GHG emissions resulting from municipal solid waste and wastewater treatment.

IPCC (2006) established a *Tier* concept of defining the accuracy and precision of a method(s) for collecting data and calculating GHG emissions. Tier 1 is the basic method, often considered the “default” approach. Tier 2 and Tier 3 indicate an increasing demand of complexity and data requirements, and are generally considered more accurate and precise methods.

For stationary combustion the IPCC defines Tier 2 as, “fuel combustion from national energy statistics, together with country-specific emission factors derived from national fuel characteristics”(IPCC, 2006). Based on this definition, we achieved a Tier 2 accounting of GHG emissions for Electric Power and Mobile Energy Sources. Electric Power GHG emissions are constructed from fuel values collected from Hawaiian Electric Company representatives and DBEDT energy analysts and emission factors from the United States Energy Information Administration (U.S. EIA).

We also approached a Tier 2 level for calculating Mobile Energy Sources. Fuel values were collected from Doug Oshiro at DBEDT for ground, aviation and marine sectors and GHG emissions were calculated with emission factors from the U.S. EIA.

The remaining sectors were calculated using a Tier 1 approach, relying on the EPA State Inventory Tool (U.S. EPA July, 2008) default values for Hawai‘i. Population values were updated using *de facto* values from the Hawai‘i State Data Book, published by DBEDT.

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UHERO thanks the Executive Sponsors of Energy and Greenhouse Gas Solutions:

Michael Saalfeld

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Science Education for New Civic Engagements and Responsibilities

Special appreciation is extended to Michael Saalfeld for providing dedicated funding to support the UHERO in compiling Hawai'i specific data on energy, greenhouse gas emissions, and the economy. Mahalo nui loa!

Energy and Greenhouse Gas Solutions (EGGS) seeks to provide economic solutions to climate change in Hawai'i. We combine a careful understanding of local conditions with frontier economic modeling and analysis to offer solutions that work for Hawai'i's people and environment. EGGS is an initiative of the University of Hawai'i Economic Research Organization (UHERO).

For more information, please visit <http://www.uhero.hawaii.edu/eggs>

For questions or inquiries, please contact Dr. Denise Eby Konan at konan@hawaii.edu.

Upcoming EGGS Reports

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