Hawaii Climate Change Action Plan

November 1998

State of Hawaii
Department of Business, Economic Development & Tourism
Energy, Resources, and Technology Division
and
Department of Health
Clean Air Branch

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TABLE OF CONTENTS

CHAPTER 1 OVERVIEW AND SUMMARY OF RECOMMENDATIONS

1.1 Introduction

1.1.1 Hawaii and Climate Change

Hawaii faces many potential negative consequences from global warming and climate change. Higher temperatures could make Hawaii less of a paradise, not only due to the greater heat, but also due to potential effects on climate. Greater heat may cause more heat-related mortality. Concentrations of ground-level ozone could increase, causing respiratory illnesses. Warmer seas could enhance growth of toxic algae and bacterial contamination of coastal waters. Warmer weather could expand the habitat of disease-carrying insects to Hawaii.

Sea level rise is occurring and could lead to coastal flooding, erosion of beaches, and saltwater contamination of drinking water. During storms, additional areas will become vulnerable to waves and storm surge. In addition, Hawaii can expect negative effects on its water resources, agriculture, forests, and ecosystems.

1.1.2 Hawaii and Reduction of Greenhouse Gas Emissions

The Intergovernmental Panel on Climate Change (IPCC) established by the United Nations Framework Convention on Climate Change has determined that "the balance of evidence suggests a discernable human influence on global climate" (IPCC 1996). The IPCC notes the increased concentration of greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) since pre-industrial times largely due to human activity. These increased concentrations have warmed the surface and tend to produce other changes in climate. Climate change effects have already been observed and will occur in the future.

It will be necessary to stabilize concentrations of greenhouse gases to prevent even more dramatic changes in climate than are expected over the next century due to greenhouse gases already in the atmosphere. Hawaii can and should play a role in reducing its greenhouse gas emissions that contribute to climate change. All states and all nations will ultimately need to contribute to efforts to mitigate effects on future climate change.

1.1.3 Hawaii's Climate Change Action Plan

This is Hawaii's first iteration of a *Climate Change Action Plan*.
It does not set specific goals. It is intended to be a catalyst for discussions by Hawaii's people about their involvement in future efforts to reduce emissions and to adapt to climate change. The major recommendation of this first plan is to develop consensus as to Hawaii's goals for greenhouse gas emission reductions.

A Hawaii Climate Change Action Plan Workshop on October 30, 1997 was a preliminary effort to obtain citizen input on Hawaii's goals and suggestions for greenhouse gas emission reduction measures. About 100 citizens heard a report on the state's efforts in the area of climate change action and provided their views on ways to reduce future greenhouse gas emissions. A Workshop summary is provided as Appendix D to this Plan.

Hawaii could become part of future national efforts to reduce greenhouse gas emissions under the Kyoto Protocols signed on November 12, 1998. Should the United States Senate ratify the Protocols, or should the Federal government set some other goal, such a goal could serve as Hawaii's goal. Hawaii's people may not want to wait for such action to deal with the growing problem. Hawaii can set its own goals for action now.

In addition, further work is needed to identify future effects of climate change on Hawaii's people, environment, ecosystems, and economy in order to identify changes to which the state must adapt. To assist in any goal setting effort that may evolve, a more detailed discussion of goal setting is contained in Chapter 5.

1.1.4 About This Plan

This plan is Phase II of the Program for Developing, Implementing, and Evaluating a Greenhouse Reduction Strategy for the State of Hawaii conducted jointly by the State of Hawaii Department of Business, Economic Development, & Tourism’s (DBEDT) Energy, Resources, and Technology Division; and the Department of Health’s (DOH) Clean Air Branch. This work was performed with the support of a grant from the U.S. Environmental Protection Agency (USEPA) as part of the State and Local Outreach Program. In addition, other State agencies, notably the Department of Land and Natural Resources, the Department of Agriculture, Department of Transportation and the Public Utilities Commission provided data, technical assistance, and review. The four Counties, various federal agencies, and many private companies made additional contributions. These contributions are acknowledged in Appendix A.

1.2 Chapter 2: Hawaii and Global Climate Change

Chapter 2 discusses Hawaii and Global Climate Change. It includes an overview of the greenhouse gases that cause climate change and the potential impact of climate change on Hawaii.

1.2.1 The Science of Climate Change

Chapter 2 provides an extract from *Climate Change 1995: The Science of Climate Change, Summary for Policymakers and Technical Summary of the Working Group I Report* (IPCC 1996), published in 1996 by the Intergovernmental Panel on Climate Change (IPCC). The key conclusions covered the Chapter include the following:

- Greenhouse gas concentrations have continued to increase;
- Climate has changed over the past century;
- The balance of evidence suggests a discernible human influence on global climate;
- Climate is expected to continue to change in the future; and
- There are still many uncertainties (IPCC 1996).

1.2.2 Potential Effects on Hawaii

Chapter 2 also provides a summary of potential effects on Hawaii based upon the Intergovernmental Panel on Climate Change (IPCC) Working Group II's *Summary for Policy Makers: Scientific-Technical Analysis of Impacts, Adaptations and Mitigations of Climate Change* (IPCC 1995b) and the U.S. Environmental Protection Agency's *Climate Change and Hawaii* (USEPA 1998a). Major effects expected for Hawaii include:

- Warmer temperatures;
- Increases in heat-related deaths and illnesses;
- Sea level rise with resultant flooding, beach erosion, saltwater contamination of drinking water, and damage to coastal property;
- Increased vulnerability to storm damage;
- Effects on water resources expected to become more variable;
- Undetermined effects on agriculture and forestry; and
- Stresses on ecosystems.

Hawaii Should Take Action to Deal with Climate Change

The fundamental recommendation of this plan is that Hawaii should take action to reduce its emissions that contribute to global warming and climate change. Hawaii should also identify the future effects on its people, environment, ecosystems, and economy that will be caused by climate change already occurring. Hawaii should then develop a long-range plan to adapt to such climate change.

1.3 Chapter 3: 1990 Hawaii Greenhouse Gas Emissions

Chapter 3 presents a summary of Hawaii's estimated emissions of the greenhouse gases in 1990. The summary is based upon the work done in Phase I of the Program for Developing, Implementing, and Evaluating a Greenhouse Reduction Strategy for the State of Hawaii which produced the *Inventory of Hawaii*

Greenhouse Gas Emissions, Estimates for 1990 (State of Hawaii 1997a). The *Inventory* was updated with additional information.

1.3.1 Estimated 1990 Hawaii Greenhouse Gas Emissions

An estimated 15,985,225 tons of CO_2, 75,736 tons of CH_4, and 690 tons of N_2O comprised Hawaii greenhouse gas emissions in 1990. These emissions were produced by energy uses, industrial processes, and non-energy sources within the state. The Hawaii baseline estimate did not include about 29% of the fuels imported, refined, or produced in Hawaii in 1990. These fuels were not used in Hawaii, but were sold as fuel for aircraft for international flights, ships involved in overseas operations, sold to the military, or exported.

1.3.2 Estimated Global Warming Potential of Hawaii Greenhouse Gas Emissions

Global Warming Potential, or GWP, is used to compare the relative effects of each of the different greenhouse gases on radiative forcing of the atmosphere over some future time horizon. It translates the level of emissions of CO_2, CH_4 and N_2O into a common metric -- their CO_2 equivalent.

Hawaii's GWP in 1990 was the equivalent of 18,784,299 tons of CO_2. CO_2 emissions produced 90% of Hawaii’s global warming potential, followed by CH_4 at 9%, and N_2O at 1%. Energy use emissions dominated Hawaii's GWP at 89%. Transportation energy use produced 42% of GWP, followed by electricity generation at 41%, municipal waste management at 7%, industrial energy use at 4%, agriculture at 3%, and commercial energy uses at 1% were significant. The remaining sectors, residential energy and industrial processes, each contributed less than one percent to total global warming potential. This breakdown is useful in focusing efforts to control greenhouse gas emissions on the major sources.

1.3.3 Comparison of Estimated Hawaii Greenhouse Gas Emissions with Selected States

The global warming potential of the United States in 1990 was 5,567,000,000 tons of CO_2 equivalent (USEPA 1994b, ES-5). Hawaii’s GWP of 18,784,299 tons of CO_2 equivalent was 1/3 of one percent of the United States total.

In Section 3.6 of Chapter 3, Hawaii’s GWP in tons of CO_2 equivalent is compared with the GWP of 17 other states that completed greenhouse gas inventories under the EPA’s State and Local Outreach Program. The GWP in tons of CO_2 equivalent per capita, based on 1990 resident population and in pounds CO_2 equivalent per dollar of 1990 Gross State Product (GSP) were also presented for comparison. Among this group of states, Hawaii produced the fourth-smallest quantity of CO_2 equivalent emissions per capita and the third-lowest per dollar of GSP (USDOE 1992a, 224 and USEPA 1998k).

Jet fuel use for Hawaii's domestic air transportation (interisland and to/from the United States Mainland) created 3.84 million tons CO_2, or 21% of the total. This was a greater percentage than for any other state. When the estimated CO_2 emissions from jet fuel use were subtracted from each state's total GWP, Hawaii had the lowest GWP per capita and lowest GWP per dollar of GSP. These results point out the relatively low impact of Hawaii's people on climate change, but also emphasize the difficulty Hawaii faces in making significant reductions in its emissions. Jet fuel is essential to Hawaii's tourism-based economy and the well-being of its people.

1.4 Chapter 4: Forecast of Hawaii's Greenhouse Gas Emissions to 2020

Chapter 4 presents and compares forecasts of Hawaii's greenhouses gas emissions to the year 2020. The ENERGY 2020 model was used for the energy portion of the forecast. The generation units in the baseline scenario included current operating units and future retirements and additions according to utility integrated resource plans. It was assumed utility DSM plans were implemented for 20 years. The effects of all federal appliance standards and the Hawaii Model Energy Code were also modeled. A description of the ENERGY 2020 model is provided in Appendix C.

Municipal waste management and agriculture baseline estimates were from projections developed by the University of Hawaii Environmental Center. The estimates included emissions from municipal solid waste management, wastewater treatment, livestock, manure management, and fertilizer use.

1.4.1 Forecast Greenhouse Gas Emissions to 2020

The Baseline Forecast indicated that, without additional actions, Hawaii's global warming potential will increase by 20% over 1990 levels by 2010 and by 33% of 1990 levels by 2020. In 2010, it was estimated that Hawaii's global warming potential could be 5,060,992 tons CO_2 equivalent, or 29% above the Kyoto target of 17,574,758 tons CO_2 equivalent. Total global warming potential was estimated to increase from 18,897,590 tons of CO_2 equivalent to 25,094,245 tons by 2020 -- 7,519,487 tons CO_2 equivalent, or 43%, above the Kyoto target. Hawaii clearly faces major challenges in its efforts to reduce greenhouse gas emissions.

1.4.2 Climate Change Action Plan Scenario

In the following chapters, a number of measures were identified that could significantly reduce greenhouse gas emissions in Hawaii. In this first Climate Change Action Plan, these measures were intended to offer a direction for future action. Many will require significant changes over current practices. While it is not clear which recommended measures will be implemented, it was useful to examine their aggregate effect on Hawaii's global warming potential. Together, these measures were termed the "Climate Change Action Plan Scenario."

The Climate Change Action Plan Forecast assumed actions under Scenario C3 were taken. C3, described in detail in Chapter 9, was intended to examine the emission reductions under the control of various entities in Hawaii. The measures proposed under the Climate Change Action Plan Scenario have the potential to reduce the growth of Hawaii's greenhouse gas emissions significantly. Only the energy sector was projected to increase its emissions under this scenario. Nevertheless, emissions from all sectors grew about 4% by 2010, which was 2,116,882 tons CO_2 equivalent or about 12% above the Kyoto target.

1.4.3 Hawaii Technical Potential Scenario

The Technical Potential Forecast added possible technical improvements in the energy sector such as the availability of more efficient aircraft and ground transportation vehicles to the Climate Change Action Plan. The Technical Potential Scenario resulted in a forecast global warming potential in 2010 that was 1,734,123 tons CO_2-equivalent, or about 10%, greater than the Kyoto target.

Comparison of the Scenarios and Additional Measures

Figure 1.1, on the following page, provides a graphic comparison of the three scenarios discussed above. It does not appear that Hawaii could meet the Kyoto goals at any time by 2020 through a comprehensive deployment of currently available greenhouse gas reduction measures. Although actions in the areas of municipal waste management and agriculture can make significant contributions to reducing Hawaii's global warming potential, the energy sector creates the overwhelming majority of Hawaii's greenhouse gas emissions. Accordingly, it should be the focus of continuing attention. New technologies may provide greater energy efficiency that may change these forecasts in the future. Potential technologies are summarized in Chapter 14.

Forestry in Hawaii also offers a major potential to offset Hawaii's emissions and other areas of the world. As discussed in Chapter 13, Hawaii's forests already act as a carbon sink for 126 million tons of carbon, or the equivalent of 457 million tons of CO_2. It is estimated that forestry projects identified have the potential to sequester an additional 26 million tons of carbon (about 94 million tons CO_2-equivalent). The amount and type of reforestation that may be undertaken will drive the amount of carbon that can be offset by Hawaii forestry projects. Further analysis is recommended to develop a detailed plan to offset or help offset in excess of whatever goals are adopted.

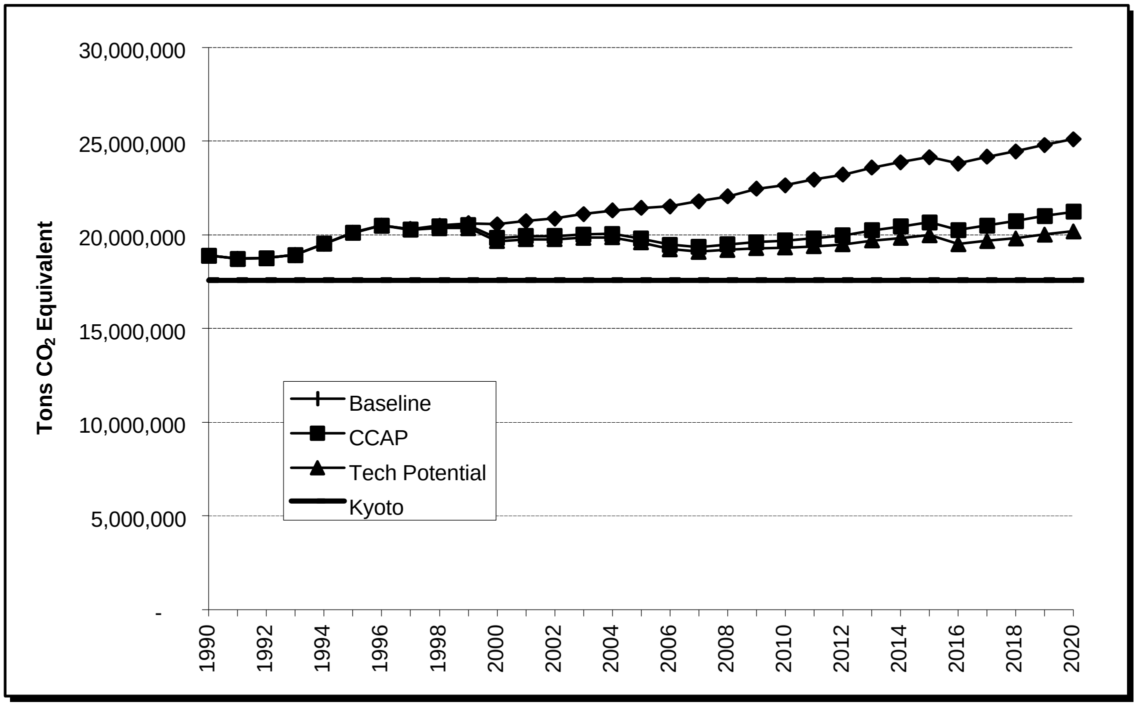


Figure 1.1 Comparison of the Global Warming Potentials of Three Reduction Scenarios for Hawaii, 1990-2020

In addition, experimental work being conducted by the University of Hawaii on the deep ocean sequestration of carbon dioxide may offer a long-term solution to CO_2 emissions from stationary sources in Hawaii and elsewhere if successful. Exports of greenhouse gas emission reducing and mitigating technologies, and related expertise and services from Hawaii to the Asia/Pacific region can produce economic benefits to Hawaii, while decreasing emissions in the Asia/Pacific region. These activities are described in Chapter 14.

1.5 Chapter 5: Greenhouse Gas Emissions Reduction Goals and Criteria for Hawaii

As noted above, this document is Hawaii's first iteration of a Climate Change Action Plan, but it does not set specific goals. It is intended as a catalyst for discussion among Hawaii's people to stimulate their involvement in a future effort to set specific goals. One of the major recommendations of this first Plan is to develop consensus as to the goals that Hawaii should seek to achieve in greenhouse gas emission reductions. Should the United States government ratify the Kyoto Protocols, or set some other goal, a national goal could serve as Hawaii's goal or as a basis for setting higher goals.

Chapter 5 suggests considerations for formal establishment of greenhouse gas reduction goals for the State of Hawaii. It includes a brief discussion of the goals of the Kyoto Protocol. A discussion of development of goals and criteria for greenhouse gas emission reductions from the U.S. Environmental Protection Agency's *States Guidance Document, Policy Planning to Reduce Greenhouse Gas Emissions* (USEPA 1998) is provided to assist in developing Hawaii's goals.

1.5.1 Recommendations for Goal Setting in Hawaii

Based upon the discussion in Chapter 5, the following recommendations were made regarding goal setting in Hawaii. Each is discussed in more detail in Chapter 5. The recommendations were:

Goal Setting Should Involve a Wide Range of Hawaii's People. Public input should be solicited to help set any Hawaii-specific greenhouse gas reduction goals. A Commission or Task Force charged with considering public input could lead this effort. Educational efforts to inform the population on the issues should precede the goal-setting process.

Goals Should Focus on Emissions under Hawaii's Control. Hawaii should focus only on those emissions that can be managed locally. This would exclude emissions from overseas marine activities, all international aviation activities, and military activities. In the near term, due to the high level of their contribution of emissions, the focus should be on electricity generation, ground transportation, and municipal waste management. Carbon offset forestry offers a way to offset some of Hawaii's emissions.

Goals Should Recognize Hawaii's Uniqueness. There are many geographic, climatological, technological, economic, environmental, cultural, and other considerations that must be considered. In particular, Hawaii's high level of energy efficiency reduces emissions reduction options. At the same time, Hawaii offers such resources as abundant sunshine for solar power and tradewinds for wind power. These should be more fully developed.

Hawaii's tourism-based economy poses yet another unique challenge. For example, the State economy is dependent on transoceanic air travel and interisland air travel, thus a large percentage of Hawaii's emissions are from jet fuel use. As discussed above, there is little chance of reduction within Hawaii's control. Significant reductions in air travel would be an economic disaster.

Future Effects of Climate Change on Hawaii Should Be Identified and Adaptation Measures Planned. Hawaii will experience various effects from climate change caused by past and current greenhouse gas emissions (See Chapter 2). As global reductions in emissions are likely to take many years, the effects forecasted for the next century on temperature change, sea level rise, and other concerns **will** happen. Their specific effects on Hawaii should be further explored and modeled. Adaptation measures may also take many years, if not decades, to implement. The measures required must be identified and initiated soon.

1.6 Chapter 6: Transportation Energy Sector

Baseline and Forecast Transportation Energy Sector Emissions

Figure 1.2 shows the forecast of domestic transportation CO_2 emissions by category under the Baseline assumptions. In 1990, emissions from Hawaii transportation fuels uses produced the greatest amount (42%) of Hawaii's total CO_2-equivalent greenhouse gas emissions. Forecasted 2010 transportation CO_2 emissions were 8,999,472 tons, or about 15.6% greater than 1990 levels.

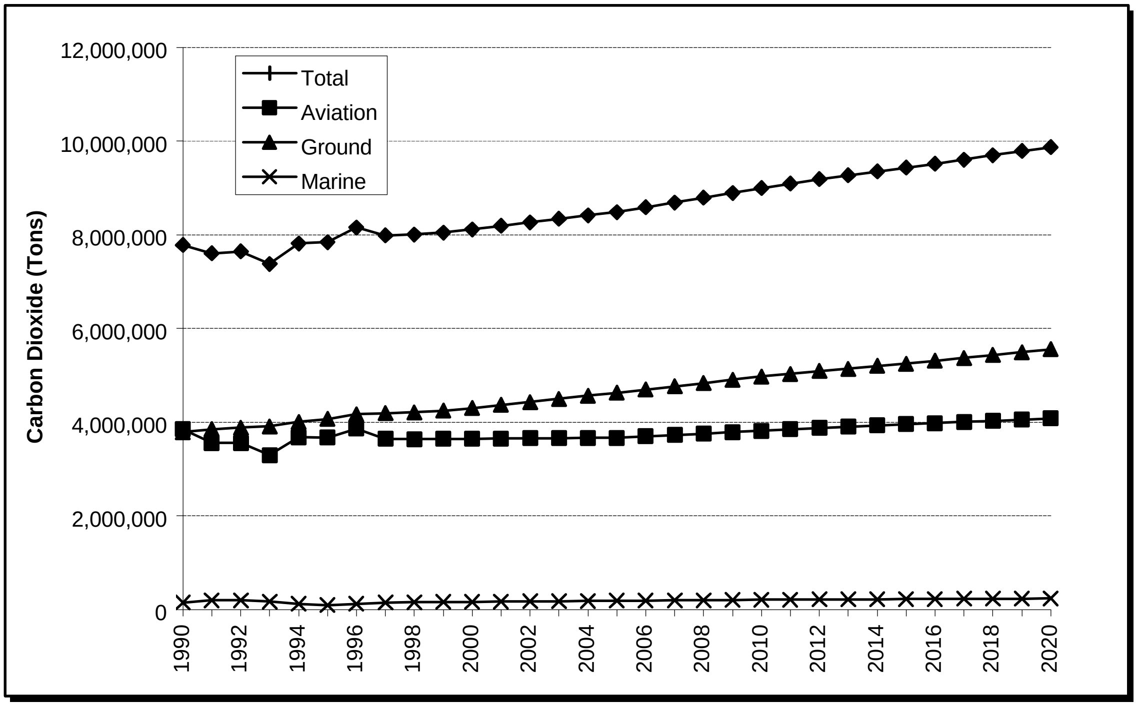


Figure 1.2 Estimated Hawaii Transportation Sector CO_2 Emissions (Tons) 1990 - 2020

1.6.2 Recommended Measures to Reduce Greenhouse Gas Emissions through Ground Transportation Energy Demand Reduction

Greenhouse gas reductions in the transportation sector can be accomplished by either reducing the demand for transportation energy or replacing current transportation fuels with low or no emission alternatives. The following are recommendations to reduce emissions in the ground transportation sector which are described in more detail in Chapter 6:

- Increase the visibility of driving costs;
- Use an Environmental Impact Information Sheet to increase awareness of the environmental costs of vehicle use;
- Increase use of mass transit;
- Improve the bicycle transportation system;

- Use land use planning to reduce congestion and need for transportation;
- Reduce congestion through transportation control measures (TCM);
- Develop an estimate of the energy- and emission-saving effectiveness of TCMs;
- Publicize incentives for alternate fuel vehicle (AFV) ownership;
- Consider additional incentives for AFV ownership;
- Encourage early production and sale of 10% ethanol-blend gasoline in Hawaii;
- Encourage early deployment of electric vehicles in Hawaii;
- Encourage electric vehicle manufacturers to offer electric vehicles for sale;
- Expand Hawaii Electric Vehicle Development Program;
- Assist fleets in complying with EPACT requirements for alternative fuel vehicles; and
- Support Honolulu Clean Cities Program.

1.6.3 Air Transportation

Air transportation is vital to Hawaii's tourism-based economy, providing transportation to millions of visitors and residents annually. Overseas transportation is the only regular passenger connection to the Mainland United States and international destinations. Inter-island air transportation is equally critical, as it is the only passenger connection between Hawaii's islands for residents and visitors alike.

Given the essential nature of Hawaii's domestic air transportation, and the amounts of greenhouse gas emissions involved, efficient operation and efficient aircraft are generally the most effective measures for emissions reductions. The following are recommendations that could contribute to reducing emissions.

- Adopt operating measures for fuel efficiency;
- Examine ways to increase load factors, especially on inter-island flights;
- Re-equip inter-island airlines with newer, more efficient aircraft; and
- Encourage use of efficient aircraft on Hawaii to Mainland routes.

Future gains in commercial aviation energy efficiency could be obtained through technological improvements to engines and airframes, and, in the more distant future, new technologies for aircraft propulsion. These measures are beyond the control of Hawaii, but will set the standard as to what may be achievable in future reductions of greenhouse gas emissions from air transportation.

Recommendations for the long term include:

- Support potential technological improvements in aircraft;
- Maintain high load factors; and
- Be alert to possible aviation fuel substitution opportunities.

1.6.4 Marine Transportation

If inter-island air transportation of passengers can be described as analogous to the mainland interstate highway system, inter-island marine shipping is the analog of intrastate trucking and railroads. Inter-island marine transport, primarily using towed barges, ships most of Hawaii's cargo between the islands. The following are recommendations to reduce emissions from marine transportation:

- Consider changes in operating procedures for energy efficiency;
- Adopt technical improvements to ships; and
- Improve data collection for use in estimating future marine fuel use.

1.7 Chapter 7: Electricity Sector

Hawaii's electricity sector includes electricity generated by the four electric utilities, independent power producers and cogenerators, and the sugar industry that is sold to consumers through the four utility systems. In 1990, emissions from the electricity sector were the second greatest contributor to its global warming potential. The sector produced a global warming potential of 7,652,966 CO_2-equivalent tons or 41% of the total.

1.7.1 Baseline and Forecast Electricity Sector Emissions

In the first part of this decade, electricity sales and generation to meet that sales growth resulted in greater increases in greenhouse gas emissions in the electricity sector than any other source category. Figure 1.3 shows that the increase in electricity use significantly outpaced growth in Hawaii's population and GSP from 1990 to 1997, growing by almost 13%. During the same period, defacto population grew about 1.1%, while GSP grew only 3.8%.

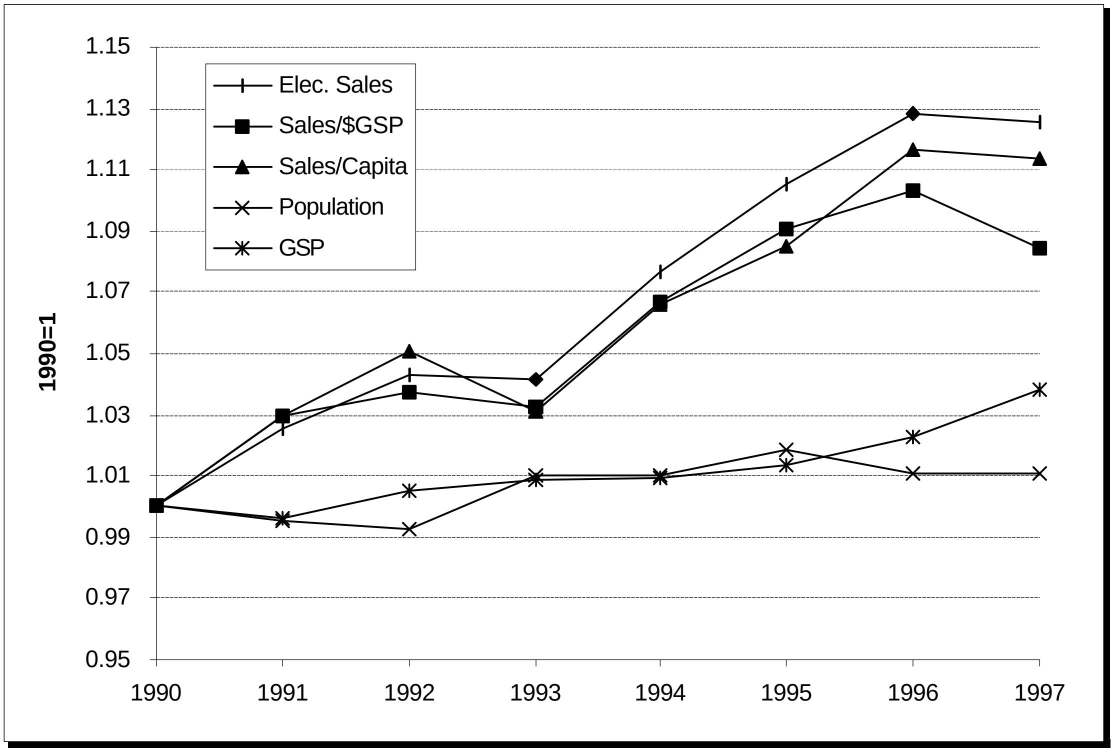


Figure 1.3 Hawaii Electricity Sales, De Facto Population, and Gross State Product, 1990-1997

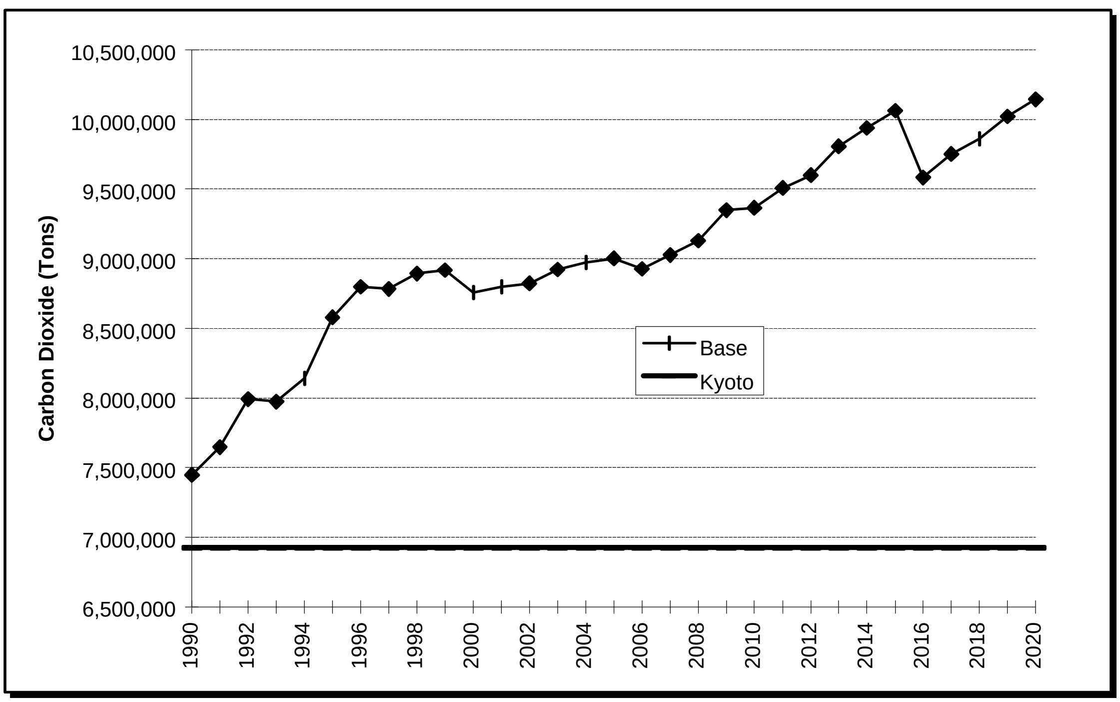


Figure 1.4 Estimated Hawaii Electricity Sector CO_2 Emissions, 1990 - 2000

Figure 1.4 shows the estimated increase in CO_2 emissions based upon the projected growth in demand and sales. A line representing the Kyoto Protocol goal of reducing greenhouse gas emissions 7% below 1990 emissions was provided for reference. **It is not intended to be a specific goal or to imply that the electricity sector alone can or should meet the goal. Efforts to reduce emissions will involve efforts in all sectors, but each sector will not necessarily be able to reach a sector goal of 7% below 1990 levels.**

Under current utility Integrated Resource Planning (IRP), it was estimated that electricity sector emissions would be 26% higher at 9,860,634 tons CO_2 in 2010 than the 1990 base of 7,813,323 tons. This would be 37% greater than the Kyoto target.

1.7.2 Measures to Reduce Electricity Sector Greenhouse Gas Emissions

Crosscutting Actions. Crosscutting actions create a more efficient electricity system by employing a combination of both demand-side measures and supply-side measures. Crosscutting recommendations for the electricity sector included:

- Continue IRP in Hawaii unless replaced by an alternate form of planning;
- Enhance utility participation in Climate Challenge Program;
- Continue efforts to restructure Hawaii's electric utilities; and
- Under a restructured system, establish a Renewable Energy Portfolio Standard and set maximum greenhouse gas emission standards.

Demand-Side Management. Demand-Side Management, or DSM, is defined as any utility activity aimed at modifying the customer's use of energy to reduce demand. It includes conservation, load management, and efficiency programs. DSM offers the potential for lower customer utility bills, deferral of major power plant investments, reduced environmental impacts, and potential diversification of resources (NEOS 1995, ES-1). The following list summarizes recommendations discussed in detail in Chapter 7:

- Continue and expand electric utility DSM programs;
- Continue to increase State government efforts to improve energy efficiency;
- Expand State government energy performance contracting;
- Continue and expand County government energy efficiency programs;
- Maintain and extend the Hawaii Model Energy Code;
- Adopt Model Energy Code for Maui County (currently under consideration) and adopt Residential Building Model Energy Code in all counties;

- Encourage continued use of HiLight software program by lighting designers to ensure Model Energy Code compliance;
- Design and construct buildings appropriate to Hawaii's climate to reduce energy use;
- Continue and enhance Hawaii participation in U.S. government-sponsored energy efficiency programs; and
- Support Federal Energy Management Program in Hawaii.

Supply-Side Activities. Greenhouse gases can also be reduced by activities that improve the efficiency of electricity generation or provide electricity without or with less greenhouse gas emissions. Chapter 7 discusses the following measures in more detail:

- Establish carbon offset programs or permit trading systems;
- Maximize cost-effective cogeneration;
- Continue to encourage renewable energy through tax credits;
- Increase use of solar water heating;
- Implement recommendations of the Renewable Energy Resource Docket;
- Implement HES Renewable Energy Implementation Plan; and
- Determine technical capability of electric utility systems to use intermittent renewable energy.

1.7.3 Electricity Sector CO_2 Emissions Savings

Chapter 7 concludes with a summary of CO_2 emissions savings from efforts currently underway in Hawaii. By 2010, it was estimated that DSM efforts could reduce emissions by almost 966,000 tons of CO_2 in that year alone. On the supply side, cogeneration was expected to continue to reduce emissions by about 218,000 tons of CO_2, and renewable energy use would avoid 800,000 tons of CO_2 emissions. Additional renewable energy generation as discussed in Chapter 9's Scenario E2 could avoid an additional million tons of CO_2 emissions by 2010.

1.8 Chapter 8: Residential, Commercial, and Industrial Energy Sectors

Chapter 8 examines non-electricity greenhouse gas emissions from energy uses in the residential, commercial, and industrial sectors. These sectors used utility and non-utility gas, self-generation of electricity, non-highway vehicles, and oil-fired water heating, kiln heating, and steam production.

Together, these sectors produced about 8% of Hawaii's CO_2 emissions and about 7% of Hawaii's GWP in tons of CO_2 equivalent, or about 4.

Estimated Residential, Commercial, and Industrial Greenhouse Gas Emissions to 2000

CO_2 emissions in these three sectors were forecast to grow by 2%, from 1.26 million tons in 1990 to 1.28 million tons in 2010. The commercial sector's CO_2 emissions were forecasted to increase by 34% to 362,000 tons. However, a 4% decline in emissions was forecasted in the industrial sector, primarily due to the end of cement kiln operations and closure of several sugar plantations reduced that total to 870,000 tons. Residential emissions were forecasted to decline to about 56,000 tons by 2010 if trends in reduced utility gas and LPG sales observed in the early 1990s continue. This may not be the case and this estimate should be reviewed carefully in the future.

1.8.2 Actions to Reduce Greenhouse Gas Emissions

Utility and Non-Utility Gas. Hawaii has no natural gas resources. Gas service is provided using synthetic natural gas (SNG) and liquid propane gas (LPG). Measures recommended to reduce emissions in this area include:

- Implement gas utility demand-side management programs;
- Develop energy efficiency programs for non-utility gas customers; and
- Consider fuel-switching opportunities between electricity and gas.

Sugar Industry. CO_2 emissions from generation of electricity and steam for internal use have declined significantly statewide (about 34%), mostly due to closure of sugar mills since 1990. On Kauai, emissions from the remaining mills were only 38% of 1990 levels. On Maui, however, emissions were up in 1997 to a level 44% greater than 1990. Hawaii's sugar mills are already among the most efficient in the world and continuing cost pressures are expected to result in high efficiency levels. There were no specific recommendations for improvement.

1.9 Chapter 9: Energy System Scenarios

Chapter 9 examined a number of hypothetical energy sector scenarios designed to reduce Hawaii's greenhouse gas emissions. The scenarios were run on the ENERGY 2020 model of Hawaii's energy system in each of Hawaii's four counties. See Appendix C for additional information about ENERGY 2020.

The purpose of these model runs was to evaluate whether actions under consideration could be effective in reducing emissions and to look at their economic costs or benefits. The scenarios were compared to a Baseline scenario designed to replicate the current energy system and known plans. While the options examined may not necessarily be possible to fully implement, the results suggest areas in which actions could be pursued to reduce emissions.

In this study, four groups of scenarios were run on the model. These included electricity generation scenarios, transportation scenarios, carbon tax scenarios, and composite scenarios. Due to the complexity of the scenarios and their presentation, the reader is referred to Chapter 9 for further details.

1.9.1 Scenario-Based Recommendations

The following recommendations were based upon ENERGY 2020 model runs:

Do Not Use Carbon Taxes in Efforts to Reduce Greenhouse Gas Emissions. The model results suggest that the negative economic effects were most significant in the scenarios with carbon taxes.

Consider Implementing Elements of Scenario C3. Since the options modeled in Scenario C3 could be implemented at the state level, they are recommended for consideration in an initial Hawaii Climate Change Action Plan for the energy sector. They included E2 – Maximize Renewable Energy in the electricity sector, and in the ground transportation sector, GT2 – 10% Ethanol-based Gasoline, and GT3 – 50 Cents per Gallon Increase in Gasoline Prices. The increase in gasoline prices is not a recommended option, but is a possible scenario. Together these options offer significant reductions in emissions but do not achieve the Kyoto Protocol goal for the United States of 7% below 1990 levels.

Support Efforts to Increase Aircraft and Ground Vehicle Fuel Efficiency. Since jet fuel and ground transportation fuel use constitutes a majority of Hawaii's energy use, improvements in fleet efficiency would significantly help reduce CO_2 emissions. Hawaii should support aircraft efficiency research and development efforts at the national level, and encourage airlines serving Hawaii to use their most efficient types of aircraft. Hawaii should also encourage auto manufacturers' efforts to develop and deploy alternative fuel vehicles and high-efficiency vehicles, and to support increases in national CAFE standards. Hawaii's citizens should also be made aware of the effects of vehicle use on climate change and should be encouraged to purchase fuel-efficient vehicles and to operate them in an efficient manner.

Maximize Renewable Energy and Demand-Side Management in the Electricity Sector. Hawaii should continue efforts to maximize the use of renewable energy and it should conduct research and development and demonstration projects. Hawaii's utility DSM programs should be encouraged and continue to be supported with appropriate tax credits. The utilities should evaluate the full range of possible DSM programs in each IRP cycle to ensure that any measure is included which may become cost-effective in the face of increasing electricity prices. There should also be provisions to enhance renewable energy and DSM programs under any electricity restructuring that may occur. Possible measures include the use of system benefit charges and/or renewable portfolio standards.

1.10 Chapter 10: Industrial Processes

Oil refining and synthetic natural gas production were responsible for a very low percentage of Hawaii's greenhouse gas emissions. The following were the recommendations for future activities in this area.

- Encourage refiners to carry out and report actions to reduce greenhouse gas emissions; and
- Encourage The Gas Company to implement and report actions to reduce greenhouse gas emissions.

1.11 Chapter 11: Municipal Waste Management

Chapter11 examines options for reduction of greenhouse gas emissions produced by municipal solid waste (MSW) management and wastewater treatment in Hawaii. Municipal waste emitted 189,684 tons of CO_2 and 53,490 tons of methane in 1990. Municipal solid waste produced 98% of the global warming potential from municipal waste management in Hawaii in 1990. Together, these emissions were the equivalent of 1,389,058 tons of CO_2 since methane emissions are estimated to have 22 times the global warming potential of CO_2 emissions

Reducing Municipal Solid Waste Emissions

A variety of measures are examined in Chapter 11 to reduce greenhouse gas emissions, principally CH_4 and CO_2 from municipal solid waste in Hawaii. Figure 1.6, on the following page, compared three scenarios. The base recommendation is the forecast growth in emissions if no changes were made in current practices. The priority recommendations and all recommendation scenarios both have the potential of reducing emissions below the Kyoto Protocol goal, contributing to Hawaii's overall efforts.

Pre-Consumer Source Reduction. Source reduction is perhaps the easiest and most straightforward method of reducing methane emissions in Hawaii. Source reduction can occur either prior to the sale of goods to the consumer, or when the consumer discards that refuse. It is estimated that product packaging takes as much as 30% of landfill space nationwide (State of Hawaii 1991, 5-8). Pre-consumer source reduction measures include:

- State and County government leadership in pre-consumer source reduction; and
- Encourage consumer actions in pre-consumer source reduction.

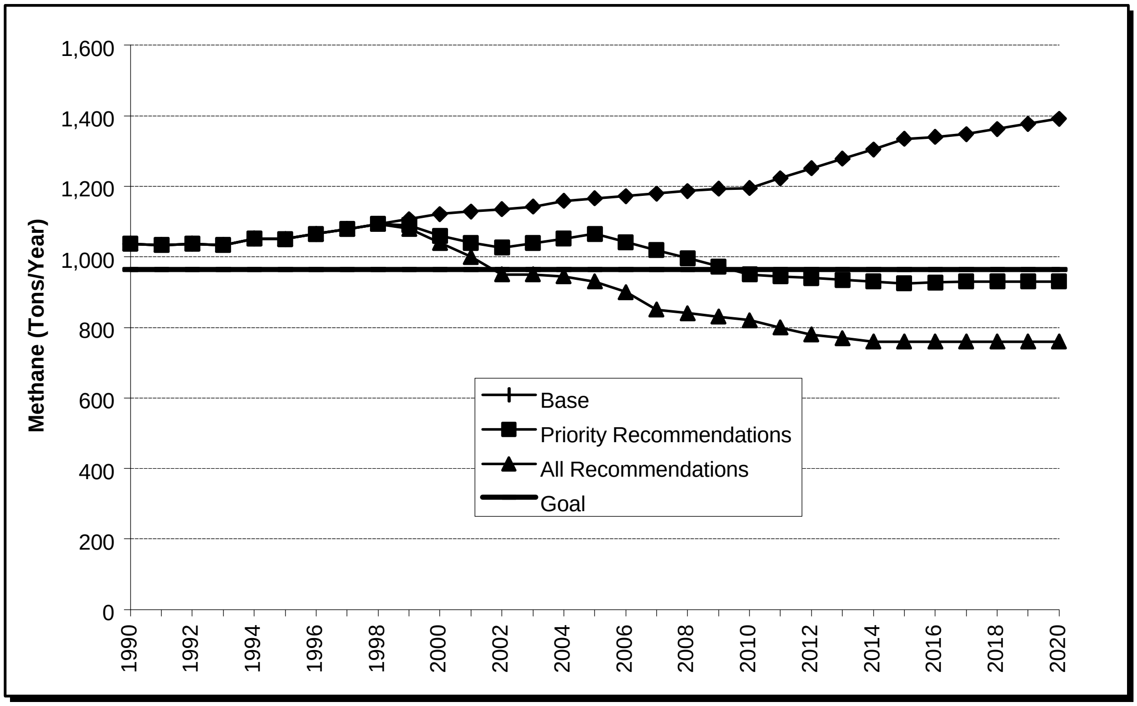


Figure 1.6 Estimated Methane Emissions from Solid Waste Management Comparing Alternative Mitigation Measures (Tons/Year), 1990-2020

Post-Consumer Source Reduction. After goods have been used by the consumer and are ready to be discarded, there are several options for reducing the amount of solid waste that goes to landfills, including

- Support county recycling programs and improve coordination efforts and internal programs of state government offices; and
- Provide incentives for private recycling, reuse, and remanufacturing.

Construct and Operate Waste-to-Energy Plants. H-POWER (Honolulu Program of Waste Energy Recovery), located in Campbell Industrial Park, Oahu is an excellent example of a successful waste-to-energy plant. It is estimated that through reductions in landfill CH_4 and CO_2, H-POWER avoided about 229,000 tons of CO_2 equivalent emissions in 1996, after including CO_2 emissions produced by burning the waste. Chapter 11 discusses possible waste-to-energy facilities for neighbor islands.

Reduce Methane Emissions from Landfills by Flaring or Use as a Fuel. Landfills produce methane and CO_2 in approximately equal volumes. Any landfill containing more than a few thousand tons of MSW can continuously fuel a methane flaring system. Options discussed in Chapter 11 could avoid emission of up to 46,000 tons of CH_4 emissions annually, which is equivalent to just over 1 million tons of CO_2.

1.11.2 Reducing Emissions from Municipal Wastewater Treatment

Municipal wastewater treatment produces both effluent and sludge (biosolids), which in turn produce CH_4 and CO_2. Emission of CO_2 is largely unavoidable, but methane emissions can be reduced significantly at some cost. Chapter 11 offers the following recommendations in this area for further consideration:

- Use recovered CH_4 at sewage treatment plants;
- Use directly applied dried sewage sludge as fertilizer and use sewage effluent for nutrient-rich irrigation;
- Compost sewage sludge for use on vegetables and other crops and pastures;
- Inject CO_2 and possibly CH_4 into sewage effluent being sent into offshore outfall pipes if practice is found to provide sequestration; and
- Use sewage effluent as reinjection fluid for geothermal wells.

1.12 Chapter 12: Agriculture

Chapter 12 suggests measures to reduce Hawaii's greenhouse gas emissions from agricultural activities, including livestock and manure management, fertilizer and compost, crop burning and bioenergy crops, and land use management. Agriculture contributed only 3% to Hawaii's global warming potential. Recommendations discussed in more detail in Chapter 12 included:

- Recover CH_4 from stored manure;
- Improve the diet quality of ruminants;
- Improve efficiency of livestock feed application;
- Increase aerobic treatment of manure;
- Promote expanded use of organic fertilizers;
- Improve efficiency of fertilizer use;
- Promote planting of cover crops which capture nitrogen;
- Promote improved soil management; and
- Consider measures involving crop burning and bioenergy crops.

1.13 Chapter 13: Forestry

Chapter 13 examines the contribution of forestry in Hawaii in taking up greenhouse gas emissions from the atmosphere and reducing effects on climate change. A low-cost way to reduce levels of CO_2 in the atmosphere is by planting or preserving trees, which absorb the gas through their normal growth process.

The State of Hawaii has a unique combination of attributes that make it an ideal place to establish carbon offset forestry (COF) projects. These attributes include:

- Thousands of acres of vacant sugar land and underutilized pasture lands;
- Tropical growth rates which sequester large amounts of carbon in a short time period;
- A developing forest industry supported by private sector investors; and
- The political stability of being a state of the United States to assure long-term project success.

Carbon offsets through forestry may play a significant role in ameliorating global environmental problems as well as helping Hawaii's economy. Opportunities for carbon offset forestry in Hawaii are further detailed in Chapter 13 and include the following recommendations:

- Expand the State forest inventory to all forestlands to determine existing timber resources and reforestation opportunities;
- Assure that disposition of wood from State lands and future leasing of forest lands add value and optimize carbon sequestration;
- The State should review its pasture leases to identify lands that have the potential for reforestation and to determine which of these lands could make the best contribution to a value-added forest industry and COF projects;
- The State should sponsor a COF conference to determine how COF projects can help contribute to Hawaii's forestry sector.
- The State's major financial institutions should design the appropriate investment platform such as "Certifiable Tradable Offsets" (CTOs) or "carbon bonds" or other forms of "carbon banking" that could help encourage COF projects in Hawaii.

1.14 Chapter 14: Research and Development, Future Technology, and Technology Export

Most of the *Hawaii Climate Change Action Plan* focused on ways to reduce greenhouse gas emissions by considering existing technologies in developing and addressing options. Especially in the energy sector, it was forecasted that it will be very difficult, if not impossible, using existing technology, to reach the Kyoto Protocol goal of reducing emissions to 7% below 1990 levels. Recommendations discussed in Chapter 14 include:

- Support deep-ocean carbon sequestration research in Hawaii;

- Conduct research and development and demonstration (RD&D) on carbon sequestration and ocean thermal energy conversion at the Natural Energy Laboratory of Hawaii Authority;
- Conduct RD&D using Hawaii's abundant renewable energy resources;
- Conduct building efficiency RD&D in Hawaii;
- Conduct RD&D on clean energy and transportation energy efficiency to reduce Hawaii's overdependence on oil;
- Conduct RD&D on electricity system efficiency and clean energy for electricity generation in Hawaii;
- Emphasize sustainable development projects supporting reduction of greenhouse gas emissions in the DBEDT Strategic Technology Marketing and Development Program; and
- Promote and support increased commercial exports from Hawaii of technologies, expertise, and services that reduce or mitigate greenhouse gas emissions, especially to the Asia/Pacific Region.

In the Chapters that follow, the topics discussed and the recommendations summarized in this Introduction, are covered in more detail. The ideas, practices, and recommendations herein can be considered and combined into an effective strategy to reduce Hawaii's greenhouse gas emissions and reduce Hawaii's effects on climate change, while contributing to sustainable economic growth.

CHAPTER 2 HAWAII AND GLOBAL CLIMATE CHANGE

2.1 Overview

This chapter presents an overview of the problem posed by greenhouse gas emissions. It discusses greenhouse gases, their effects on climate change, and the potential impact of climate change on Hawaii.

2.2 Greenhouse Gases and Climate Change

2.2.1 The Greenhouse Gases

This section is intended to provide the reader with background information on the relationship of the greenhouse gases to global climate change. The primary focus is on the greenhouse gases carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). In addition, data on Hawaii emissions of the photochemically important gases carbon monoxide (CO), oxides of nitrogen (NOx), and nonmethane volatile organic compounds (NMVOCs) were collected and summarized in the baseline *Inventory of Hawaii Greenhouse Gas Emissions, Estimates for 1990* (State of Hawaii, 1997a). The *Inventory* is summarized briefly in the following Chapter. The remainder of this section, based closely upon the U.S. Environmental Protection Agency's *State Workbook* (USEPA 1995b, iii), discusses the nature of each of the gases.

2.2.1.1 Description of Greenhouse Gases

Carbon dioxide. The combustion of liquid, solid, and gaseous fuels is the main anthropogenic source of CO_2 emissions. Some non-energy processes, notably cement production, municipal waste management, and sugarcane waste burning in the fields also produce CO_2.

In nature, CO_2 is cycled between various atmospheric, oceanic, land biotic, and marine biotic reservoirs. The largest fluxes are between the atmosphere and land biota, and between the atmosphere and the surface water of the oceans. There are also terrestrial non-biotic sources (soils) and crustal (sedimentary rock) sources.

Methane. CH_4 is produced through anaerobic decomposition of organic matter in biological systems. Enteric fermentation in animals, decomposition of animal wastes, and decomposition of municipal solid waste produce CH_4. CH_4 is also emitted in the production and distribution of natural gas (synthetic natural gas in Hawaii) and oil, and by incomplete fuel combustion.

The major sink for CH_4 is its interaction with the hydroxyl radical (OH) in the troposphere. This results in chemical destruction of the CH_4 compound as the hydrogen molecules in CH_4 combine with the oxygen in OH to form water vapor (H_2O) and CH_3. After a number of other chemical interactions, the remaining CH_3 turns into CO which itself reacts with OH to produce CO_2 and hydrogen (H).

Nitrous Oxide. Anthropogenic sources of N_2O of concern include use of fertilizers, fossil fuel combustion, and biomass burning for energy production and in the fields.

Halogenated Fluorocarbons, HFCs, and PFCs. Halogenated fluorocarbons are man-made compounds that include chlorofluorocarbons (CFCs), halons, methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs). All of these compounds not only enhance the greenhouse effect, but also contribute to stratospheric ozone depletion (USEPA, 1995b, iii). While many of these gases have been used in Hawaii, there is no information that they were ever manufactured in the state.

In 1989, Hawaii was the first state to enact legislation to regulate and require recovery and recycling of chlorofluorocarbons. The United States has phased out production and use of all halons, CFCs, HCFCs, and other ozone depleting substances under the 1987 Montreal Protocol and 1992 Copenhagen Amendments (Cook 1996, 9). Perfluorinated carbons (PFCs) and hydrofluorocarbons (HFCs), a family of CFC and HCFC replacements, not covered under the Montreal Protocol, are also powerful greenhouse gases (iii).

2.2.1.2 Description of Photochemically Important Gases

The photochemically important gases play a role in increasing production of tropospheric ozone (also known as urban smog). These gases – NOx, CO, and NMVOCs -- are known as criteria pollutants and are regulated under the Clean Air Act of 1970 and subsequent amendments. Ozone itself is both produced and destroyed in the atmosphere through natural processes. Approximately 90 percent reside in the stratosphere, where it controls the absorption of solar ultraviolet radiation; the remaining 10 percent are found in the troposphere and could play a significant greenhouse role.

Oxides of Nitrogen. Oxides of nitrogen, NO and NO_2, are created from biomass burning, fossil fuel combustion, and are generated in the stratosphere from nitrous oxide. They contribute to formation of ozone.

Carbon Monoxide. CO is created when carbon-based fuels are burned incompletely. CO elevates concentrations of CH_4 and tropospheric ozone through chemical reactions with atmospheric constituents (e.g., OH) that would otherwise assist in destroying methane and ozone. It eventually oxidizes to CO_2.

Nonmethane Volatile Organic Compounds. NMVOCs include propane, butane, and ethane. They participate, along with NOx, in the formation of ground-level ozone and other photochemical oxidants. VOCs are primarily emitted by transportation and industrial processes (USEPA 1995b, iii).

2.2.2 Climate Change: The Summary for Policymakers

The following section on climate change was extracted from *Climate Change 1995: The Science of Climate Change, Summary for Policymakers and Technical Summary of the Working Group I Report* (IPCC 1996), published in 1996 by the Intergovernmental Panel on Climate Change (IPCC). The IPCC was jointly established by the World Meteorological Organization and the United Nations Environmental Programme to provide an authoritative international statement of the current understanding of climate change (2). The Summary for Policymakers, approved in detail at the fifth session of the IPCC Working Group I in Madrid, 27-29 November 1995, represents the IPCC's formally agreed statement on the current understanding of the science of climate change (7).

While there are many who disagree with elements or all of the IPCC statement, it is supported by the United States government and is the basis for the actions taken in the United States Climate Action Program. As a basis for understanding the need to inventory greenhouse gases, a major excerpt of the Summary for Policymakers is presented here (including its use of British spelling). While the summary also discussed CFCs, HCFCs, and other aerosols, those sections are not included below, as Hawaii is not a manufacturer of such gases. As noted above, in 1989, Hawaii was the first state in the Nation to enact legislation to regulate and require recovery and recycling of chlorofluorocarbons. The excerpt that follows focuses on the principal greenhouse gases discussed in this report: CO_2, CH_4, and N_2O.

Summary for Policymakers

Considerable progress has been made in the understanding of climate change science [1]

Greenhouse gas concentrations have continued to increase

Increases in greenhouse gas concentrations since pre-industrial times (i.e., since about 1750) have led to a positive *radiative forcing* [2] of climate, tending to warm the surface and to produce other changes of climate.

[1] Climate change in the IPPC Working Group I usage refers to any change in climate over time whether due to natural variability or as a result of human activity. This differs from the usage in the Framework Convention on Climate Change where climate change refers to a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

[2] A simple measure of the importance of a potential climate change mechanism. Ratiative forcing is the perturbation to the energy balance of the Earth-atmosphere system (in watts per square metre [Wm^{-2}])

- The atmospheric concentrations of greenhouse gases, inter alia carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have grown significantly: by about 30%, 145% and 15% respectively (values for 1992). These trends can be attributed largely to human activities, mostly fossil fuel use, land-use change, and agriculture.
- The growth rates of CO_2, CH_4 and N_2O concentrations were low during the early 1990s. While this apparently natural variation is not yet fully explained, recent data indicate that the growth rates are currently comparable to those averaged over the 1980s.
- The direct radiative forcing of the long-lived greenhouse gases (2.45 Wm^{-2}) is due primarily to increases in CO_2 (1.56 Wm^{-2}), CH_4 (0.47 Mm^{-2}) and N_2O (0.14 Wm^{-2}) (values for 1992).
- Many greenhouse gases remain in the atmosphere for a long time (for CO_2 and N_2O, many decades to centuries), hence they affect radiative forcing on long time-scales. . . .
- If carbon dioxide emissions were maintained at near current (1994) levels, they would lead to a nearly constant rate of increase in atmospheric concentrations for at least two centuries, reaching about 500 ppmv [parts per million by volume] (approaching twice the pre-industrial concentration of 280 ppmv) by the end of the 21st century.
- A range of carbon cycle models indicates that stabilization of atmospheric CO_2 concentrations at 450, 650, or 1000 ppmv could be achieved only if global anthropogenic CO_2 emissions drop to 1990 levels by, respectively, approximately 40, 140 or 240 years from now, and drop below 1990 levels subsequently.
- Any eventual stabilized concentration is governed more by the accumulated anthropogenic CO_2 emissions from now until the time of stabilization, than by the way those emissions change over the period. This means that, for a given stabilized concentration value, higher emissions in early decades require lower emissions later on . . . .
- Stabilization of CH_4 and N_2O emissions at today's levels would involve reductions of 8% and more than 50% respectively. . . .

Climate has changed over the past century

At any one location year-to-year variations in weather can be large, but analyses of meteorological and other data over large areas and over periods of decades or more have produced evidence for some important systematic changes.

- Global mean surface air temperature has increased by between about 0.3 and 0.6°C since the late 19th century; the additional data available since 1990 and the re-analyses since then have not significantly changed this range of estimated increase.
- Recent years have been among the warmest since 1860, i.e., in the period of instrumental record, despite the cooling effect of the 1991 Mt. Pinatubo volcanic eruption.
- Nighttime temperatures over land have generally increased more than daytime temperatures.
- Regional changes are also evident. For example, the recent warming has been greatest over the mid-latitude continents in winter and spring, with a few areas of cooling, such as the North Atlantic Ocean. Precipitation has increased over land in high latitudes of the Northern Hemisphere, especially in the cold season.
- Global sea level has risen by between 10 and 25 cm [3.9 to 9.75 inches] over the past 100 years and much of the rise may be related to the increase in global mean temperature.
- There are inadequate data to determine whether consistent global changes in climate variability or weather extremes have occurred over the 20th century. On regional scales there is clear evidence of changes in some extremes and climate variability indicators (e.g., fewer frosts in several widespread areas; an increase in the proportion of rainfall from extreme events over the contiguous states of the USA). Some of these changes have been toward greater variability; some have been toward lower variability.
- The 1990 to mid-1995 persistent warm-phase of the El Nino-Southern Oscillation (which causes droughts and floods in many areas) was unusual in the context of the last 120 years.

The balance of evidence suggests a discernible human influence on global climate

Any human-induced effect on climate will be superimposed on the background “noise” of natural climate variability, which results both from internal fluctuations and from external causes such as solar variability or volcanic eruptions. Detection and attribution studies attempt to distinguish between anthropogenic and natural influences. “Detection of change” is the process of demonstrating that an observed change in climate is highly unusual in a statistical sense, but does not provide a reason for that change. “Attribution” is the process of establishing cause and effect relations, including the testing of competing hypotheses.

Since the 1990 IPCC Report, considerable progress has been made in attempts to distinguish between natural and anthropogenic influences on climate. This progress has been achieved by including effects of sulfate aerosols in addition to greenhouse gases, thus leading to more realistic estimates of human-induced radiative forcing. These have been used in climate models to provide more complete simulations of the human-induced climate change "signal." In addition, new simulations with coupled atmospheric-ocean models have provided important information about decade to century time-scale natural internal climate variability. A further major area of progress is the shift of focus from studies of global-mean changes to comparisons of modeled and observed spatial and temporal patterns of climate change.

The most important results related to the issues of detection and attribution are:

- The limited available evidence from proxy climate indicators suggests that the 20th century global mean temperature is at least as warm as any other century since at least 1400 AD. Data prior to 1400 AD are too sparse to allow the reliable estimation of global mean temperature.

- Assessments of the statistical significance of the observed global mean surface temperature trend over the last century have used a variety of new estimates of natural internal and externally forced variability. These are derived from instrumental data, palaeodata, simple and complex climate models, and statistical models fitted to observations. Most of these studies have detected a significant change and show that the observed warming trend is unlikely to be entirely natural in origin.

- More convincing recent evidence for the attribution of a human effect on climate is emerging from pattern-based studies, in which the modeled climate response to combined forcing by greenhouse gases and anthropogenic sulfate aerosols is compared with observed geographical, seasonal and vertical patterns of atmospheric temperature change. These studies show that such pattern correspondences increase with time, as one would expect as an anthropogenic signal increases in strength. Furthermore, the probability is very low that these correspondences could occur by chance as a result of natural internal variability only. The vertical patterns of change are also inconsistent with those expected for solar and volcanic forcing.

- Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long-term natural variability and the time-evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land surface changes. Nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate.

Climate is expected to continue to change in the future

The IPCC has a developed a range of scenarios, IS92a-f, of future greenhouse gas and aerosol precursor emissions based on assumptions concerning population and economic growth, land-use, technological changes, energy availability and fuel mix during the period 1990 to 2100. Through understanding of the global climate cycle and of atmospheric chemistry, these emissions can be used to project atmospheric concentrations of greenhouse gases and aerosols and the perturbation of natural radiative forcing. Climate models can then be used to develop projections of future climate.

- The increasing realism of simulations of current and past climate by coupled atmosphere-ocean climate models has increased our confidence in their use for projection of future climate change. Important uncertainties remain, but these have been taken into account in the full range of projections of global mean temperature and sea level change.
- For the mid-range IPCC emission scenario, IS92a, assuming the "best estimate" value of climate sensitivity[3] and including the effects of future increases in aerosol, models project an increase in global mean surface air temperature relative to 1900 of about 2^{o}C [3.6^{o}F] by 2100. This is due primarily to lower emission scenarios (particularly for CO_2 and the CFCs), the inclusion of the cooling effect of sulfate aerosols, and improvements in the treatment of the carbon cycle. Combining the lowest IPCC emission scenario (IS92c) with a "low" value of climate sensitivity and including the effects of future changes in aerosol concentrations leads to a projected increase of about 1^{o}C [1.8^{o}F] by 2100. The corresponding projection for the highest IPCC scenario (IS92e) combined with a "high" value of climate sensitivity gives a warming of about 3.5^{o}C [6.3^{o}F]. In all cases the average rate of warming would probably be greater than any

[3] In IPCC reports, climate sensitivity usually refers to the long-term (equilibrium) change in global mean surface temperature following a doubling of atmospheric equivalent CO_2 concentration. More generally, it refers to the equilibrium change in surface air temperature following a unit change in radiative forcing (C/Wm^{-2}).

seen in the last 10,000 years, but the actual annual to decadal changes would include considerable natural variability. Regional temperature changes could differ substantially from the global mean value. Because of the thermal inertia of the oceans, only 50-90% of the eventual equilibrium temperature change would have been realized by 2100 and temperature would continue to increase beyond 2100, even if concentrations of greenhouse gases were stabilized by that time.

- Average sea level is expected to rise as a result of thermal expansion of the ocean and melting of glaciers and ice-sheets. For the IS92a scenario, assuming the "best estimate" values of climate sensitivity and of ice melt intensity to warming, and including the effects of future changes in aerosol, models project an increase in sea level of about 50 cm [19.5 inches] from the present to 2100. This estimate is approximately 25% lower than the "best estimate" in 1990 due to the lower temperature projection, but also reflecting improvements in the climate and ice melt models. Combining the lowest emission scenario (IS92c) with the "low" climate and ice melt sensitivities and including aerosol effects gives a projected sea level rise of about 15 cm [5.85 inches] from the present to 2100. The corresponding projection for the highest emission scenarios (IS92e) combined with the "high" climate and ice melt sensitivities gives a sea level rise of about 95 cm [37.05 inches] from the present to 2100. Sea level would continue to rise at a similar rate in future centuries beyond 2100 even if concentrations of greenhouse gases were stabilized by that time, and would continue to do so even beyond the time of stabilization of global mean temperature. Regional sea level changes may differ from the global mean value owing to land movement and ocean current changes.

- Confidence is higher in the hemispheric-to-continental scale projections of coupled atmosphere-ocean climate models than in the regional projections, where confidence remains low. There is more confidence in temperature projections than hydrological changes. . . .

- A general warming is expected to lead to an increase in the occurrence of extremely hot days and a decrease in the occurrence of extremely cold days.

- Warmer temperatures will lead to a more vigorous hydrological cycle; this translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places. Several models indicate an increase in precipitation intensity, suggesting a possibility for more extreme rainfall events. Knowledge is currently insufficient to say whether there will be any changes in the occurrence or geographic distribution of severe storms, e.g., tropical cyclones.

- Sustained rapid climate change could shift the competitive balance among species and even lead to forest dieback, altering the terrestrial uptake and release of carbon. The magnitude is uncertain, but could be between zero and 200 GtC [giga-tonnes of carbon] over the next one to two centuries.

There are still many uncertainties

Many factors currently limit our ability to project and detect future climate change. In particular, to reduce uncertainties further work is needed on the following priority topics.

- estimation of future emissions and biogeochemical cycling (including sources and sinks) of greenhouse gases, aerosols and aerosol precursors and projections of future concentrations and radiative properties;
- representation of climate processes in models, especially feedbacks associated with clouds, oceans, sea ice and vegetation, in order to improve projections of rates and regional patterns of climate change;
- systematic collection of long-term instrumental and proxy observations of climate system variables (e.g., solar output, atmospheric energy balance components, hydrological cycles, ocean characteristics and ecosystem changes) for the purposes of model testing, assessment of temporal and regional variability and for detection and attribution studies.

Future unexpected, large and rapid climate system changes (as have occurred in the past) are, by their nature, difficult to predict. This implies that future climate changes may also involve "surprises." In particular these arise form the non-linear nature of the climate system. When rapidly forced, non-linear systems are especially subject to unexpected behavior. Progress can be made by investigating non-linear processes and sub-components of the climatic system. Examples of such non-linear behavior include rapid circulation changes in the North Atlantic and feedbacks associated with terrestrial ecosystem changes. (8-13)

2.3 Potential Effects of Global Climate Change on Hawaii

In 1995, the Intergovernmental Panel on Climate Change (IPCC) Working Group II completed a "review of the state of knowledge concerning climate change on physical and economic systems, human health and socio-economic sectors" (IPCC 1995b). The *Summary for Policy Makers: Scientific-Technical Analysis of Impacts, Adaptations and Mitigations of Climate Change* is available on the Internet at www.unep.ch/ipcc/wg2.html.

The IPPC report discussed a wide range of potential vulnerabilities to climate change faced by human societies. The report noted that the stresses posed by human-induced climate change add an important additional stress to ecological and socio-economic systems already affected by pollution, increasing resource demands and nonsustainable management practices. It addresses effects on agriculture and food security; sea levels, oceans, and coastal areas; biological diversity and ecosystems; water resources; human health; infrastructure, industry, and human settlement; and climatic disasters and extreme events (IPCC 1995b).

In addition, the U.S. Environmental Protection Agency has produced an analysis of the effects of climate change on each state of the United States. *Climate Change and Hawaii* (USEPA 1998a) was published in September 1998.

Hawaii, directly or indirectly, is potentially vulnerable to negative effects from climate. The remainder of this section was extracted from *Climate Change in Hawaii*.

2.3.1 Local Climate Changes

In Honolulu the average temperature has increased 4.4 degrees F over the last century, and precipitation has decreased approximately 20% over the last 90 years. It is not clear whether these trends will continue in the future (2).

Over the next century, climate in Hawaii may change even more. For example, based on projections made by the Intergovernmental Panel on Climate Change and results from the United Kingdom's Hadley Centre's climate model , a model that accounts for both greenhouse gases and aerosols, by 2100 temperatures in Hawaii could increase by 3 degrees F (with a range of 1 to 5 degrees F) in all seasons, slightly more in fall. Future changes in precipitation are highly uncertain because they depend in part on how El Nino might change, and reliable projections of changes in El Nino have yet to be made. It is possible that quite large precipitation increases could occur in summer (particularly) and fall. Other climate models may show different results, especially regarding estimated changes in precipitation. The impacts described take into account estimates from different models. The frequency of extreme hot days in summer would increase because of the general warming trend. It is not clear how the severity of storms such as hurricanes might be affected, although an increase in the frequency and intensity of summer thunderstorms is possible (2).

Human Health

Higher temperatures and increased frequency of heat waves may increase the number of heat-related deaths and the incidence of heat-related illnesses. The elderly, particularly those living alone, are at greatest risk. These effects have been studied only for populations living in urban areas; however, even those in rural areas may be susceptible (2-3).

Climate change could increase concentrations of ground-level ozone. For example, high temperatures, strong sunlight, and stable air masses tend to increase urban ozone levels. Although Hawaii is in compliance with current air quality standards, increased temperatures could make remaining in compliance more difficult. Ground-level ozone is associated with respiratory illnesses such as asthma, reduced lung function, and respiratory inflammation. Air pollution is also made worse by increases in natural hydrocarbon emissions such as emissions of terpenes by trees and shrubs during hot weather. If a warmed climate causes increased use of air conditioners, air pollution emissions from power plants will also increase (3).

Warmer seas could enhance the growth of toxic algae, and can lead to harmful algal blooms, that is, red tides. The increased intensity, duration, and extent of harmful algal blooms can damage habitat and shellfish nurseries. These blooms can be toxic to humans and can carry bacteria like those causing cholera. Viral and bacterial contamination of shellfish has repeatedly caused illness, and warmer waters could contribute to these illnesses. Future warming combined with local pollution most likely would continue to damage fish and shellfish and thus affect human health (3).

Warming and other climate changes may expand the habitat and infectivity of disease-carrying insects, increasing the potential for transmission of diseases such as malaria and dengue fever. Although dengue fever is currently uncommon in the United States, conditions already exist in Hawaii that make it vulnerable to the disease. Warmer temperatures resulting from climate change could increase the risk. Developed countries such as the United States should be able to minimize the impacts of these diseases through existing disease protection and control methods (3).

2.3.3 Coastal Areas

Sea level rise could lead to flooding of low-lying property, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and decreased longevity of low-lying roads, causeways, and bridges. In addition, sea level rise could increase the vulnerability of coastal areas to storms and associated flooding (3).

The 1,000 mile tidally influenced shorelines of the Hawaiian Islands contain some of the world's most famous white-sand beaches as well as steep cliffs. Hawaii's beaches are generally not subject to erosion by waves because of the protective influence of offshore climate reefs. The coral reefs, which are the source of the with sand, could provide sufficient natural nourishment to the beaches under sea level rise. However, the effects of accelerated sea level rise on coral reef ecosystems are poorly understood, and these beaches may require additional sand replenishment (3).

At Honolulu, Nawiliwili, and Hilo, sea level already is rising by 6-14 inches per century, and it is likely to rise another 17-25 inches by 2100. Possible responses to sea level rise include building walls to hold back the sea, allowing the sea to advance and adapting to it, and raising the land (e.g., by replenishing beach sand, elevating houses and infrastructure). Each of these responses will be costly, either in out-of-pocket costs or in lost land and structures. For example, the cumulative cost of sand replenishment to protect the coast of Hawaii from a 20-inch sea level rise by 2100 is estimated at $340 million to $6 billion. However, sand replenishment may not be cost-effective for all coastal areas in the state, and costs may be lower (although some coastal areas would be inundated) (3).

2.3.4 Water Resources

In a warmer climate, runoff and water availability in Hawaii would be influenced primarily by higher temperatures, increased evaporation, and changes in rainfall. Increased rainfall and runoff could recharge aquifers and ease water supply problems; however it could also increase flooding. In Hawaii, hurricanes, severe storms, storm runoff, and high surf (including tsunamis) cause flooding, extensive property damage, and loss of life. Although the effect of a warmer climate on the frequency and severity of tropical cyclones is uncertain, the combination of rising sea level and increased rainfall could exacerbate flooding. The northern and western coasts of each island are particularly vulnerable to high surf, which often damages homes, roads, and resort complexes. The extensively developed coasts of Oahu are particularly susceptible to costly damage (3).

Additionally, in a warmer climate, heavier rains are expected. The resulting increase in runoff could also impair water quality by increasing sediment and pollutant runoff from agricultural lands, overgrazed pasturelands, and urban areas (3).

Hawaii's water resources are very susceptible to prolonged droughts. During these periods, low rainfall and streamflow often lead to increased usage of groundwater, which causes groundwater levels to decline and increases the likelihood of salt-water intrusion. Severe droughts also result in crop damage, livestock losses, and water-use restrictions. Under warmer conditions, the variability of climate is expected to increase, which could lead to more frequent and intense droughts (3).

2.3.5 Agriculture

The mix of crop and livestock production in a state is influenced by climatic conditions and water availability. As climate warms, production patterns could shift northward. Increases in climate variability could make adaptation by farmers more difficult. Warmer climates and less soil moisture due to increased evaporation may increase the need for irrigation. However, these same conditions could decrease water supplies, which also may be needed by natural ecosystems, urban populations, industry, and other users (4).

Understandably, most studies have not fully accounted for changes in climate variability, water availability, crop pests, changes in air pollution such as ozone, and adaptation by farmers to changing climate. Including these factors could change modeling results substantially. Analyses that assume changes in average climate and effective adaptation by farmers suggest that aggregate U.S. food production would not be harmed, although there may be significant regional changes (4).

In Hawaii, production agriculture is a $500 million annual industry, 80% of which comes from crops. Almost one-half of the farmed acres are irrigated. The major crops in the state are sugarcane and pineapple. Climate change could increase their yields by about 10%. Farmed acres could remain fairly constant (4).

2.3.6 Forests

Trees and forests are adapted to specific climate conditions, and as climate warms, forests will change. These changes could include changes in species composition, geographic range, and health and productivity. If conditions also become drier, the current range and density of forests could be reduced and replaced by grasslands and pasture. Even a warmer and wetter climate could lead to changes; trees that are better adapted to these conditions would thrive. Under these conditions, forests could become more dense. These changes could occur during the lifetimes of today's children, particularly if the change is accelerated by other stresses such a fire, pests, and diseases. Some of these stresses would themselves be worsened by a warmer and drier climate (4).

The native Hawaiian tree 'ohi'a appears to be strongly influenced by long-term changes in climate, and older trees are particularly sensitive to both drought and heavy rains. 'Ohi'a is a widely distributed species that is essential habitat for many important Hawaiian animals, especially the endangered Hawaiian honey-creeper found in old growth 'ohi'a forests. Native Hawaiian forests are being reduced and in some cases eliminated by competition by non-native trees and plants. Changes in climate could cause further stress because the non-native species are more tolerant of temperature and rainfall changes than native species (4).

Climatic stress on trees also tends to make them more vulnerable to fungal and insect pests. For example, one fungus, Phytophthora cinnamomi, is a widespread cause of declining forests in Hawaii, and is often triggered by unusual climate conditions that stress trees (4).

Warmer conditions could alter the extent and composition of the unique forests surrounding the taller mountains . . . of Hawaii. Worldwide, tropical cloud forests are one of the rarest of natural habitats, and may be among the most sensitive to climate change. At present this cloud forest is one of the wettest ecosystems on earth. Even small changes in climatic conditions could cause major changes in the cloud cover and precipitation regimes that maintain the rainforests of Haleakala. The upper limit of the cloud forest zone is determined by the altitude of the upper cloud zone (a function of climate). Climate change could cause a shift in distribution of cloud forest species (4).

The increased possibility of forest fire under drought conditions is especially damaging in tropical forests, where species are not adapted to this type of disturbance. Fire is typically a primary mechanism whereby non-native species invade ecosystems. Increased frequency or intensity of hurricanes will exacerbate the problems associated with fire and invasive species. An increase in the severity or frequency of hurricanes and tropical storms could alter forest composition [in the islands] (4).

2.3.7 Ecosystems

Hawaii is surprisingly diverse geographically, from atolls to snow capped peaks more than 12,000 feet high. The remote and unpopulated outer islands are home to some of the largest seabird colonies in the world -- up to 10 million albatrosses, frigatebirds, shearwaters, boobies, sooty and fairy terns, and petrels breed here. The diversity of environments and the extreme isolation of the state have resulted in a spectacular variety of species, many of which are endemic to the islands. An estimated 91% of flowering plant species, 81% of birds, and 99% of terrestrial snails and anthropods are found only here (4).

At the same time, Hawaii is the world's capital for species extinction and endangerment. Of the known U.S. extinctions, 70% have occurred here. Since 1778, the year of European contact, 263 species are known to have become extinct, including 50% of the bird fauna and perhaps 50% of plants and 90% of native land snails. Currently, there are more endangered species per square mile on these islands than any other place on the planet. Twenty-five percent of U.S. endangered species are found here, including 2 mammals, 30 birds, 5 reptiles and amphibians, 1 snails genus, and 279 plant taxa. Important contributions to this wave of loss and endangerment are habitat loss, introduced diseases, and impacts from introduced organisms, especially pigs, goats, sheep, and cattle (4).

The estimated increases in temperature and changes in precipitation due to climate change adds another threat to this onslaught of human created problems. One of nine endemic bird species in the Hawaiian honeycreeper family found in the cloud forests of east Maui, the endangered i'iwi has survived in the higher forests of Haleakala National Park because mosquitos that transmit deadly avian malaria cannot breed at higher elevations because of the cooler temperatures. A warmer climate might allow the mosquito to move further up the mountain (4).

2.4 RECOMMENDATION: Hawaii Should Take Action to Deal with Global Climate Change

2.4.1 Hawaii Should Take Action at Home

This is the fundamental and principal recommendation of the Hawaii Climate Change Action Plan. As noted above, significant climate change will occur regardless of whatever local, statewide, national, or international actions may be taken in the next few decades. The people of Hawaii cannot stop climate change by themselves. However, due to the significance of the potential effects, Hawaii should take action to reduce its contribution of greenhouse gases that contribute to climate change. The remainder of this report identifies Hawaii's emissions and recommends ways to reduce or mitigate these emissions.

In addition, Hawaii must continue efforts to identify future effects of climate change, which is in the process of occurring, on the people, environment, ecosystems, and economy. Based upon these estimated future effects Hawaii can begin necessary efforts to adapt.

Hawaii Can Contribute to Reducing Greenhouse Gas Emissions Overseas

U.S. and Hawaii technology and expertise can be commercially exported to the developing nations of the Asia/Pacific region. This can help reduce greenhouse emissions from a region whose emissions are forecast to grow at a greater rate than the rest of the world. This type of commercial activity can help these nations achieve significant greenhouse gas reductions and substantial economic benefits for Hawaii and the United States as a whole.

CHAPTER 3 1990 HAWAII GREENHOUSE GAS EMISSIONS

3.1 Overview

This chapter summarizes Hawaii's estimated greenhouse gas emissions in 1990. The summary is based upon the work done in Phase I of the Hawaii Climate Change Action Program and the *Inventory of Hawaii Greenhouse Gas Emissions, Estimates for 1990* (State of Hawaii 1997a). The methods used in the calculation of these estimates was detailed in the *Inventory*.

The values summarized below, however, are an increase over the estimate made in 1997 for the *Inventory*. Since then, more complete information became available about the use of jet fuel by civil aviation in Hawaii. In the *Inventory*, previously reported data on interisland aviation use was included in the Hawaii share while the remaining overseas and military uses were not included.

The new data provided the amounts of fuel used by domestic flights and bonded fuel for international flights. Domestic flights include interisland flights and flights between Hawaii and other states in the United States. Bonded international fuel was used for flights between Hawaii and international destinations and also included flights between mainland United States and international locations that stopped in Hawaii.

The use of emissions estimates from fuel used for domestic flights better fits the reporting requirements under the Framework Convention on Climate Change. Accordingly, the baseline for 1990 Hawaii Greenhouse Gas Emissions was revised. The revised estimate of Hawaii's global warming potential was 18,784,299 tons of CO_2-equivalent compared to the previous estimate of 17,302,113 tons.

3.2 Estimated 1990 Hawaii Greenhouse Gas Emissions

As depicted on Table 3.1, on the following page, Hawaii 's anthropogenic greenhouse gas emissions in 1990 were estimated at 15,985,225 tons of CO_2, 75,736 tons of CH_4, and 690 tons of N_2O. These emissions were produced by energy uses, industrial processes in the oil and cement industries, and non-energy sources within the state. CO_2 emissions from the burning of bagasse, macadamia nut shells, and wood chips to generate electricity and process heat are not included in this total as those fuels sequestered similar amounts of CO_2 as they are grown and were assumed to be replanted.

The Hawaii baseline estimate did not include exports, international, or military uses of fuels sold, distributed, or refined in Hawaii. An estimated total of 322,981,982 million Btu of various fuels was imported, refined, or produced in Hawaii in 1990. Of that amount, 29%, or 92,874,783 Btu was not used in Hawaii. It was sold as fuel for aircraft for international flights, ships involved in overseas operations, sold to the military, or exported as cargo. However, the emissions from these fuels were calculated and reported separately to provide a complete record.

Table 3.1 Estimated Greenhouse Gas Emissions in Hawaii, 1990 (Tons)

Sector/Fuel	Net CO_2	CH_4	N_2O
Energy Use			
Residential Sector	94,760	2	N/A
Commercial Sector	278,767	6	13
Industrial Sector	836,667	42	6
Electricity Sector	7,647,046	109	13
Transportation Sector	7,763,422	857	454
Subtotal	16,620,662	1,015	486
Non-Energy Sources			
Oil Industry	N/A	237	N/A
Cement Industry	109,274	N/A	N/A
MSW Management	189,684	53,490	N/A
Wastewater Treatment	N/A	1,027	N/A
Domestic Animals	N/A	13,368	N/A
Manure Management	N/A	6,056	N/A
Sugarcane Burning	N/A	543	8
Fertilizer	N/A	N/A	196
Changes in Biomass	(415,158)	N/A	N/A
Abandoned Lands	(519,237)	N/A	N/A
Subtotal	(635,437)	74,721	204
Total	15,985,225	75,736	690

Fuel not included in the baseline includes jet fuel used for international flights by U.S. and foreign airlines. Distillate and residual bunker fuel oils excluded from the Hawaii totals were primarily sold to vessels engaged in international or overseas trade, or to fishing vessels from foreign nations. High-sulfur residual fuel oil was also exported.

The fuel purchased by the armed forces in Hawaii was not included in this accounting. In addition to being home to many military bases, Hawaii is a key logistics center. Data was not available on the amounts of the fuel purchased from Hawaii refiners that may be used on naval vessels refueling in Hawaii or otherwise used outside of Hawaii. The large fluctuations in the amounts of fuels purchased from Hawaii sources noted in the available data suggested that additional fuels were brought into Hawaii by military logistics agencies. Data was not available to determine the amounts of these fuels or whether they were used by forces stationed in Hawaii, used at sea, or if they were shipped to forces overseas. Nevertheless, as this report will serve as the basis for developing mitigation measures, it should also be noted that military fuel use is not subject to State influence or direction.

Emissions from fuel used in fixed military boilers and generators are included in this report since data was available on most of this use. In addition, it should be noted that the Department of Defense is the largest electricity customer in the state, so significant emissions from the electricity sector result from generation of electricity for military use. These emissions, produced by Hawaii's electric utilities, were included in the *Inventory* and mitigation measures are discussed in Chapter7. A summary of emissions from overseas and military uses is provided in Section 3.4.

Table 3.2 summarizes the percentage contribution of each source to Hawaii's estimated greenhouse gas emissions. Hawaii's energy sectors clearly dominated production of CO_2 and N_2O, while non-energy sources led in CH_4 production. CO_2 was taken out of the atmosphere by changes in biomass and by abandoned lands as shown on Table 3.1. However, these were not included in this table as the focus of this report is on identifying ways to reduce CO_2 and other greenhouse gas production by human activities in Hawaii. While such measures as carbon offset forestry may increase Hawaii's uptake of CO_2, such offsets have not yet been accurately quantified.

Table 3.2 Percent Contribution to Estimated Greenhouse Gas Emissions in Hawaii, 1990

Sector/Fuel	CO_2	CH_4	N_2O
Energy Use			
Residential Sector	1%	0.003%	N/A
Commercial Sector	2%	0.01%	2%
Industrial Sector	5%	0.06%	1%
Electricity Sector	45%	0.1%	2%
Transportation Sector	46%	1%	66%
Subtotal	98%	1%	70%
Non-Energy Sources			
Oil Industry		0.3%	
Cement Industry	1%		
MSW Management	1%	71%	
Wastewater Treatment		1%	
Domestic Animals		18%	
Manure Management		8%	
Sugarcane Burning		1%	1%
Fertilizer			28%
Subtotal	2%	99%	30%
Total	100%	100%	100%

Note: CO_2 uptake was not included in the computation of percentage GHG emissions

3.3 Estimated Global Warming Potential of Hawaii Greenhouse Gas Emissions

Global Warming Potential, or GWP, is a measure used to compare the relative effects of each of the different greenhouse gases on radiative forcing of the atmosphere over some future time horizon. To allow such comparisons, an index is needed to translate the level of emissions of each gas into a common metric. The index used in this report converted CH_4 and N_2O emissions into their CO_2-

equivalent using the methodology of the Intergovernmental Panel on Climate Change (IPCC) as recommended by the *State Workbook* (USEPA 1995b, vii).

The IPCC method compares the radiative forcing effect of the concurrent emission into the atmosphere of an equal quantity of CO_2 and another greenhouse gas. Each gas has a different instantaneous effect and the atmospheric concentration of each gas declines at a different rate over time. In general, other greenhouse gases have a much stronger instantaneous radiative effect than CO_2, but CO_2 has a longer atmospheric lifetime and slower decay rate. The atmospheric concentrations of some greenhouse gases may decline due to atmospheric chemical processes, which in turn create other greenhouse gases or contribute to their creation or longevity. These indirect effects are uncertain and will not be included in calculating the Hawaii GWP (vii).

GWP is defined as "the time-integrated commitment to climate forcing from the instantaneous release of 1 kilogram of trace gas expressed relative to that from 1 kilogram of carbon dioxide" (viii). The value is time sensitive and, for the purposes of this report, a 100-year time horizon was used. Over this time period, CH_4 has 22 times the radiative forcing direct impact as CO_2, and N_2O has 270 times the direct impact (viii). Thus, to calculate GWP in tons CO_2 equivalent, emissions CH_4 in tons were multiplied by 22, and N_2O emissions in tons were multiplied by 270.

Table 3.3 Global Warming Potential of Greenhouse Gas Emissions in Hawaii, 1990 (Tons CO_2-Equivalent)

Sector	CO_2	CH_4	N_2O	Total
Energy Use				
Residential Sector	94,760	44	N/A	94,804
Commercial Sector	278,767	124	3,522	282,412
Industrial Sector	836,667	932	N/A	837,599
Electric Utility Sector	7,647,046	2,396	3,524	7,652,966
Transportation Sector	7,763,422	18,846	136,350	7,918,618
Subtotal	16,620,662	22,341	143,396	16,786,399
Non-Energy Sources				
Oil Industry	N/A	5,214	N/A	5,214
Cement Industry	109,274	N/A	N/A	109,274
MSW Management	189,684	1,176,780	N/A	1,366,464
Wastewater Treatment	N/A	22,594	N/A	22,594
Domestic Animals	N/A	294,096	N/A	294,096
Manure Management	N/A	133,232	N/A	133,232
Sugarcane Burning	N/A	11,946	2,160	14,106
Fertilizer	N/A	N/A	52,920	52,920
Subtotal	298,958	1,643,862	55,080	1,997,900
Total	16,919,620	1,666,203	198,476	18,784,299
Percent	**90%**	**9%**	**1%**	**100%**

Table 3.3 presents the GWP of CO_2, CH_4, and N_2O emissions in Hawaii in 1990 -- the equivalent of 18,784,299 tons of CO_2. This value was not reduced by the estimated amount of CO_2 uptake from changes and biomass and uptake by

abandoned lands since the focus of this *Hawaii Climate Change Action Plan* is on emissions as a basis for future consideration of mitigation measures. The GWP of each of Hawaii's emission sources is important as it allows comparison of sources which emit different greenhouse gases and will assist in identifying areas for focus in developing greenhouse gas mitigation measures.

Figure 3.1 compares relative GWP contribution of the three major greenhouse gases emitted in Hawaii in 1990. CO_2 emissions were 90% of Hawaii's global warming potential, followed by CH_4 at 9% and N_2O at 1%.

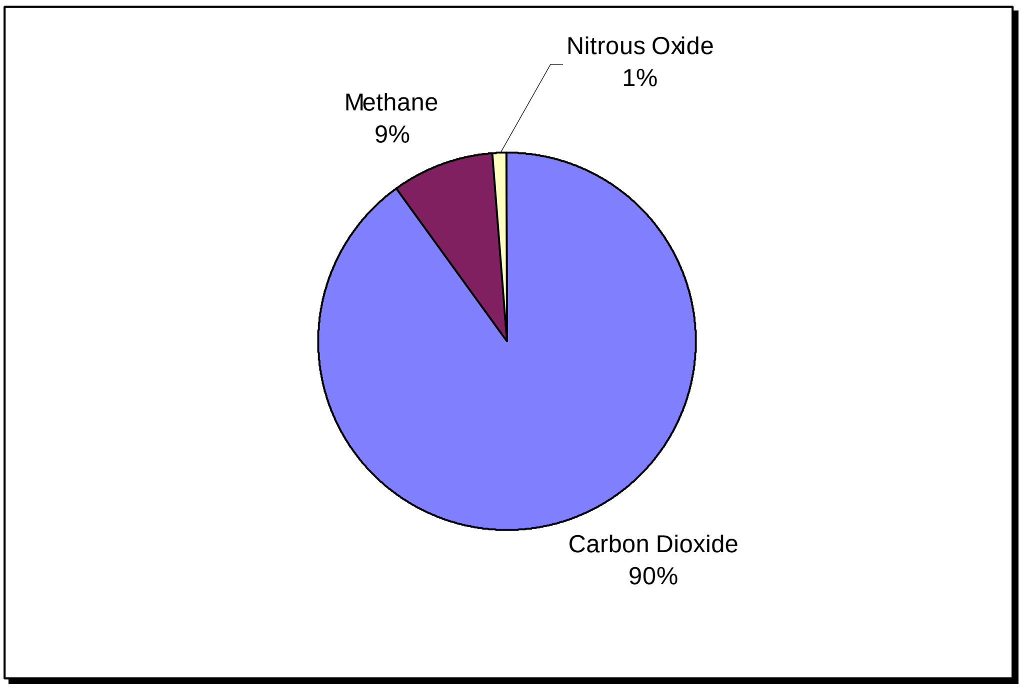


Figure 3.1 Global Warming Contribution of Hawaii Greenhouse Gas Emissions, 1990

Figure 3.2 shows a comparison of the relative GWP by source category. Energy use emissions dominated at 89%. Waste management, which includes municipal solid waste management and wastewater treatment, was in second place at 7%. The various agricultural sources, including domestic animals, manure management systems, sugarcane burning, and fertilizer use together contributed 3% to GWP. Finally, industrial processes in the oil refining and cement industries created about 1% of Hawaii's GWP.

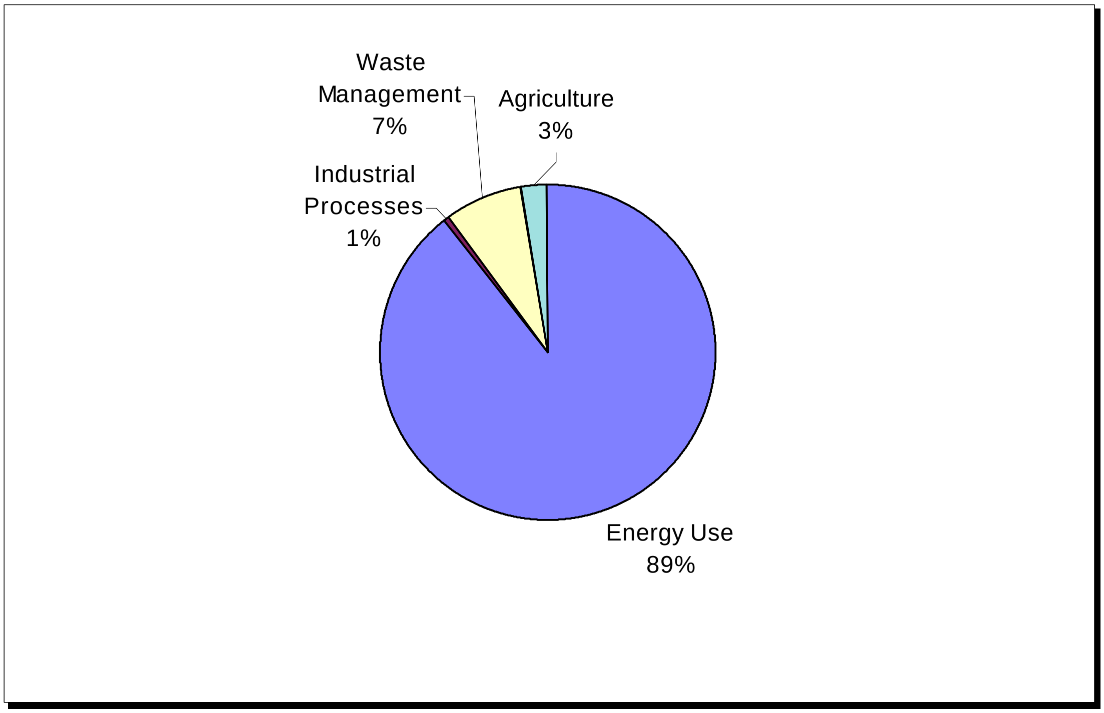


Figure 3.2 Global Warming Contribution of Hawaii Greenhouse Gas Emissions by Source Category, 1990

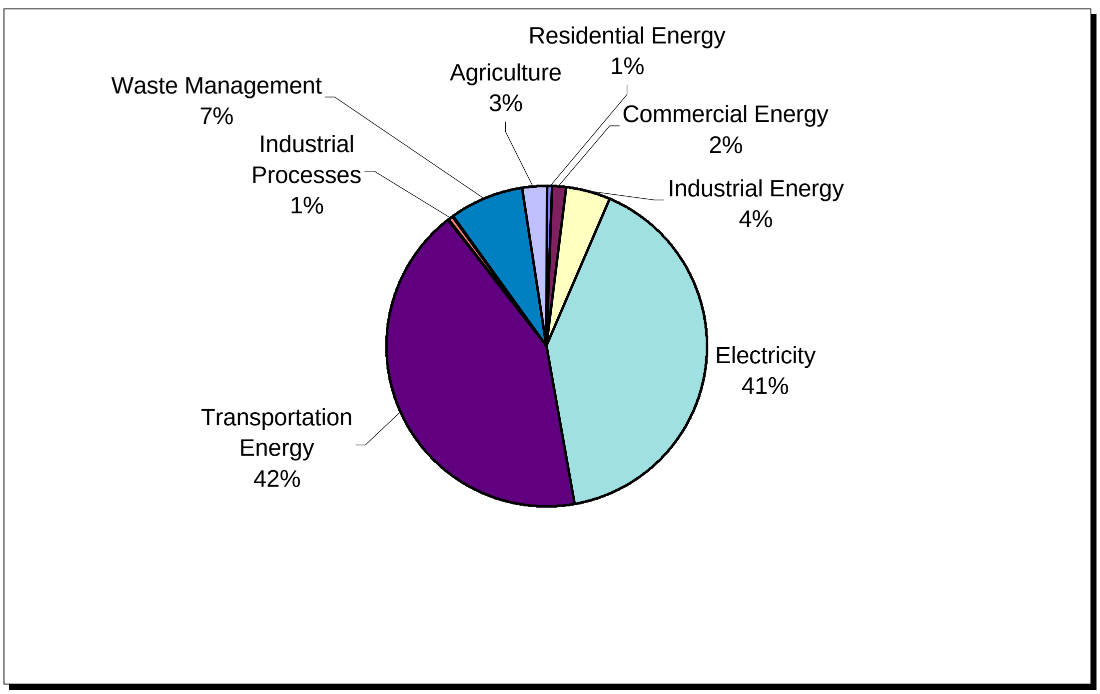


Figure 3.3 Global Warming Contribution of Hawaii Greenhouse Gas Emissions by Sector, 1990

In Figure 3.3, above, a more detailed view of GWP is presented by sector. In this breakout, transportation energy use produced 42% of GWP, followed by electricity generation at 41%, waste management at 7%, industrial energy use at 4%, agriculture at 3%, and commercial energy uses at 1%. The remaining sectors, including residential energy use and industrial processes each contributed less than one percent to total global warming potential (rounded to 1% on chart).

Figure 3.4 summarizes the relative contribution to CO_2 emissions by sector. Again, the transportation and electricity sectors clearly dominate; they produced 46% and 45% of CO_2 emissions, respectively. Industrial energy accounted for 5% and commercial energy was 2%. Other uses, including waste management, the cement industry, and residential energy use combined contributed about 2% to Hawaii's total CO_2 emissions.

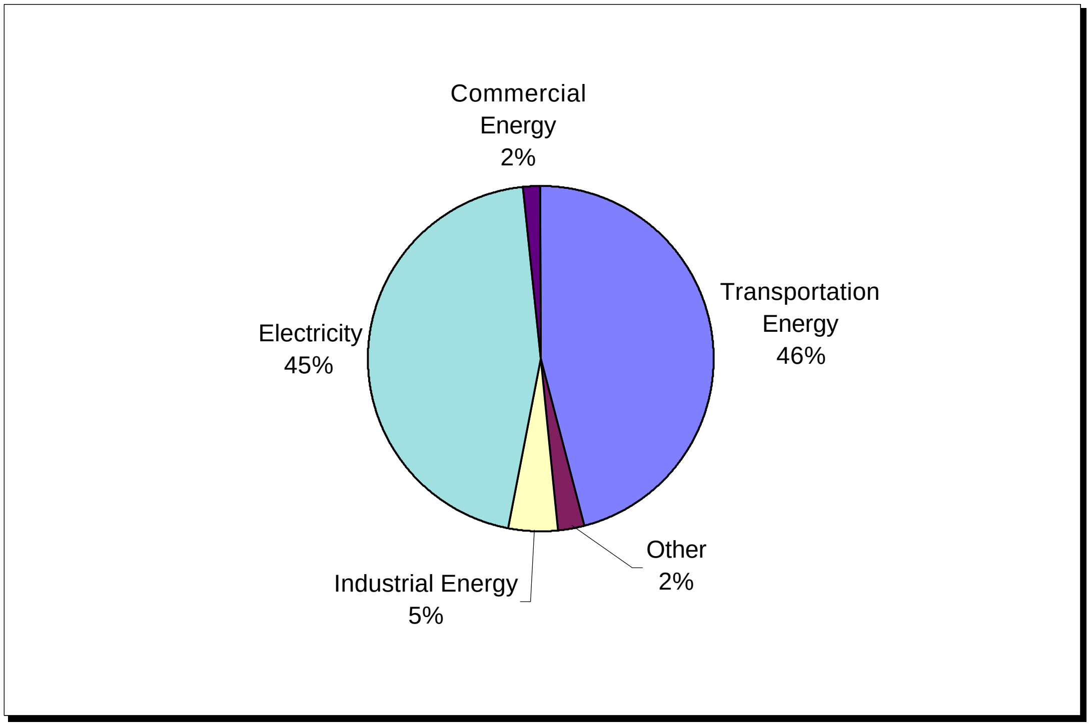


Figure 3.4 Hawaii Carbon Dioxide Emissions by Sector, 1990

Figure 3.5, on the next page, summarizes the sources of methane emissions. Waste management produced 72%, agriculture (primarily ruminant domestic animals and manure management) emitted 26%, and transportation energy produced 1% and other sources accounted for the remaining 1%.

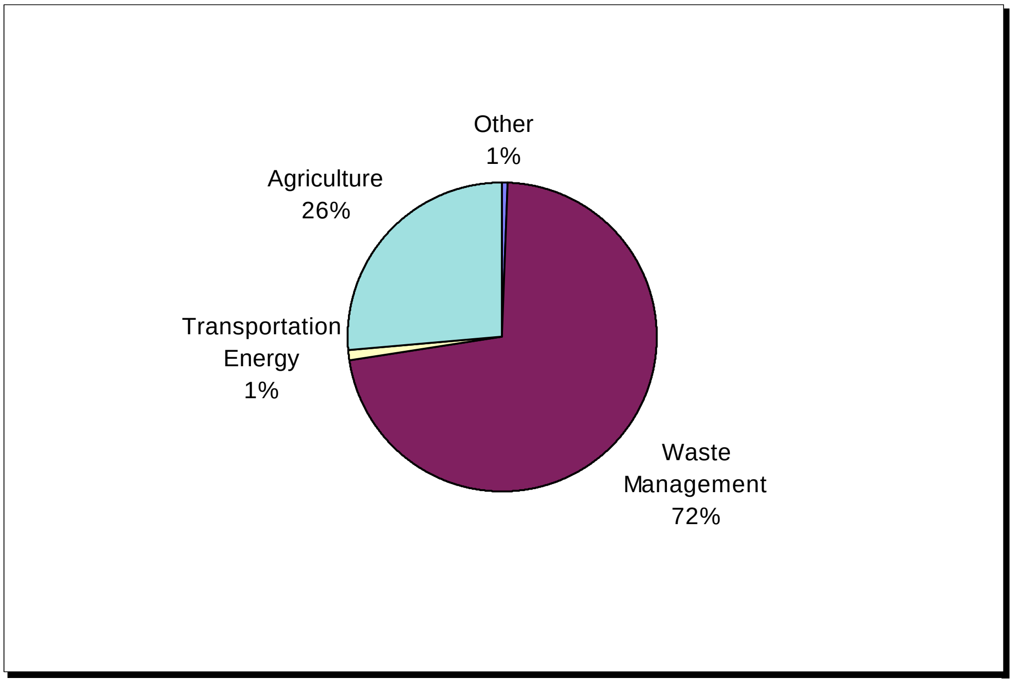


Figure 3.5 Hawaii Methane Emissions by Sector, 1990

The largest share of N_2O emissions, as depicted on Figure 3.6, was produced by transportation energy sources (65%). Agriculture sector (30%) emissions were also significant. The commercial energy sector and electricity sector each added about 2% while the industrial sector accounted for about 1%.

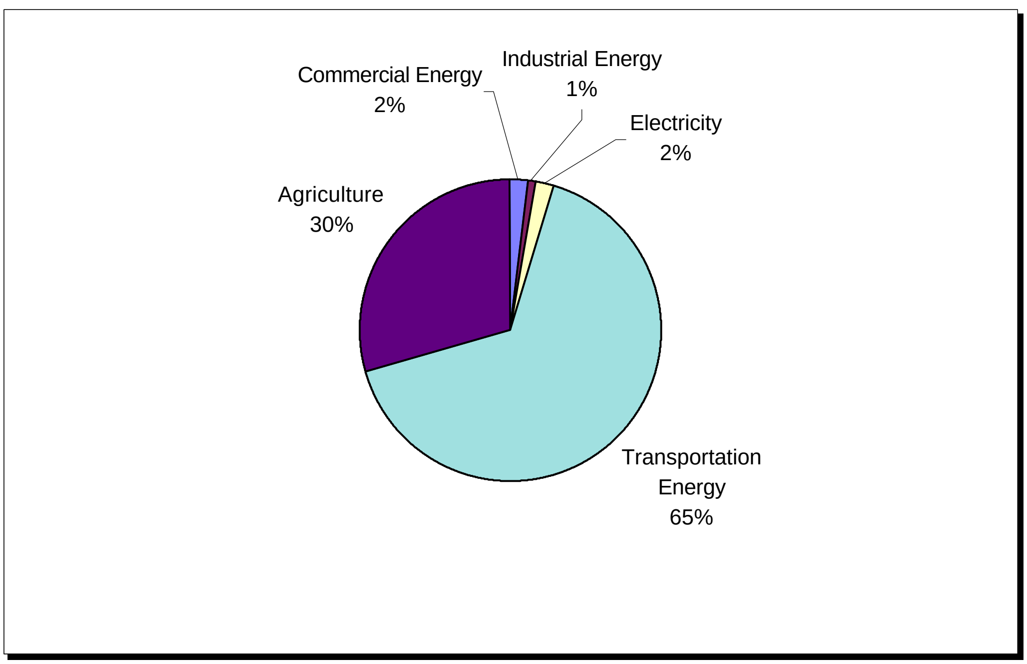


Figure 3.6 Hawaii Nitrous Oxide Emissions by Sector, 1990

3.4 Estimated Greenhouse Gas Precursor Emissions

In the *Inventory*, emissions of nitrogen oxides (NO_x), carbon monoxide (CO), and non-methane volatile organic compounds were estimated. These are known as photochemically important gases, or tropospheric ozone precursors. Although these are not greenhouse gases, they contribute indirectly to the greenhouse effect. They influence the rate at which ozone and other gases are created and destroyed in the atmosphere. NO_x contributes to the formation of ozone in the upper atmosphere. CO elevates concentrations of CH_4 and atmospheric ozone through chemical reactions with atmospheric constituents that would otherwise destroy CH_4 and ozone. It eventually oxidizes to CO_2. NMVOCs participate along with nitrogen oxides in the formation of ground-level ozone and other photochemical oxidants (USEPA 1995b, iii).

Table 3.4 Estimated Precursor Gas Emissions in Hawaii, 1990

	Emissions in Tons			Percent of Emissions		
Sector/Fuel	**NO_x**	**CO**	**NMVOC**	**NO_x**	**CO**	**NMVOC**
Energy Use						
Residential Sector	72	15	N/A	0.1%	0.01%	N/A
Commercial Sector	15	47	0.4	0.02%	0.03%	0%
Industrial Sector	7,314	1,915	225	10%	1%	1%
Electricity Sector	30,218	3,347	626	40%	2%	3%
Transportation Sector	37,041	121,605	19,263	50%	73.8%	96%
Subtotal	74,661	126,929	20,115	99.8%	77%	100%
Industrial Processes	None Reported					
Non-Energy Sources						
MSW Management	N/A	27,101	N/A	N/A	N/A	N/A
Sugarcane Burning	140	10,857	N/A	0.2%	7%	N/A
Subtotal	140	37,958	N/A	0.2%	23%	N/A
Total	74,801	164,887	20,115	100%	100%	100%

Table 3.4 details the amounts of each gas emitted in tons and the relative percentage contribution of each source. These values have been revised since the original *Inventory* was completed on the basis of new data as discussed in Section 3.1, above. These emissions were not included global warming potential as a conversion factor was not available. Virtually all NO_x and NMVOC emissions came from Hawaii's energy sector. The energy sector also produced just over three-quarters of CO emissions. In this *Hawaii Climate Change Action Plan*, the emissions for these gasses will not be calculated or reported. Instead, the focus will be on the three primary greenhouse gases – CO_2, CH_4, and N_2O.

3.5 Estimated Emissions from International, Overseas, and Military Uses

As noted in Section 3.2, above, the estimate of Hawaii greenhouse and precursor gas emissions did not include international, overseas, or military uses of aviation and marine fuel or exports of fuel sold, distributed, or refined in Hawaii.

International uses included jet fuel for overseas commercial airline flights. Overseas uses included distillate and residual fuel oil used for bunkering ships in overseas operations in Hawaii ports, and distillate and fuel oil exported from Hawaii. Military uses in mobile sources were excluded due to a lack of data on location and amount of actual use. To provide a complete record of greenhouse gas and tropospheric precursor gas emissions of all fuels sold, distributed, or refined in Hawaii, the emissions from overseas and military uses were calculated and are presented in Table 3.5.

Table 3.5 Estimated International, Overseas, and Military Emissions, 1990 (Tons)

Fuel	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
International and Overseas Use						
Distillate	807,253	N/A	22	23,451	505	N/A
Jet Fuel	4,362,167	122	N/A	17,680	7,459	1,105
Residual	1,032,705	N/A	28	30,001	647	N/A
	6,202,125	122	51	71,132	8,611	1,105
Military Use						
Avgas	589	1	0.0	1	207	5
Distillate	388,078	22	11	6,439	2,041	486
Gasoline	26,416	2	1	451	143	34
Jet Fuel	676,704	19	N/A	2,743	1,157	171
Residual	69,349	N/A	1	2,676	40	N/A
	1,161,136	43	13	12,309	3,588	696
International, Overseas, and Military Emissions by Fuel						
Avgas	589	0.5	0.01	1	207	5
Distillate	1,195,331	22	33	29,890	2,546	486
Gasoline	26,416	2	1	451	143	34
Jet Fuel	5,038,871	140	N/A	20,423	8,616	1,276
Residual	1,102,054	-	29	32,677	687	180
	7,363,261	165	64	83,442	12,199	1,981

The global warming potential was calculated for CO_2, CH_4, and N_2O emissions from overseas and military fuel use, as presented on Table 3.6 on the following page. The total GWP was equivalent to 7,384,357 tons CO_2. When added to the 18,784,299 tons of CO_2-equivalent GWP of the emissions from in-state fuel use, industrial processes, and non-energy sector activities, the total GWP from all fuels sold, distributed, or refined in Hawaii was 26,168,618 tons of CO_2-equivalent.

As Table 3.6 and Figure 3.7 show, international and overseas uses of Hawaii origin fuels were 6,218,485 tons of CO_2-equivalent, or 24% of total GWP. Military uses produced 1,165,872 tons of CO_2-equivalent, or 4% of GWP from all sources. All Hawaii greenhouse gas emission sources produced a GWP of 18,784,299 tons, or 73% of the total.

Table 3.6 International, Overseas, and Military Greenhouse Gas Emissions Global Warming Potential, 1990 (Tons CO_2-Equiv.)

Fuel	CO_2	CH_4	N_2O	Total
International and Overseas Use				
Distillate	807,253	N/A	6,004	813,257
Jet Fuel	4,362,167	2,674	N/A	4,364,841
Residual	1,032,705	N/A	7,681	1,040,386
Subtotal	6,202,125	2,674	13,686	6,218,485
Military Use				
Avgas	589	11	2	603
Distillate	388,078	484	2,970	391,532
Gasoline	26,416	44	540	27,000
Jet Fuel	676,704	415	N/A	677,119
Residual	69,349	N/A	270	69,619
Subtotal	1,161,136	954	3,782	1,165,872
Total GWP by Fuel				
Avgas	589	11	2	603
Distillate	1,195,331	484	8,974	1,204,789
Gasoline	26,416	44	540	27,000
Jet Fuel	5,038,871	3,089	N/A	5,041,960
Residual	1,102,054	N/A	7,951	1,110,005
Total	7,363,261	3,628	17,468	7,384,357

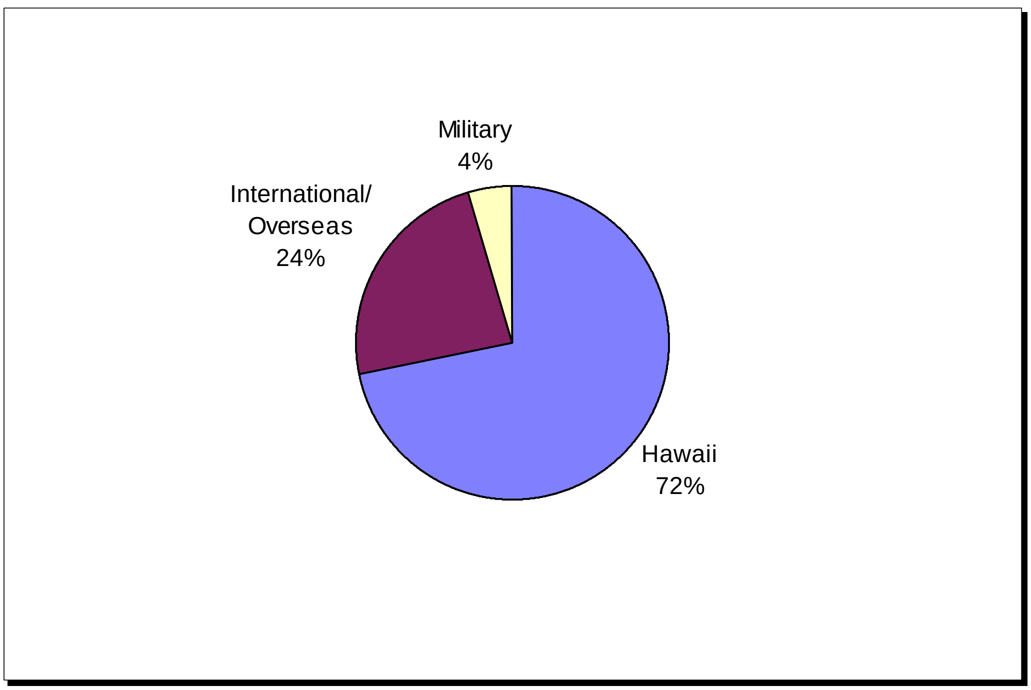


Figure 3.7 Contributions to GWP of Hawaii Sources and Hawaii-origin Fuels, 1990

3.6 Comparison of Estimated Hawaii Greenhouse Gas Emissions with Selected States

The global warming potential of total United States emissions of CO_2, CH_4, and N_2O in 1990 was 5,567,000,000 tons CO_2-equivalent (USEPA 1994b, ES-5). Hawaii's GWP of 18,784,299 tons CO_2-equivalent was 1/3 of one percent of the national total.

3.6.1 Comparing the States

Table 3.7, on the next page, compares Hawaii's GWP in tons of CO_2-equivalent with the GWP of 17 other states that completed greenhouse gas inventories under the EPA's State and Local Outreach Program. GWP in tons CO_2-equivalent per capita, based on 1990 resident population and in pounds CO_2-equivalent per dollar of 1990 Gross State Product (GSP) are also presented for comparison.

Table 3.7 Comparison of the Global Warming Potential of Emissions Produced in Selected States, 1990

	HAWAII	**Alabama**	**Illinois**	**Iowa**	**Kentucky**
Emissions (10^6 TCDE)	**18.7**	141.8	253.3	96.2	162.2
1990 Population [1]	**1,108,000**	4,041,000	11,434,000	2,777,000	3,685,000
TCDE/Capita	**16.9**	35.1	22.2	34.6	44.0
1990 GSP (Billion $) [2]	**29**	70	272	56	67
Lbs. CO2-Equiv./$ GSP	**1.3**	4.1	1.9	3.4	4.8
	Maine	**Mississippi**	**Missouri**	**New Jersey**	**New York**
Emissions (10^6 TCDE)	23.0	92.2	135.3	129.2	270.3
1990 Population [1]	1,228,000	2,573,000	5,117,000	7,730,000	17,990,000
TCDE/Capita	18.8	35.8	26.4	16.7	15.0
1990 GSP (Billion $) [2]	23	40	104	208	467
Lbs. CO2-Equiv./$ GSP	2.0	4.6	2.6	1.2	1.2
	N. Carolina	**Oregon**	**Pennsylvania**	**Tennessee**	**Utah**
Emissions (10^6 TCDE)	138.2	55.5	278.6	114.8	62.1
1990 Population [1]	6,629,000	2,842,000	11,882,000	4,877,000	1,723,000
TCDE/Capita	20.8	19.5	23.4	23.5	36.1
1990 GSP (Billion $) [2]	141	55	245	95	31
Lbs. CO2-Equiv./$ GSP	2.0	2.0	2.3	2.4	4.0
	Vermont	**Washington**	**Wisconsin**		**USA**
Emissions (10^6 TCDE)	8.5	85.7	101.1		5,677.0
1990 Population [1]	563,000	4,867,000	4,892,000		248,710,000
TCDE/Capita	15.1	17.6	20.7		22.8
1990 GSP (Billion $) [2]	11	109	101		5,499
Lbs. CO2-Equiv./$ GSP	1.5	1.6	2.0		2.1

TCDE = Tons Carbon Dioxide Equivalent (short tons). No credit was given for land use or other sinks

Data on States' emissions from EPA site at http://www.icf-infotech.com/ghg/ghg.nsf/ReportStateLookup/

Sources: [1] U.S. Department of Commerce 1994, 27; [2] U.S. Department of Commerce 1994, 449

It should be noted that Hawaii's 1990 *de facto* population of 1,257,000, 114% of its resident population of 1,108,000, contributed to the emissions produced in many of the categories in this report. However, in the absence of comparable *de facto* population data from other states, and recognizing that the emissions produced by visitors to Hawaii are an integral part of Hawaii's economy and environment, it seems logical to evaluate per capita emissions on the basis of resident population.

Among this group of states, Hawaii produced the fourth smallest quantity of CO_2-equivalent emissions per capita and the third lowest per dollar of GSP. New Jersey, New York, and Vermont produced fewer emissions per capita. In 1990, all three states used significant amounts of electricity produced by hydroelectric and nuclear plants that do not emit greenhouse gases. In contrast, Hawaii's electricity sector dominated its production of greenhouse gases and oil-fired generators produced about 90% of Hawaii's electricity in 1990. New Jersey and New York also emitted less CO_2-equivalent greenhouse gas emissions per dollar of GSP in 1990 (USDOE 1992a, 224 and USEPA 1998k).

3.6.2 Comparing the States Omitting Jet Fuel Emissions

Table 3.8 Comparison of the Global Warming Potential of Emissions Produced in Selected States with Emissions from Jet Fuel Use Omitted, 1990

	Hawaii	Alabama	Illinois	Iowa	Kentucky
Emissions (10^6 TCDE)	14.9	140.9	251.5	95.8	159.6
1990 Population [1]	1,108,000	4,041,000	11,434,000	2,777,000	3,685,000
TCDE/Capita	13.4	34.9	22.0	34.5	43.3
1990 GSP (Billion $) [2]	29	70	272	56	67
Lbs. CO_2-Equiv./$ GSP	1.0	4.0	1.8	3.4	4.8
	Maine	**Mississippi**	**Missouri**	**New Jersey**	**New York**
Emissions (10^6 TCDE)	21.9	89.1	132.3	108.5	267.9
1990 Population [1]	1,228,000	2,573,000	5,117,000	7,730,000	17,990,000
TCDE/Capita	17.8	34.6	25.9	14.0	14.9
1990 GSP (Billion $) [2]	23	40	104	208	467
Lbs. CO_2-Equiv./$ GSP	1.9	4.5	2.5	1.0	1.1
	N. Carolina	**Oregon**	**Pennsylvania**	**Tennessee**	**Utah**
Emissions (10^6 TCDE)	135.7	54.0	273.2	112.9	59.8
1990 Population [1]	6,629,000	2,842,000	11,882,000	4,877,000	1,723,000
TCDE/Capita	20.5	19.0	23.0	23.2	34.7
1990 GSP (Billion $) [2]	141	55	245	95	31
Lbs. CO_2-Equiv./$ GSP	1.9	2.0	2.2	2.4	3.9
	Vermont	**Washington**	**Wisconsin**		**USA**
Emissions (10^6 TCDE)	8.4	75.7	100.5		5,539
1990 Population [1]	563,000	4,867,000	4,892,000		248,710,000
TCDE/Capita	15.0	15.6	20.5		22.3
1990 GSP (Billion $) [2]	11	109	101		5,499
Lbs. CO_2-Equiv./$ GSP	1.5	1.4	2.0		2.0

Notes: TCDE = Tons Carbon Dioxide Equivalent (short tons). Jet fuel use data from EIA 1997b. Data for Illinois, NJ, and NY reflects sales; not use. Based on EIA data, it appears that much of Illinois jet fuel is purchased in Indiana, and much of NY jet fuel is purchased in NJ. No credit was given for land use or other sinks.

Sources: [1] U.S. Department of Commerce 1994, 27; [2] U.S. Department of Commerce 1994, 449

Data on States' emissions from EPA site at http://www.icf-infotech.com/ghg/ghg.nsf/ReportStateLookup/

Of Hawaii's GWP, jet fuel for domestic air transportation (interisland and to/from the United States Mainland) created 3.84 million tons of CO_2, or 21% of the total. This is a greater percentage than any other state. In Table 3.8, estimated CO_2

emissions from jet fuel use for each of the states were subtracted from the state's total GWP. When this was done, Hawaii has the lowest GWP per capita and lowest GWP per dollar of GSP compared to the other 17 states. These results point out the relatively low impact of Hawaii's people on climate change, but also emphasize the difficulty Hawaii faces significantly reducing its emissions. Jet fuel is essential to Hawaii's tourism-based economy and the economic well being of its people.

From these comparisons, we can see that Hawaii's greenhouse gas emissions are relatively low compared to other states. Although fossil fuel use dominated Hawaii's energy sector, Hawaii's system was relatively efficient. In 1990, Hawaii's total per capita energy use ranked 41st in the nation and was 83 percent of the national average (USDOE 1992a, 11). Efficiency was aided by the lack of major space heating requirements and the limits that island geography place on driving. High energy costs also contributed to increased efficiency. Hawaii's energy prices in 1990 averaged $9.76 per million Btu, ranking 11th highest in the nation. This amounted to $1,966 per capita, ranking 22nd in the nation (USDOE 1992b, 10-11). Additional cost rankings by fuel are depicted on Table 3-9.

Table 3.9 Hawaii Energy Cost National Rankings, 1990

Category	Dollars per Million Btu	Ranking
Average Energy Prices	9.76	11
Petroleum	6.42	50
Gasoline	11.71	1
Synthetic Natural Gas [1]	12.25	1
Coal	1.82	10
Electricity	26.53	7

[1] SNG price as compared to Mainland US natural gas prices

Source: USDOE, 1992b, 10-16

While petroleum prices were relatively low, at the consumer level, petroleum refined as gasoline and synthetic natural gas were the most expensive in the Nation. Oil was used to produce about 90% of Hawaii's electricity at a cost seventh in the Nation. While coal was relatively inexpensive, in 1990 it was only used in relatively small amounts by two sugar plantations and a cement kiln.

These costs help explain the structure of Hawaii's energy use and resulting energy sector greenhouse gas emissions. They are also factors that must be considered in future mitigation measures. The high costs make energy efficiency measures more valuable. The low cost of fossil fuels compared to many alternatives, however, makes substitution for those fuels less attractive.

CHAPTER 4 FORECAST OF HAWAII'S GREENHOUSE GAS EMISSIONS TO 2020

4.1 Overview

This chapter presents and compares forecasts of Hawaii's greenhouses gas emissions through the year 2020. The forecasts include the Baseline Forecast, a Climate Change Action Plan Forecast, and a Technical Potential Forecast.

4.2 Hawaii's Greenhouse Gas Emissions to 2020

The 1990 estimate of greenhouse gas emissions reported in Chapter 3 was based upon a very detailed analysis of historical data. Estimates in this Chapter are provided for CO_2, CH_4, and N_2O emissions. To allow direct comparison between these different greenhouse gases, CH_4 emissions and N_2O emissions were converted to their global warming potential, or tons of CO_2-equivalent. This reflected the greater effect of these two gases on global warming and climate change. CH_4 emissions have a global warming potential 22 times that of CO_2, and N_2O emissions have 270 times the effect of CO_2.

The Baseline Forecast projected current trends for Hawaii's greenhouse gas emissions into the future. The energy portion of the Baseline Forecast was the Base or E1 Scenario produced by the ENERGY 2020 model. The generation units in the E1 scenario included current operating units and future retirements and additions according to utility integrated resource plans. It was assumed utility DSM plans were implemented for 20 years. The energy-saving effects of federal appliance standards and the Hawaii Model Energy Code were also modeled. Ground transportation efficiency was assumed to be at observed fuel efficiency based upon current vehicle purchase patterns. Air transportation was assumed to improve in efficiency at an average 0.7% per year based upon USDOE base case forecasts. Marine fuel use was assumed to grow at a rate similar to population growth.

Municipal waste management and agriculture base estimates were from projections developed by the University of Hawaii Environmental Center. The estimates included in the forecast included estimated emissions from municipal solid waste management, wastewater treatment, livestock, manure management, and fertilizer use.

Table 4.1 Estimated Future Hawaii Global Warming Potential by Category, 1990-2020 (Tons CO_2-Equivalent)

Year	Energy	MSW	Waste-water	Livestock	Manure Mgmt.	Fertilizer	Total
1990	17,028,284	1,366,464	22,594	294,096	133,232	52,920	18,897,590
1991	16,832,108	1,345,097	22,726	326,130	144,747	53,676	18,724,484
1992	16,884,460	1,374,627	22,814	292,343	126,180	53,487	18,753,910
1993	17,047,949	1,419,645	22,726	269,731	121,947	53,487	18,935,486
1994	17,692,212	1,391,730	23,144	253,753	120,195	53,676	19,534,710
1995	18,278,813	1,387,654	23,122	263,162	118,890	52,866	20,124,507
1996	18,658,900	1,388,064	23,430	262,790	117,722	52,353	20,503,259
1997	18,450,691	1,408,207	23,738	264,264	116,314	51,489	20,314,703
1998	18,612,061	1,430,469	24,046	264,880	116,402	50,139	20,497,996
1999	18,707,502	1,454,113	24,354	265,826	113,850	49,680	20,615,325
2000	18,630,158	1,477,796	24,662	268,400	115,302	48,924	20,565,242
2001	18,771,125	1,504,488	24,825	264,968	114,664	48,627	20,728,697
2002	18,898,136	1,533,152	24,979	260,788	113,432	48,087	20,878,573
2003	19,099,388	1,563,860	25,133	253,814	111,430	47,898	21,101,523
2004	19,251,200	1,596,686	25,485	256,476	112,926	47,628	21,290,401
2005	19,366,250	1,630,375	25,639	254,276	111,826	47,628	21,435,994
2006	19,413,258	1,667,103	25,793	258,676	111,584	47,115	21,523,529
2007	19,640,870	1,706,155	25,947	252,076	111,848	46,926	21,783,823
2008	19,869,817	1,747,617	26,101	249,876	111,342	46,710	22,051,462
2009	20,227,747	1,791,576	26,255	252,076	110,880	47,007	22,455,540
2010	20,367,549	1,836,851	26,290	247,676	110,242	47,142	22,635,750
% Change 1990-2010	**20%**	**34%**	**16%**	**-16%**	**-17%**	**-11%**	**20%**
2011	20,632,792	1,886,131	26,902	247,676	109,780	46,521	22,949,802
2012	20,836,255	1,938,193	27,518	247,676	110,726	46,845	23,207,213
2013	21,148,806	1,993,139	28,112	252,076	109,758	46,467	23,578,358
2014	21,388,751	2,051,076	28,706	247,676	109,098	47,682	23,872,988
2015	21,612,400	2,107,028	29,348	245,476	108,856	47,439	24,150,547
2016	21,202,377	2,170,533	29,480	243,276	108,636	46,899	23,801,201
2017	21,484,478	2,237,351	29,656	245,476	108,834	46,656	24,152,451
2018	21,706,798	2,307,605	29,833	245,476	109,098	46,656	24,445,466
2019	21,979,101	2,381,423	30,011	245,476	108,856	46,656	24,791,524
2020	22,206,929	2,456,358	30,190	245,476	108,636	46,656	25,094,245
% Change 1990-2020	**30%**	**80%**	**34%**	**-17%**	**-18%**	**-12%**	**33%**

While estimates for municipal waste management trended with growth in Hawaii's defacto population, estimates for agricultural activities were based upon recent activity. Agricultural activities of concern have been declining, thus emissions from agriculture were forecasted to decline over the period. No correlation with population, economic activity, or other variable was observed to provide a better basis for such estimates. Market conditions could change in the future, reversing this decline. However, agriculture represents a relatively small source of emissions, especially if recommended emissions reduction measures were followed.

Table 4.1, above, depicts the estimated global warming potential by sector for the Baseline Forecast from 1990-2020. The forecast indicated that Hawaii's global warming potential would increase by 20% over 1990 levels by 2010 and by 33% of 1990 levels by 2020. Without greenhouse gas mitigation measures beyond those already in place, total global warming potential was estimated to increase from 18,897,590 tons of CO_2-equivalent to 25,094,245 tons by 2020 -- 7,519,487 tons

CO_2-equivalent, 43%, above the Kyoto Protocol target. In 2010, it was estimated that Hawaii's global warming potential could be 5,060,992 tons CO_2-equivalent, 29% above the Kyoto target of 17,574,758 tons CO_2-equivalent. Hawaii clearly faces major challenges in seeking to reduce greenhouse gas emissions.

Table 4.2 shows the percentage contribution to Hawaii's Global Warming Potential of each sector in 1990 and as estimated for 2010 and 2020.

Table 4.2 Percentage of Hawaii Global Warming Potential by Sector

Category	1990	2010	Change 1990-2010	2020	Change 1990-2020
Energy	90.1%	90.0%	-0.1%	88.5%	-1.6%
Landfill	7.2%	8.1%	0.9%	9.8%	2.6%
Waste Water	0.1%	0.1%	-0.003%	0.1%	0.001%
Livestock	1.6%	1.1%	-0.5%	1.0%	-0.6%
Manure Mgmt	0.7%	0.5%	-0.2%	0.4%	-0.3%
Fertilizer	0.3%	0.2%	-0.1%	0.2%	-0.09%

As Tables 4.1 and 4.2 show, energy use, at around 90%, was forecasted to dominate greenhouse gas emissions in Hawaii throughout the period. Energy sector emissions were forecasted to be 20% higher than in 1990 by 2010, and 30% higher than 1990 by 2020. Municipal solid waste management (landfill) emissions were forecasted to grow at the most rapid rate if current practices were maintained, accounting for 8.1% of Hawaii's emissions by 2010, and a level 34% higher than in 1990. By 2020, landfill emissions were forecasted to be 9.8% of the total and to reach a level 80% higher than 1990.

Although industrial process emissions, sugar cane residue field burning, and fertilizer use were included in the 1990 baseline presented in *Inventory of Hawaii Greenhouse Gas Emissions, Estimates for 1990* (State of Hawaii 1997a), they were not included in the forecast. Emissions from oil refining were estimated at 5,214 tons CO_2-equivalent in 1990, but information was not available for an estimate of future emissions. In 1990, cement manufacture created 109,274 tons of CO_2-equivalent emissions, but cement production in Hawaii ended by 1996, so that category was not included in the forecast. In the agriculture sector, CH_4 and N_2O emissions from sugarcane burning in the field created only 14,106 tons of CO_2-equivalent, and data was not available to project future emissions.

4.3 Climate Change Action Plan Scenario

In the following chapters, a number of measures are identified that could significantly reduce greenhouse gas emissions in Hawaii. In this first *Hawaii Climate Action Plan*, these measures were intended to offer a direction for future action within the control of Hawaii entities. Many will require significant changes from current practices. While it is not clear which of the recommended measures will be implemented, it is useful to examine scenarios combining their aggregate effect on reducing Hawaii's global warming potential. Together, these measures were termed the "Climate Change Action Plan Scenario."

The Climate Change Action Plan Forecast assumed all of the actions recommended by this Plan that were under the control of Hawaii entities were taken. The energy portion of the Climate Change Action Plan Forecast was Scenario C3 in the ENERGY 2020 model. The scenario combined the E2 – Maximize Renewable Energy Electricity Scenario, Ground Transportation Scenarios GT2 – 10% Ethanol-based Gasoline, and GT3 – 50 Cents per Gallon Increase in Gasoline Prices. (Note: The gasoline price increase is not recommended at this time, but is a possible scenario.)

Under Scenario E2, detailed in Chapter 9 on Table 9.3, a maximum amount of renewable energy was used for electricity generation. Renewable energy resources considered were based upon projects known to be under negotiation as of fall 1998 and projects recommended by the *Hawaii Energy Strategy* (see State of Hawaii 1995 a and b). Intermittent renewable resources in this scenario were added to the utility generation plans and were not assumed to displace fossil fuel generation. Their main effect was to reduce fossil fuel use and consequent emissions.

Several renewable units that provided firm capacity were included and avoided of some fossil fuel. No firm capacity renewable generation was modeled for Oahu and the HECO system. The 15 MW of additional geothermal power on the Big Island was assumed to be installed in three MW increments and ultimately deferred the installation of the 21 MW DTCC Phase 1 scheduled for 2017 on the HELCO system. On Kauai, a 25 MW refuse-to-energy plant (which could also burn biomass) was added in 2005, as an analog for the proposed plasma-arc plant. It offset the addition of the 24 MW coal steam plant scheduled for 2014. The 25 MW biomass plant modeled for installation on Maui was assumed to defer the second phase 21 MW DTCC scheduled for 2013.

The ground transportation scenario, GT2 – 10% Ethanol-based Gasoline, assumed that the use of a 10% ethanol/90% gasoline blend would begin in 2000. Initially, most of the ethanol would be imported, but eventually all would be produced in Hawaii from Hawaii-grown crops. Although the model depicted reaching the 10% ethanol level in the first year, in practice, this could take somewhat longer. However, if initiated in 2000, it was estimated that the full 10% level would be reached before 2010.

Scenario GT2 could be implemented without major modifications to vehicles and gasoline distribution infrastructure. The 10% ethanol component of the motor gasoline fuel was considered to be without greenhouse gas emissions, as CO_2 would be used in the growing cycle of the feedstock biomass.

Table 4.3 Estimated Hawaii Global Warming Potential Under Climate Change Action Plan Scenario for GHG Emissions Reduction, 1990-2020 (Tons CO_2 Equivalent)							
Year	Energy	MSW	Waste-water	Livestock	Manure Mgmt.	Fertilizer	Total
1990	17,028,284	1,366,464	22,594	294,096	133,232	52,920	18,897,590
1991	16,832,108	1,345,097	22,726	319,286	144,738	52,677	18,716,632
1992	16,884,460	1,374,627	22,814	287,012	126,170	52,488	18,747,570
1993	17,047,949	1,419,645	22,726	264,462	121,946	52,488	18,929,216
1994	17,692,212	1,391,730	23,144	248,028	120,186	52,677	19,527,977
1995	18278813	1,378,660	23,122	257,664	118,888	51,894	20,109,041
1996	18,658,900	1,386,931	23,430	253,000	118,602	50,571	20,491,434
1997	18,450,691	1,395,253	23,738	248,600	114,400	49,680	20,282,362
1998	18,610,174	1,403,625	24,046	246,400	112,200	48,600	20,445,045
1999	18,645,428	1,453,815	23,760	237,600	107,800	47,844	20,516,247
2000	17,932,124	1,486,238	22,880	233,200	104,500	46,521	19,825,463
2001	18,044,331	1,502,325	22,000	220,000	99,000	43,848	19,931,504
2002	18,081,044	1,485,000	20,900	213,400	96,800	42,525	19,939,669
2003	18,183,629	1,472,625	20,900	209,000	92,400	42,012	20,020,566
2004	18,253,308	1,447,875	20,790	206,800	88,000	41,445	20,058,218
2005	18,014,216	1,435,500	20,460	202,400	81,400	40,770	19,794,746
2006	17,775,994	1,348,875	19,800	198,000	80,300	40,257	19,463,226
2007	17,769,126	1,249,875	18,700	198,000	80,300	39,906	19,355,907
2008	17,954,503	1,200,375	18,480	195,800	81,400	39,690	19,490,248
2009	18,093,738	1,188,000	18,260	195,800	79,200	39,717	19,614,715
2010	18,222,476	1,138,500	18,040	195,800	77,000	39,825	19,691,641
% Change 1990-2010	**7%**	**-17%**	**-20%**	**-33%**	**-42%**	**-25%**	**4%**
2011	18,341,989	1,138,500	17,600	193,600	81,400	39,231	19,812,320
2012	18,495,922	1,138,500	17,160	193,600	83,600	39,528	19,968,310
2013	18,775,255	1,138,500	16,940	195,800	77,000	38,880	20,242,375
2014	18,968,189	1,138,500	16,720	193,600	79,200	39,123	20,435,332
2015	19,194,824	1,138,500	16,720	195,800	77,000	38,907	20,661,751
2016	18,791,315	1,138,500	16,720	195,800	74,800	39,285	20,256,420
2017	19,039,106	1,138,500	16,720	193,600	74,800	39,879	20,502,605
2018	19,242,415	1,162,409	16,820	193,600	74,800	39,879	20,729,922
2019	19,488,954	1,186,819	16,920	193,600	74,800	39,879	21,000,972
2020	19,697,243	1,211,742	17,021	193,600	74,800	38,610	21,233,017
% Change 1990-2020	**16%**	**-11%**	**-25%**	**-34%**	**-44%**	**-27%**	**12%**

Ground transportation scenario, GT-3 – 50 Cents per Gallon Gasoline Price Increase was not an energy efficiency scenario; however it was developed to examine the effects of a price increase on fuel use. The reasons for such an increase could be additional taxes or environmental fees, or as has been discussed in Hawaii, a 50 cents per gallon pay-at-the-pump insurance premium. This scenario was not developed as a recommendation, but to examine the effects of a gasoline price increase as such an increase remains a possibility.

Further details on Scenario C3 are provided in Chapter 9. Measures for municipal waste management and agriculture emissions reduction are described in Chapters 11 and 12. Figure 4.3, above, summarizes the estimated global warming potential for Hawaii under the Climate Change Action Plan Scenario.

Measures considered in the Climate Change Action Plan Scenario have the potential to reduce the growth of Hawaii's greenhouse gas emissions significantly.

Table 4.3 shows that only the energy sector was projected to increase emissions under this Scenario. As a result, emissions grew about 4% by 2010, but this was 2,116,882 tons CO_2-equivalent, or almost 12% above the Kyoto target. By 2020, emissions were forecasted to grow by 12% compared to 1990, a level 3,658,258 tons CO_2-equivalent, or 21% above the Kyoto target.

4.4 Hawaii Technical Potential Scenario

The Hawaii Technical Potential Forecast added possible technical improvements in the energy sector, such as the availability of more efficient aircraft and ground transportation vehicles, to the Climate Change Action Plan. Such improvements were assumed to be beyond Hawaii's control, but possible. The energy portion of the Hawaii Technical Potential Forecast was Scenario C1. Scenario C1 combined the electricity scenario with the greatest CO_2 reductions, E2 – Maximize Renewable Energy Electricity Scenario (described above and in Chapter 9), with all of the transportation scenarios (see Chapter 9).

Table 4.4, below, summarizes the estimated global warming potential under the Hawaii Technical Potential Scenario. As under the Climate Change Action Plan Scenario, all sectors showed reductions of global warming potential except the energy sector. However, since aircraft and ground transportation vehicle efficiencies were assumed to be improved, energy sector emissions were reduced in comparison to the previous two scenarios.

The energy portion of the Hawaii Technical Potential Forecast was Scenario C1. In addition to Scenario E2, the Scenario included the following scenarios in ENERGY 2020 model runs: GT2 – 10% Ethanol-based Gasoline; GT3 – 50 Cents per Gallon Increase in Gasoline Price; GT4 – Improved Vehicle Efficiency Standards; GT5 – Increased Alternate Fueled Vehicle Use and A2 – Aircraft Efficiency Improvements.

Measures for municipal waste management and agriculture emissions reduction are described in Chapters 11 and 12. These measures were the same as used in the Hawaii Climate Change Action Plan Forecast. The Hawaii Technical Potential Forecast of global warming potential in 2010 was 1,734,123 tons CO_2-equivalent, or about 10%, greater than the Kyoto target. By 2020, the forecast projected a global warming potential 2,610,580 tons CO_2-equivalent, or 15%, greater than the Kyoto target.

Table 4.4 Estimated Hawaii Global Warming Potential Under Technical Potential Scenario for GHG Emissions Reduction, 1990-2020 (Tons CO_2 Equivalent)

Year	Energy	MSW	Waste-water	Livestock	Manure Mgmt.	Fertilizer	Total
1990	17,028,284	1,366,464	22,594	294,096	133,232	52,920	18,897,590
1991	16,832,108	1,345,097	22,726	319,286	144,738	52,677	18,716,632
1992	16,884,460	1,374,627	22,814	287,012	126,170	52,488	18,747,570
1993	17,047,949	1,419,645	22,726	264,462	121,946	52,488	18,929,216
1994	17,692,212	1,391,730	23,144	248,028	120,186	52,677	19,527,977
1995	18,278,524	1,378,660	23,122	257,664	118,888	51,894	20,108,752
1996	18,658,686	1,386,931	23,430	253,000	118,602	50,571	20,491,221
1997	18,442,687	1,395,253	23,738	248,600	114,400	49,680	20,274,358
1998	18,520,274	1,403,625	24,046	246,400	112,200	48,600	20,355,145
1999	18,482,183	1,453,815	23,760	237,600	107,800	47,844	20,353,002
2000	17,770,524	1,486,238	22,880	233,200	104,500	46,521	19,663,862
2001	17,878,425	1,502,325	22,000	220,000	99,000	43,848	19,765,598
2002	17,909,365	1,485,000	20,900	213,400	96,800	42,525	19,767,990
2003	18,002,648	1,472,625	20,900	209,000	92,400	42,012	19,839,585
2004	18,060,920	1,447,875	20,790	206,800	88,000	41,445	19,865,830
2005	17,806,040	1,435,500	20,460	202,400	81,400	40,770	19,586,570
2006	17,539,864	1,348,875	19,800	198,000	80,300	40,257	19,227,096
2007	17,502,538	1,249,875	18,700	198,000	80,300	39,906	19,089,319
2008	17,654,274	1,200,375	18,480	195,800	81,400	39,690	19,190,019
2009	17,755,592	1,188,000	18,260	195,800	79,200	39,717	19,276,569
2010	17,839,716	1,138,500	18,040	195,800	77,000	39,825	19,308,881
% Change 1990-2010	**5%**	**-17%**	**-20%**	**-33%**	**-42%**	**-25%**	**2%**
2011	17,909,684	1,138,500	17,600	193,600	81,400	39,231	19,380,015
2012	18,010,248	1,138,500	17,160	193,600	83,600	39,528	19,482,636
2013	18,231,926	1,138,500	16,940	195,800	77,000	38,880	19,699,046
2014	18,362,339	1,138,500	16,720	193,600	79,200	39,123	19,829,482
2015	18,520,744	1,138,500	16,720	195,800	77,000	38,907	19,987,671
2016	18,042,273	1,138,500	16,720	195,800	74,800	39,285	19,507,378
2017	18,205,186	1,138,500	16,720	193,600	74,800	39,879	19,668,685
2018	18,330,900	1,162,409	16,820	193,600	74,800	39,879	19,818,408
2019	18,506,139	1,186,819	16,920	193,600	74,800	39,879	20,018,158
2020	18,649,564	1,211,742	17,021	193,600	74,800	38,610	20,185,338
% Change 1990-2020	**10%**	**-11%**	**-25%**	**-34%**	**-44%**	**-27%**	**7%**

4.5 Comparison of the Scenarios and Additional Measures

Figure 4.1, below, provides a graphic comparison of the three forecasts of Hawaii's global warming potential. It does not appear that Hawaii can meet the Kyoto goals at any time through 2020 through a comprehensive deployment of currently available greenhouse gas reduction measures. Although actions in the areas of municipal waste management and agriculture can make significant contributions to reducing Hawaii's global warming potential, it is clear that the energy sector creates the overwhelming majority of Hawaii's greenhouse gas emissions. Accordingly, it should be the focus of continuing attention. New technologies may provide greater energy efficiency in particular that may change these forecasts in the future (See Chapter 14).

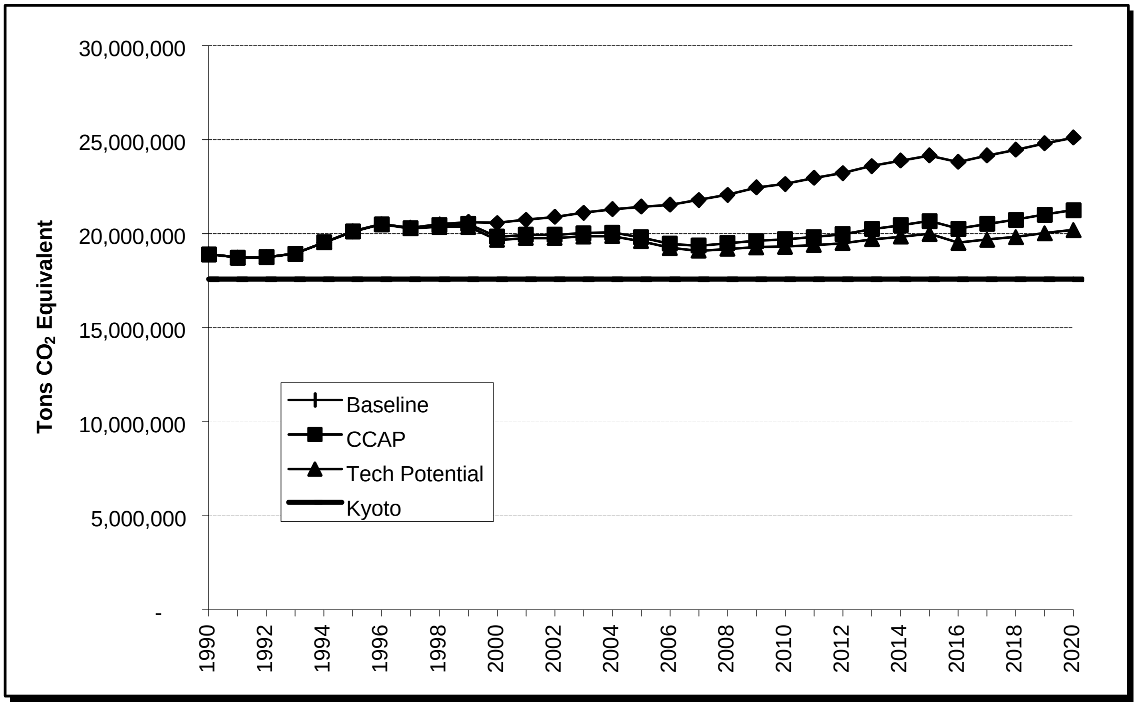


Figure 4.1 Comparison of the Global Warming Potentials of Three Reduction Scenarios for Hawaii, 1990-2020

Forestry in Hawaii also offers a major potential way to offset Hawaii's emissions and those of other areas of the world. As discussed in Chapter 13, Hawaii's forests already act as a carbon sink for 126 million tons of carbon, or the equivalent of 457 million tons of CO_2. It is estimated that the forestry projects identified have the potential to sequester an additional 26 million tons of carbon (about 94 million tons CO_2-equivalent). The amount and type of reforestation that will occur will determine the amount of carbon that can be offset by Hawaii forestry projects. Further analysis is recommended to develop a detailed plan.

In addition, experimental work being conducted by the University of Hawaii on the deep ocean sequestration of CO_2 may offer a long-term solution to CO_2 emissions from stationary sources in Hawaii and elsewhere if successful. The experiment is described in Chapter 14.

Finally, U.S. and Hawaii technology and expertise can be commercially exported to the developing nations of the Asia/Pacific region. This can help reduce greenhouse emissions from a region whose emissions are forecasted to grow at a greater rate than the rest of the world. This type of commercial activity can help these nations achieve significant greenhouse gas reductions and substantial economic benefits for Hawaii and the United States as a whole. Activity currently underway in this area is also described in Chapter 14.

CHAPTER 5 GREENHOUSE GAS EMISSIONS REDUCTION GOALS AND CRITERIA FOR HAWAII

5.1 Overview

This document is the first iteration *Hawaii Climate Change Action Plan*. It does not set specific goals. It is intended as a catalyst for discussion by Hawaii's people about their involvement in future efforts to reduce emissions and to adapt to climate change. The major recommendations of this first Plan is to develop consensus as to Hawaii goals for greenhouse gas emission reductions.

Hawaii could become part of future national efforts to reduce greenhouse gas emissions under the Kyoto Protocols to the United Nations Framework Climate Convention signed on November 12, 1998. Should the United States Senate ratify the Protocols, or should the federal government set some other goal, such a national goal could serve as Hawaii's goal. Hawaii's people may not want to wait for federal action to deal with the growing problem. Hawaii can set its own goals for action now.

This chapter suggests considerations for establishment of greenhouse gas reduction goals for the State of Hawaii. It includes a brief discussion of the goals agreed by the United States delegation at the Kyoto Summit in December 1997. It summarizes goals set by other states. A discussion of development of goals and criteria for greenhouse gas emission reductions, from the U.S. Environmental Protection Agency's *States Guidance Document, Policy Planning to Reduce Greenhouse Gas Emissions* (USEPA 1998j) is provided as a guide to assist in developing Hawaii's goals.

5.2 Reasons for State Action

The U.S. Environmental Protection Agency has involved individual states in its State and Local Climate Program out of recognition that "although problems such as global warming need to be addressed through cooperative national and international efforts, many of the critical responses can be initiated locally. If the adverse effects of climate change are to be avoided, states will need to take an active and immediate role in addressing greenhouse gas emissions" (2-11).

States retain much of the policy jurisdiction over emissions sources. The State of Hawaii has influence and authority over energy use, utility regulation, land use, transportation, taxation, air pollution regulation, environmental programs, permitting, and other areas. The State can also encourage action at the County level. An example was the development of the Model Energy Code to improve building energy efficiency, which was developed by DBEDT and has been adopted by three of the four counties. Maui County is currently considering adopting the Code.

The state and counties are also involved in municipal waste management with the counties operating landfills and wastewater treatment centers which can be managed to reduce greenhouse gas emissions. State and county agencies are also involved in recycling efforts (2-12).

The United States Climate Change Action Plan (CCAP) creates new opportunities for States. The CCAP provides for opportunities and support to state action. These are offered in the energy, transportation, agriculture, and other sectors. The CCAP commits federal agencies to link their programs with state and local efforts (2-12). As the federal government's efforts increase, there will likely be opportunities for greater federal support of state programs in areas such as renewable energy, energy efficiency, air pollution control, forestry, etc. These can benefit States in related areas.

States have the capacity for enacting "low risk" policies to address climate change. Hawaii is involved in a number of actions that were developed for other policy purposes that also have climate change mitigation benefits. For example, energy efficiency programs intended to reduce energy use and energy costs also reduce greenhouse gas emissions. Renewable energy programs intended to reduce oil use, to reduce the danger of oil spills, and to diversify Hawaii's energy supplies also reduce emissions. Integrated resource planning, mandated by the Public Utilities Commission for Hawaii's utilities, seeks to ensure the most efficient resource selection and consideration of environmental externalities. Air pollution control programs tend to result in more efficient use of energy and lower greenhouse gas emissions along with their intended purpose of reducing criteria pollutants. These and other programs are in place and are discussed in detail in subsequent chapters of this plan.

States will feel the impacts of climate change and will likely be called upon to address them. As the USEPA points out, climate-related problems will ultimately affect local and state economic resources. They cite growing environmental consciousness on the part of voters and likely public and political pressure to respond to climate change.

States are usually more in touch with local concerns than the federal government. State approaches should be favored over one-size-fits-all federal approaches. Hawaii in particular has a much different greenhouse gas emission profile than the nation as a whole and in comparison to other states. Policies developed in Hawaii can take this into account for greater effectiveness.

Hawaii should also begin planning to deal with the effects of climate change on the economy, infrastructure, public health and safety, and other areas. Even if greenhouse gas emissions can be reduced significantly on a global basis, changes in weather patterns, temperature rise, and sea level rise that will still occur due to past emissions could have significantly adverse impacts as discussed in Chapter 2.

5.3 Examples of Climate Change Action Goals

5.3.1 International Goals

5.3.1.1 United Nations Framework Convention on Climate Change

The United Nations Framework Convention on Climate Change (UNFCC) was established in 1992 and entered into force in March 1994. Its objective is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system and to do so within a time-frame sufficient to allow ecosystems to adapt naturally to climate change" (4-2).

Under Annex I, most members of the Organization for Economic Cooperation and Development (OECD), to which the United States belongs, and the nations of central and eastern Europe committed themselves to returning their emissions to 1990 levels by the year 2000. Under Annex II, the richest countries (the OECD countries, including the United States) were to provide financial resources and facilitate transfer of technologies to reduce emissions. As of July 1998, 175 countries, including the United States, had ratified the UNFCC (IISD 1998). It is also clear that the United States will not reach the year 2000 objective.

The first meeting of the Conference of the Parties of the UNFCC, also known as COP-1, was held in Berlin in early 1995. COP-1 addressed a number of issues regarding future implementation of the Convention and discussed the adequacy of the commitments that made by the parties. An ad hoc group, called the Ad Hoc Group on the Berlin Mandate (AGBM) began looking at actions beyond 2000. One of these options was a protocol or other legal instrument to set legally binding goals for greenhouse gas reductions (IISD 1998).

AGMB met eight times between August 1995 and COP-3 at Kyoto in December 1997. AGBM assessed possible policies and measures to strengthen the commitments of Annex 1 parties, how they might share or distribute new commitments, and whether the new commitments should be an amendment or protocol. A negotiating text was prepared and reviewed at COP-2 in Geneva. In addition, at COP-2 the parties issued the "Geneva Declaration". The Declaration endorsed the IPCC 's scientific conclusions and called for legally binding objectives and significant reductions of greenhouse gas emissions (IISD 1998).

5.3.1.2 Third Conference of the Parties (COP-3) and the Kyoto Protocol to the United Nations Framework Convention on Climate Change

The Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP-3) was held in early December 1997 in Kyoto Japan. The Protocol agreed upon at the Session was called the Kyoto Protocol.

The Annex I parties to the Protocol (the developed nations) committed to reduce their overall agreements of six greenhouse gas emissions (CO_2, CH_4, N_2O, hydrofluorocarbons (HFCs), perflurocarbons (PFCs), and sulfur hexafluoride (SF_6)) by at least 5% below 1990 levels by the period 2008-2012. The United States committed to a 7% reduction. Of the other Annex I parties, 27 committed to 8% reductions, 4 committed to 6% reductions, and 6 were to be allowed to maintain current levels or even emit greater amounts. Each was to demonstrate progress by 2005 (UN FCCC 1997). The Kyoto Protocol will enter into force once ratified by 55 parties. These parties must also have accounted for at least 55% of 1990 baseline emissions (IISD 1998).

5.3.1.3 Fourth Conference of the Parties (COP-4) and the Buenos Aires Plan of Action

COP-4 was held in Buenos Aires, Argentina, from November 2-14, 1998. The delegates considered recommendations developed by subsidiary bodies related to implementation and to scientific and technical advice. Following extensive negotiations and a final plenary session on November 14, 1998, the delegates adopted the "Buenos Aires Plan of Action." The Plan was intended to strengthen the implementation of the UNFCCC and to prepare for the future entry into force of the Kyoto Protocol (Carpenter 1998b, 1).

The Plan sets a year 2000 deadline for completion of work on a number of important issues including:

- Financial mechanisms -- to assist the developing nations in the challenges of climate change;
- Further work on policies and measures to ensure compliance;
- Development and transfer of environmentally sound technologies to developing nations;
- Rules governing the Kyoto Mechanisms; and
- An undertaking to discuss supplementarity, ceilings, long-term convergence, and equity (Goree 1998).

In addition to the United States signing the Kyoto Protocol on November 12 in New York, one of the most noteworthy events was Argentina's commitment to binding reductions in emissions. This was a precedent setting first commitment by a non-Annex I party to the Protocol. It could result in similar commitments by other developing nations (Carpenter 1998a, 13).

The work on the Buenos Aires Plan of Action could ultimately affect the international rules under which the United States would comply with provisions of the Kyoto Protocol.

5.3.2 National Goals

In an effort to meet the commitment made in 1992 in the FCCC, the United States Climate Change Action Plan set a target of reducing greenhouse gas emissions to 1990 levels by the year 2000 with cost effective domestic actions (4-2). The United States will not be able to meet that goal. The Kyoto goal of a 7% reduction below 1990 emissions levels will not be a firm commitment by the United States until ratified by the Senate.

In the Byrd-Hagel Resolution, passed 95-0 in 1997, the Senate stated that the United States should not be a signatory to any protocol that excludes developing countries from legally binding commitments or that causes serious harm to the US economy (Carpenter 1998a, 13). Now that the United States has signed the Protocol with only Argentina and Kazakhstan among the developing countries accepting legally binding commitments as of November 1998, it remains to be seen if or when the Senate might ratify the Kyoto Protocol.

5.3.3 Western Governor's Association

The Western Governors' Association, to which the Governor of Hawaii belongs, issued the Resolution 97-002 regarding National Policies Regarding Global Climate Change on February 4, 1997. The following is the text of the Governors' policy statement portion of the resolution:

> The Western Governors' Association urges that the President, Congress, the U.S. Department of State, and other federal agencies include the interests and expertise of the states as part of any national debate on the mitigation of greenhouse gases to ensure fully coordinated policies.
>
> The Western Governors' Association supports a full and vigorous discussion, including all stakeholders, and consideration of all alternatives regarding the mitigation of greenhouse gases, adaptation of policies and other global climate change measures.
>
> The Western Governors' Association supports a coordinated research effort on the effects of human activities on the accumulation of greenhouse gases and their contribution to the impact on global climate change.
>
> The Western Governors' Association urges that the President and the U.S. Department of State international negotiating team to

proceed cautiously with regard to new aims and post-2000 commitments for greenhouse gas mitigation strategies that would place an undue cost burden on energy consumers of the states while supporting agreements for globally applicable provisions that will significantly reduce the impacts of greenhouse gas emissions.

The Western Governors' Association supports a national policy on global climate change that is consistent with efforts to develop cost-effective alternative energy sources and more efficient use of energy (WGA 1997).

5.3.4 Goals of Other States

Wisconsin, Washington, Illinois, and Oregon have set greenhouse gas emissions reduction goals and developed action plans. These goals were as follows:

- **Wisconsin**: Stabilize greenhouse gas emissions to 1990 levels by 2010.
- **Washington**: Emissions stabilization by 2010.
- **Illinois**: Stabilize greenhouse gas emissions by 2000.
- **Oregon**: Reduce emissions by at least 2 million tons in 2015 compared to the "business as usual scenario" (USEPA 1998j, 4-2).

These goals were all established prior to the United States' signature of the Kyoto Protocols. It is unknown whether signature or ratification of the Kyoto Protocols will result in revision of the goals.

5.4 Establishing Goals and Evaluative Criteria

This section is based closely upon the discussion of establishing goals and criteria from the U.S. Environmental Protection Agency's *States Guidance Document* (USEPA 1998j).

5.4.1 Definitions

Goals explicitly state the broad aims of the climate change action plan. This provides a focal point for use in diverse situations, between state agencies, and across sectors.

Criteria are standards for assessing alternative policy options. Criteria are based on two types of state policy goals – (1) those that support the climate change action plan; and (2) those that ensure the plan does not impede or negate other state policy priorities or objectives. Criteria should be more specifically defined and are frequently more directly measurable (4-1).

5.4.2 Key Questions Related to Goal Setting

- Should an emission reduction goal be relative measured against a prior, current, or future year?
- How do mitigation objectives relate to existing energy, agricultural, and development policies?
- What type of processes can be used to reach a decision on specific mitigation objectives?
- How can objectives be prioritized (4-1)?

5.4.3 Four Variable Aspects of Goal Setting Processes

The following four variables should be considered in light of Hawaii's economic, geographic, environmental, and political circumstances.

5.4.3.1 Goals with Specific Time Frames versus Permanent or Perpetual Goals

In addition to a primary objective for the climate change action plan, specific goals and milestones can be set to provide guidance for policy development and implementation. Near-term milestones can provide motivation toward meeting long-term baseline goals. Different policy options will be appropriate in different time frames. Near-term policy adoption may lower the costs of future actions. For example, by focusing on development of technologies that reduce emissions or by demonstrating early the cost-effectiveness of an option (4-3).

5.4.3.2 Quantitative Goals versus Qualitative Goals

"Programs my pursue specific numerical targets for emission controls, or they may focus on qualitative issues, such as promoting the use of the most energy-efficient technologies and processes in all economic sectors" (4-2). Qualitative goals can help focus efforts across sectors. Qualitative goals may also make it easier to assess the feasibility of alternative options and to monitor the progress of options. A qualitative goal, such as a policy to evaluate the pros and cons of CO_2 reduction, may not set a target, but will likely prompt analysis of how existing and potential new policies may affect projected emissions (4-4).

5.4.3.3 Goals Based on Prescriptive Emissions Targets versus Goals Based on Perceived Emission Reduction Capabilities

A goal may be set based on a scientific or technical prescription of emission levels needed for mitigation of climate change (e.g., stabilization at 1990 levels). Actual emissions or projections, state administrative and analytical capability to implement and support programs, or other criteria may be applied (4-4).

5.4.3.4 Broad versus Narrow Substantive Goals

Goals can cover all greenhouse gas emissions or they can emphasize specific greenhouse gases or particular economic sectors. Many entities focus on carbon dioxide emissions or fossil fuel use in electricity generation and transportation as these source categories account for the majority of anthropogenic emissions. Some focus on stationary sources rather than mobile sources since stationary sources are often easier to monitor (4-4).

5.4.4 Time Perspectives

As pointed out in the *States Guidance Document*, time frame issues are relevant in the climate change program design process. Time frame issues should also be considered in goal setting. Issues include cited in the *States Guidance Document* include:

- Greenhouse gas emissions today will affect climate change and its impacts at the local level for many decades;
- The capacity to reduce greenhouse gas emissions, especially through long-range mitigation options, depends on anticipated changes in science and technology;
- One reason current emission forecasts are important is that they provide a baseline for analyzing potential emission reduction impacts from various policy options ranging across time frames;
- Dynamic programs with goals and criteria that vary across time frames may be more effective than programs adhering to one static set of objectives; and
- Policy evaluation, entailing predictions and measurements of probable program impacts, depends heavily on time frame considerations. Key time frame assumptions are critical for conducting emissions analysis and economic impact analysis. These same time frame assumptions may plan a significant role in driving any formal emissions or climate change modeling efforts a state may decide to pursue (7-1).

5.4.5 Complications in Goal-Setting

In setting goals, further consideration must be given to a variety of complications, including scientific and technical uncertainties, uncertain impacts and interactions of policy approaches, and questions of measurability.

5.4.5.1 Scientific and Technical Uncertainties

Achieving permanent stabilization could require major CO_2 emission reductions from projected levels and significant reduction of other greenhouse gases. It is not clear what level of reduction is actually feasible. Uncertainties about climate change processes, emissions estimates, and effectiveness of specific control technologies remain (4-5).

5.4.5.2 Uncertain Impacts and Interactions of Policy Approaches

Some policies are effective in the short-term and others offer future benefits. Some policies have collateral benefits beyond greenhouse gas reduction such as energy diversity or security, local jobs, etc. At the same time, political unpopularity may make an option not feasible. Broader, more qualitative goals can sometimes address such issues, but they can create complications, too (4-5).

5.4.5.3 Measuring Results

It may be very difficult to forecast or measure the direct effects of climate change policy actions. “For example, quantitative goals, while often politically and analytically difficult to agree upon, are frequently much easier to assess and communicate than qualitative goals. On the other hand, many qualitative and inherently difficult-to-measure actions, like broad public education on climate change and energy-efficiency issues, may offer some vary good opportunities for achieving long-term climate stabilization” (4-6).

Short-term actions may be easier to measure than long-term policies because the longer-term actions face more complications, interactions, and uncertainties. A way to handle this is to set specific near-term goals and broader, mid- or long-term qualitative or quantitative goals (4-6).

5.4.6 Criteria for Evaluating Policies

The *States Guidance Document* further suggested the following criteria for evaluating policies developed to achieve climate change action plan goals:

- Effectiveness in reducing greenhouse gas emissions;
- Private sector costs and savings;
- Public sector costs;
- Institutional capacity;
- Enforceability;
- Economic efficiency;
- Social equity;
- Political impact and feasibility;
- Legal constraints; and
- Ancillary benefits and costs (4-7 – 4-9).

Further, two additional process-oriented criteria were recommended – measurability and feasibility (4-9). Some additional practical considerations are worthy of consideration:

- Extent to which substitution among energy sources, energy technologies, products, and production methods is possible;
- Extent to which market and policy distortions create opportunities for low-cost (or no-cost) improvements in energy efficiency;
- Likely rate of technological innovation and the responsiveness of such change to price signals;
- Availability and likely future cost of non-fossil, backstop energy sources;
- Potential for international 'joint implementation' of emissions reductions; and
- Possibility that carbon tax revenues would be recycled through the reduction of economically burdensome tax rates" (Repetto 1997, 5-7).

5.5 Recommendations for Goal Setting in Hawaii

RECOMMENDATION: Goal Setting Should Involve a Wide Range of Hawaii's People

Public input should be solicited to help set any Hawaii-specific greenhouse gas reduction goals. A Commission or Task Force, charged with considering public input, could lead this effort. Educational efforts to inform the population on the issues should precede the goal-setting process.

RECOMMENDATION: Goals Should Focus on Areas Under Hawaii's Control

Hawaii should focus only on those emissions generating activities that can be managed, at least in part, locally. This would include most of the sources discussed in the *Inventory of Hawaii Greenhouse Gas Emissions, Estimates for 1990* and in this plan. It would specifically exclude emissions from overseas marine activities, all aviation activities, and military activities. Emissions from overseas marine and air operations were excluded from counting under the UNFCC. While domestic aviation activities were to be considered in country totals, at the present time, airline operations involving Hawaii appear to be at a very high level of efficiency based on current technology. The efficiency should be monitored to ensure the trend continues, but further improvements are likely to be technology dependent. Finally, military operations are beyond the control of the State and data is not available to determine mobile source use in Hawaii.

In the near term, due to the level of their contribution of emissions, the focus of greenhouse gas reductions efforts should be on electricity generation, ground transportation, and municipal waste management. Carbon offset forestry offers a way to counter the effects of some of Hawaii's emissions.

RECOMMENDATION: Goals Should Recognize Hawaii's Uniqueness

There are many geographic, climatological, technological, economic, environmental, cultural, and other considerations unique to Hawaii that must be considered in goal setting. These further supports the recommendation for wide input to ensure these are all identified and duly considered.

In particular, Hawaii's very low energy intensity compared to most of the Mainland United States should be a factor. Hawaii, due to the many unique factors, is very energy-efficient. As the energy sector accounts for about 90% of its emissions, the high level of efficiency reduces emissions reduction options.

At the same time, Hawaii offers such resources as abundant sunshine for solar power and wind for wind power. These should be more fully developed. Attention must be paid, however to ensure electricity system reliability when using renewable resources since Hawaii's six separate systems are not connected.

Hawaii's tourism-based economy poses yet another unique challenge. It is dependent on transoceanic air travel and interisland air travel, which has resulted a high percentage of Hawaii's emissions coming from jet fuel. As discussed above, there is little chance of reduction within Hawaii's control. Significant further reductions in air travel would be an economic disaster.

Another factor related to tourism that must be borne in mind when setting goals is that Hawaii's defacto population is about was 114% of its resident population in 1990. This meant that an average of 149,000 visitors were present in the islands on any given day. As consumers of energy services, users of municipal waste management services, etc., they also contributed to Hawaii's greenhouse gas emissions. If targets are set on a per capita basis, this should be factored in.

RECOMMENDATION: Future Effects of Climate Change on Hawaii Should Be Identified and Adaptation Measures Planned

Hawaii will experience climate change caused by past and current greenhouse gas emissions (See Chapter 2). As global reductions in emissions are likely to take many years, the effects forecast for the next century in temperature change, sea level rise, and other concerns **will** happen. These effects on Hawaii should be further explored and modeled. Adaptation measures may also take many years, if not decades, to implement. The measures required must be identified and put into motion.

CHAPTER 6 TRANSPORTATION ENERGY

6.1 Overview

This chapter examines transportation energy use in Hawaii and recommends measures to reduce greenhouse emissions from ground, air, and marine transportation energy use.

6.2 Hawaii's Transportation Sector

6.2.1 1990 Estimated Emissions Baseline

In 1990, emissions from Hawaii transportation fuels use were an estimated 42% of Hawaii's global warming potential in tons CO_2-equivalent, ranking just ahead of electricity generation at 41%. Transportation energy produced 46% of CO_2 emissions. CH_4 emissions from transportation were 1% of the total, after waste management at 72% and agriculture at 26%. Transportation dominated N_2O emissions at 65%. These emissions estimates are summarized in Table 6.1.

Table 6.1 Hawaii Domestic Transportation Greenhouse Gas Emissions (Tons), 1990

	CO_2	CH_4	N_20	NOx	CO	NMVOC
Ground	3,731,987	713	444	13,069	107,711	17,679
Aviation	3,862,973	122	<1	15,610	12,370	1,104
Marine	154,517	N/A	2	6,440	97	N/A
Total	7,749,478	835	446	35,119	120,178	18,783

Source: State of Hawaii 1997a

The numbers above are based upon new data and different criteria than were used in the *Inventory of Hawaii Greenhouse Gas Emissions, Inventory for 1990* (State of Hawaii 1997a). The *Inventory* estimated emissions from inter-island, overseas, and military jet fuel and aviation gasoline (avgas) use. The estimates were based on reporting by energy producers, importers, and distributors to DBEDT. An element lacking from these reports was an identification of bonded fuel imported and a breakout between bonded and domestic fuel sold by the refineries.

Subsequently, more complete data on domestic and bonded jet fuel used was provided by the Hawaii Fueling Facilities Corporation, which handles virtually all jet fuel on Oahu. This resulted in a revision to the categories reported and estimates of total amounts used. Industry reporting, as required by Chapter 486j, Hawaii Revised Statutes, was used to identify the relatively small amounts used on neighbor islands and fuel sold to the military by Hawaii refiners.

Based upon the new data, the estimates of jet fuel use were recalculated. Domestic jet fuel use was defined to include civilian scheduled airline jet fuel for domestic operations, including inter-island flights, and flights between Hawaii and the Mainland United States. Unbonded fuel sold or distributed on neighbor islands was included in the domestic category. Piston-engine aircraft operating in Hawaii used domestic aviation gasoline (avgas). Emissions from the fuel used by aircraft in these categories were included in the total amount of greenhouse gases attributed to Hawaii.

Bonded jet fuel is not subject to U.S. customs duty and is counted separately. Bonded jet fuel use includes fuel used by foreign and domestic carriers in international operations. Some flights between Hawaii and the Mainland qualify as international as they originated at a foreign location, stopping in Hawaii, on the way to the Mainland United States; or originated on the Mainland and continued to a foreign destination after stopping in Hawaii.

Military transportation fuel included all fuel sold by Hawaii refiners or distributors to the U.S. military. As discussed in Chapter 4, data is not available to determine how much of military mobile source fuels are actually used in Hawaii.

6.2.2 Estimated Transportation Sector Greenhouse Gas Emissions to 2020

The ENERGY 2020 model was used to estimate Hawaii's transportation sector greenhouse gas emissions through 2020. Although the model was also provided an estimate of CH_4 and N_2O emissions, only the dominant CO_2 emissions will be discussed in this chapter. See Appendix C for further information on the ENERGY 2020 model.

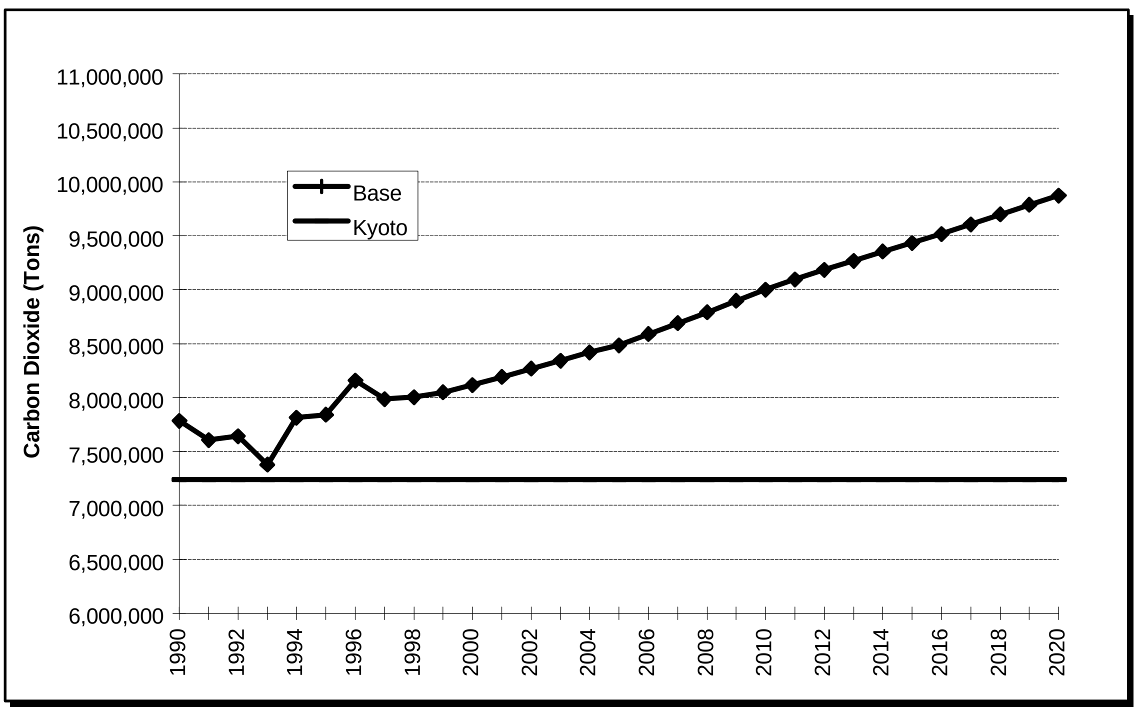


Figure 6.1 Estimated Hawaii Transportation Sector CO_2 Emissions (Tons) 1990 - 2020

Figure 6.1, on the preceding page, shows forecasted CO_2 emissions from Hawaii's domestic transportation sector from 1990 to 2020. The ENERGY 2020 model estimated emissions from 1998 to 2020. Domestic transportation emissions in this context included air, ground, and marine transportation. Domestic air transportation was defined as inter-island (intrastate) air transportation and flights to and from the U.S. Mainland. Domestic marine transportation was defined as inter-island marine fuel use as no separate breakout for shipping to and from the U.S. Mainland was available.

A line representing the Kyoto goal of reducing greenhouse gas emissions 7% below 1990 emissions was provided for reference. **It is not intended to be a specific goal nor to imply that the transportation sector alone can or should meet the target.** Efforts to reduce emissions will involve efforts in all sectors, but each sector will not necessarily be able to reduce to 7% below 1990 levels.

As noted above, 1990 transportation emissions were estimated at 7,749,478 tons of CO_2. Most of the variation through 1997 was due to fluctuations in aviation fuel use due to changes in visitor numbers and airline service. Forecast 2010 transportation CO_2 emissions were 8,999,472 tons, about 15.6% greater than 1990 levels. In 2020, the forecast was 9,872,458 tons of CO_2, 27% greater than 1990. Given the major contribution of the transportation sector to Hawaii's overall emissions, it is clear this sector should receive attention in seeking ways to reduce greenhouse gas emissions.

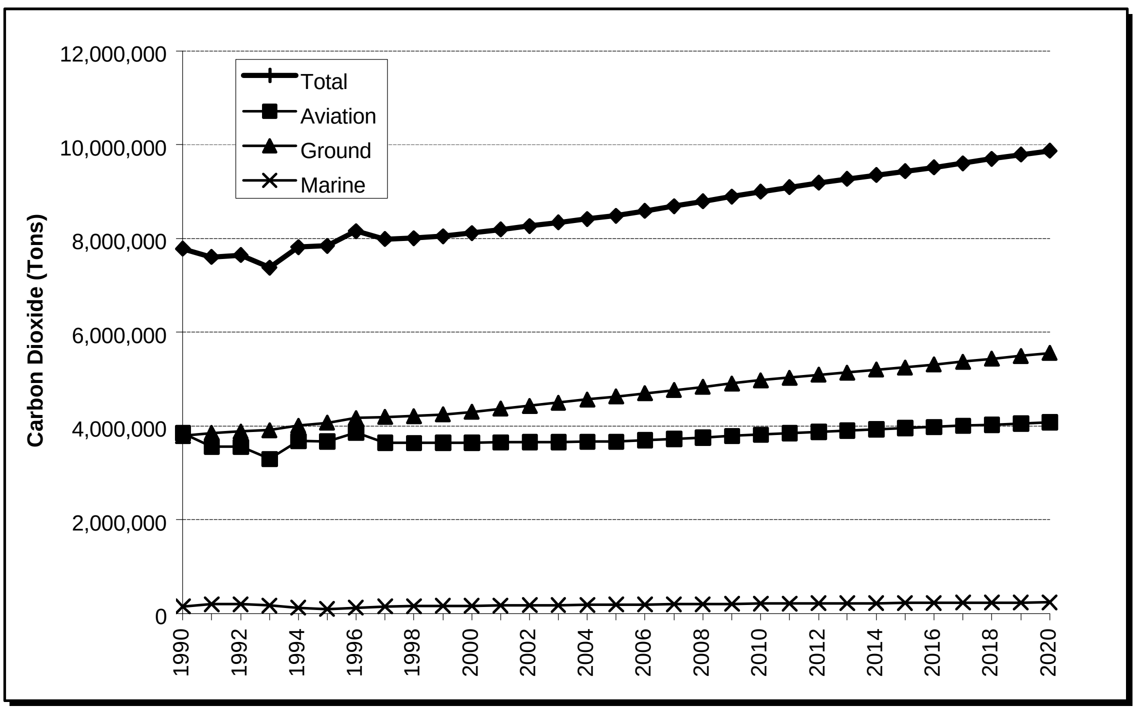


Figure 6.2 Estimated Hawaii Transportation Sector CO_2 Emissions by Category (Tons) 1990 - 2020

Figure 6.2, above, shows the forecast domestic transportation CO_2 emissions by category under the Baseline assumptions. While ground transportation emissions and air transportation emissions started out about equal, ground transportation emissions were forecast to grow more rapidly based upon the current trend of declining ground transportation vehicle efficiency. Air transportation efficiency is projected to improve at a rate of 0.7% per year in the Baseline Scenario, based upon U.S. Department of Energy forecasts. Marine fuel emissions growth was estimated at the same rate as population growth.

In the following sections, air transportation, ground transportation, and marine transportation emission reduction measures are discussed separately.

6.3 Ground Transportation

6.3.1 Ground Transportation Energy Use

Table 6.2 Hawaii Highway Vehicles, Vehicle Miles Traveled (VMT), and Fuel Use, 1990-1995

	1990	1991	1992	1993	1994	1995	Change 90-95
Registered Vehicles							
Number	889,397	867,699	815,421	881,182	845,629	847,723	(0.05)
Vehicle Miles Traveled (VMT)							
Miles (000)	8,063,579	8,141,691	8,062,945	7,887,266	7,924,880	7,944,590	-1%
Fuel Use (Bbl)							
Gasoline	8,837,169	8,877,658	9,000,218	9,094,812	9,266,699	9,391,026	6%
Diesel	582,452	595,024	625,929	595,167	706,952	652,643	12%
LPG	19,857	18,571	12,667	11,357	13,476	12,238	-38%
Total	9,439,478	9,491,253	9,638,814	9,701,336	9,987,127	10,055,907	7%
Estimated Average Vehicle Efficiency							
Miles per Gallon	**20.34**	**20.42**	**19.92**	**19.36**	**18.89**	**18.81**	**-8%**

Sources: State of Hawaii 1996b, 1997a; and City and County of Honolulu 1996

Table 6.2 depicts measurements of Hawaii ground transportation activity and energy use between 1990 and 1995. Although there was a decline in the number of registered vehicles and a slight decline in estimated vehicle miles traveled over the period 1990-1995, highway fuel use increased. Gasoline use increased 6%, diesel use increased 12%, but LPG highway use declined 38%. The number of registered diesel automobiles and light and heavy diesel trucks increased, but their total numbers remained relatively small.

Overall, the estimated average fuel economy (mileage per gallon of gasoline, diesel, and LPG) of Hawaii's vehicles declined an estimated 8%. This was despite the increased Corporate Average Fuel Efficiency (CAFE) standards for newer vehicles, which grew in numbers in relation to the total fleet of registered vehicles each year. This suggests that new vehicles registered in Hawaii were, on average, less efficient than the CAFE standard.

6.3.2 Ground Transportation Greenhouse Gas Emissions, 1990-1995

As a result of apparent declines in efficiency, Hawaii's global warming potential from ground transportation emissions increased by an estimated 7 percent between 1990 and 1995. Table 6.3 summarizes the increase in greenhouse gas emissions.

CO_2 and N_2O emissions increased by 7%. There were declines in CH_4 and the photochemically active gases due to the increasing effectiveness of emission controls on newer vehicles entering the fleet since 1990.

Table 6.3 Greenhouse Gas Emissions from Highway Vehicles in Hawaii (Tons), 1990-1995

	1990	1991	1992	1993	1994	1995	Change 90-95
CO_2	3,787,765	3,849,242	3,886,313	3,910,840	4,009,132	4,070,994	7%
CH_4	715	682	689	647	631	620	-13%
N_20	446	461	472	476	475	479	7%
NOx	13,644	13,242	13,054	12,392	12,826	12,762	-6%
CO	108,083	99,858	97,913	88,156	86,529	84,923	-21%
NMVOC	17,790	16,895	16,570	15,501	15,379	15,231	-14%
GWP	3,923,799	3,988,812	4,028,870	4,053,487	4,151,366	4,213,879	7%

The trends in ground transportation are summarized in Figure 6.3. Despite the decline in number of vehicles and estimated VMT, fuel use increased at a rate greater than the nominal 2% defacto population increase, resulting in an increase in global warming potential (tons CO_2–equivalent).

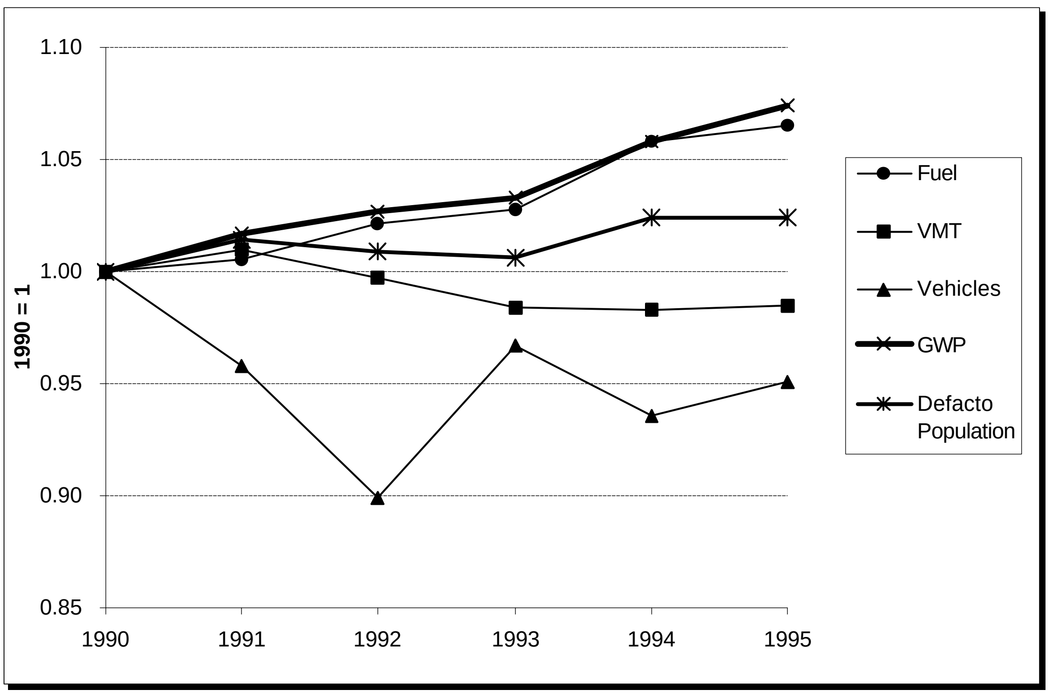


Figure 6.3 Hawaii Registered Highway Vehicles, Estimated VMT, Fuel Use, and GWP, Compared to De Facto Population, 1990-1995

As mentioned above, the expectation had been that, due to higher CAFE standards, Hawaii's vehicle fleet would become more efficient over time. It appears that this was not the case. While projections suggested that future growth in number of vehicles, VMT, and fuel used might be offset by increases in vehicle fuel efficiency associated with increasing percentages of newer vehicles on Hawaii's roads, this now appears unlikely. Fuel use probably increased due to some increase in VMT and a decline in vehicle fleet efficiency. Additional measures must be considered to reduce future greenhouse gas emissions from ground transportation.

6.3.3 Measures to Reduce Greenhouse Gas Emissions through Transportation Energy Demand Reduction

Greenhouse gas reductions in the transportation sector may be accomplished by either reducing the demand for transportation energy or replacing nonrenewable sources of transportation fuel with renewable sources of fuel.

This section focuses upon reducing emissions by reducing the demand for transportation energy. These include improving the average efficiency of vehicles used in the state, reducing the amount of energy "wasted" due to congestion, changing travel behavior, and changing land use development patterns to reduce the need for transportation.

6.3.3.1 Actions to Improve Fuel Efficiency of Hawaii Vehicle Fleet

One means of decreasing energy demand and greenhouse gas emissions in the ground transportation sector would be to increase the average fuel efficiency of vehicles operating in Hawaii.

6.3.3.1.1 RECOMMENDATION to Increase Fuel Efficiency: Increase the Visibility of Driving Costs

The federal Corporate Average Fuel Economy (CAFE) standards law (Title V of the Motor Vehicle Information and Cost Savings Act, 15 U.S.C. 2001-2013) preempts (prohibits) states from setting their own fuel efficiency standards. However, states may encourage the purchase of more fuel-efficient vehicles indirectly by increasing the proportion of driving costs paid through assessments on fuels. For example, highway maintenance is partially financed via state fuel taxes; highway law enforcement and liability insurance could also be financed via pay-at-the-pump systems. This would internalize these costs of driving in the gasoline price. It would increase the apparent fuel cost (while possibly reducing actual driving costs to insured motorists) and would make drivers more aware of their own fuel use and they may become more likely to consider fuel economy in the purchase of vehicles.

6.3.3.1.2 RECOMMENDATION to Increase Fuel Efficiency: Increase Information on the Environmental Costs of Vehicle Fuel Use by Use of a New Environmental Impact Information Sheet

If the CAFE standards were effective, Hawaii's vehicle fleet would be more efficient than it was in 1990. Newer vehicles, overall, should have greater average fuel economy, and this should be reflected in lower fuel use per registered vehicle. Of course, if the more fuel-efficient vehicles are driven greater distances as a result of lower per mile fuel costs, and there will be greater fuel use. Also, if Hawaii's vehicle fleet had an increasing percentage of relatively fuel-inefficient large automobiles, sport utility vehicles, light trucks, and minivans, overall fleet efficiency would be lower.

The Current Vehicle Fleet Does Not Meet CAFE Standards. Although information was not available on vehicle sales by model in Hawaii, Table 6.4, below, depicts the ten best-selling automobiles and light trucks nationwide in 1997. These 20 models accounted for 43% of the 15,100,000 vehicles sold nationally. Pickup trucks or minivans made up 54% of the top 20 (Camry 1998). As a result, overall fuel economy of the national vehicle fleet did not improve. Since increased fuel use per vehicle in Hawaii was also suggested by available data, it appears that Hawaii vehicle sales may be following the national trend to less-efficient vehicles.

The CAFE standard in 1997 was 27.5 mpg for automobiles and 20.7 mpg for trucks. To evaluate the fuel efficiency of these models, it was assumed, based upon estimated vehicle mileage traveled on Hawaii's roads, that the vehicles were driven in urban conditions 76% of the time and highway conditions 24% of the time (State of Hawaii 1996b). Since most vehicle types offered several engine/transmission combinations which produced different fuel economy values, an average between the high and low values was used. For trucks, fuel economy values for two-wheel drive trucks were used, and for sport-utility vehicles, the values for the four-wheel drive version were used.

If the top ten automobiles were driven in Hawaii under the above assumptions, their fuel economy would average 25.8 mpg, or 94% of the 27.5-mpg standard for automobiles. In contrast, the top ten automobiles in 1996 would have averaged 27.4 mpg under these same assumptions. The top ten in the trucks, sport utility vehicles, and minivans category would average 17.5 mpg well below the standard of 20.7 mpg, but improving over the 1996 average of 17.2 mpg for this category. In aggregate, the twenty top-selling vehicles averaged 21.7 mpg, an improvement over the 1996 top twenty average of 20.4 mpg. The most efficient models, those that had better fuel economy than the CAFE standard in their category, are listed in bold type on Table 6.4.

Table 6.4 Fuel Economy and CO_2 Emissions of Top Twenty Vehicles in Sales in U.S., 1997

Vehicle	Number Sold	Average MPG	Lbs CO_2/ Mile	Tons CO_2/ 10,000 mi	Percent of Standard
Ford F Series	780,838	15.0	1.30	6.49	72%
Chevrolet C/K	549,167	16.7	1.16	5.82	81%
Ford Explorer	402,663	17.1	1.14	5.69	83%
Ford Taurus	401,049	22.2	0.88	4.38	81%
Dodge Ram Pickup	383,960	15.0	1.30	6.49	72%
Honda Accord	382,298	23.6	0.82	4.12	86%
Toyota Camry	359,433	23.3	0.83	4.17	85%
Dodge Caravan	300,117	20.1	0.97	4.84	97%
Ford Ranger	**288,393**	**20.8**	**0.93**	**4.67**	**101%**
Honda Civic	**286,350**	**32.1**	**0.61**	**3.03**	**117%**
Ford Escort	**284,644**	**28.6**	**0.68**	**3.40**	**104%**
Jeep Gr. Cherokee	279,195	15.6	1.25	6.24	75%
Chevrolet Cavalier	**277,222**	**26.0**	**0.75**	**3.73**	**95%**
Chevrolet Blazer	246,307	17.7	1.10	5.49	86%
Chevrolet Lumina	237,973	20.7	0.94	4.70	75%
Pontiac Grand Am	222,477	24.2	0.80	4.02	88%
Toyota Corolla	**209,048**	**29.5**	**0.66**	**3.30**	**107%**
Ford Windstar	209,033	18.7	1.04	5.20	90%
Chevrolet S10 Pickup	**190,178**	**22.1**	**0.88**	**4.40**	**107%**
Auto Weighted Avg	2,451,446	27.4	0.71	3.54	100%
Truck/Van Weighted Avg	3,629,851	17.2	1.13	5.66	83%
Top 20 Weighted Avg	6,081,297	20.4	0.95	4.77	

Source: AAMA 1997; USDOE 1996

Table 6.4 also shows the estimated CO_2 emissions per vehicle based upon driving 10,000 miles per year under the estimated Hawaii urban/rural split. The performance of the vehicle relative to the standard for its class is also displayed. Such information could be made available to vehicle shoppers to for possible consideration in making their purchase decision.

The Current Fuel Economy Label. Vehicle shoppers may not consider relative fuel efficiency between vehicle options beyond the cost of the fuel, which is now relatively low. Currently, the EPA conducts tests used to certify that vehicles meet federal emissions and fuel economy standards. The Fuel Economy Label now includes estimates of gasoline mileage under city driving and highway driving conditions, an estimated range of fuel economy that most drivers achieve with the particular model, estimated annual fuel cost, and the range of fuel economy for other models of the same vehicle size class. The Fuel Economy Label is required to be placed on the window of a new vehicle for sale (USDOE 1996, 12).

The Proposed Environmental Impact Information Sheet. Vehicle buyers could be provided additional information regarding the greenhouse gas emissions of each type of vehicle. This information coupled with supporting public information programs may cause significant numbers of vehicle purchasers to consider the environmental implications of their purchase decision. The emphasis of the current Fuel Economy Label is on fuel use and cost, but many purchasers are apparently not concerned about the higher gasoline costs of a less efficient and less climate-friendly vehicle.

The current Fuel Economy Label could be changed to become an EPA Environmental Impact Information Sheet (EIIS). The EIIS would include the current information on vehicle fuel efficiency and estimated annual fuel costs, supplemented with information on the vehicles estimated contribution to global warming. This information would global warming potential in tons CO_2-equivalent per mile and for a typical year's operation. This would be compared on the EIIS against emissions based upon the current CAFE standard. In addition, since more people purchase used vehicles than new vehicles, an EIIS should be required for used cars on dealer lots. This additional information would be intended to guide automobile consumers towards choices that would more rapidly improve the fuel efficiency of the U.S. and Hawaii vehicle fleets and reduce the ground transportation vehicle contribution to greenhouse gas emissions.

6.3.3.2 RECOMMENDATION to Reduce Fuel Use: Increase Use of Mass Transit

Oahu's mass transit system consists of a fleet of 525 buses, which carried over 74.4 million passengers in 1997 (State of Hawaii 1998d). The buses also have the latest "smart bus technology," including an on-board satellite positioning unit which will eventually allow buses to be tracked in order to reduce irregularities in bus arrival frequencies. By the end of 1998, all buses will be equipped with bicycle racks.

As part of the City and County's *Oahu Trans 2K* planning now ongoing with solicitation of public input, the City recognizes the need for transportation alternatives and proposes a high-capacity electric trolley system throughout the primary urban center with easy access parking facilities serviced by the trolleys at all peripheral entrance points to downtown. Expanded fleets of express buses to bring residents from Central Oahu and other outlying districts to downtown on dedicated bus lanes would interface with the trolley system. Motorists driving downtown would be able to park conveniently within the peripheral parking structures and then transfer to a modern, efficient electric trolley that would take them anywhere within the urban core (C&C 1998b).

In addition, based upon the earlier Oahu Regional Transportation Plan (Kaku Associates 1995), the bus fleet would be enlarged to about 715 vehicles. TheBus, as the Honolulu bus system is called, would be supplemented by 125 Handi-Vans. New service types including jitneys, subscription bus services, shared-ride taxis, and local circulator and shuttles would also be considered (Table A-3b). The bus and trolley system would be also supplemented by planned additional vanpools and water taxis and ferries under the *Oahu Trans 2K Plan*.

6.3.3.3 RECOMMENDATION to Reduce Fuel Use: Improve the Bicycle Transportation System

There is considerable interest in increased use of bicycles in the counties as well as at the State level. Bicycles do not use fossil fuels and do not produce greenhouse gas emissions. The bicycle racks recently added to city buses in Honolulu are frequently used, indicating that the combination of individual mobility and mass transit is effective. However, bicycle lanes are limited statewide, making bicycling difficult and/or dangerous in many cases. Therefore, the state and counties have developed plans for increasing the number and safety of bicycle lanes and paths. The tables below summarize current conditions and proposed improvements.

6.3.3.3.1 State of Hawaii Bike Plan Hawaii, *1994*

In 1994, the State of Hawaii Department of Transportation Highways Division developed *Bike Plan Hawaii*. *Bike Plan Hawaii* identified existing bikeways and outlined plans for additional bikeways statewide as outlined below.

Existing Bikeway Facilities. Table 6.5 summarizes existing bikeway facilities in the State of Hawaii in 1994. According to the table, there were a total of 87 miles of existing bikeways. Approximately 49.7 miles were under the jurisdiction of the State, and 37.3 miles under the jurisdiction of the counties.

Table 6.5 Hawaii's Existing Bikeways, 1994

Island	State (Miles)	County (Miles)	Total (Miles)
Kauai	3.8	0	3.8
Oahu	21.2	34.2	55.4
Maui	17.8	1.8	19.6
Hawaii	6.9	1.3	8.2
Statewide	49.7	37.3	87

Source: State of Hawaii 1994b

Proposed Bikeway Facilities. Table 6.6 summarizes the proposed State of Hawaii Bikeway System including estimated mileage and costs. A total of 1,309.6 miles of bikeway were proposed at an estimated cost of $233.5 million. Approximately 762.6 miles were anticipated to be under the jurisdiction of the state, and 414.1 miles would be under the jurisdiction of the counties. Approximately 131.9 new bikeway miles were undefined as to jurisdiction and were to be developed by state, county, or private sector interests (State of Hawaii 1994b).

Island	State Length (Miles)	Cost (Million $)	Counties Length (Miles)	Cost (Million $)	Undefined* Length (Miles)	Cost (Million $)	Totals Length (Miles)	Cost (Million $)
Kauai	103.3	$22.50	63.1	$15.20	6.6	$1.60	173	$39.30
Oahu	167.1	$37.60	113.4	$20.20	12.6	$3.30	293.1	$61.10
Maui	102	$18.20	79.6	$16.70	86	$20.30	267.6	$55.20
Molokai	43.5	$11.00	5.2	$1.30	0	0	48.7	$12.30
Lanai	11.2	$2.80	0.5	$0.10	0	0	11.7	$2.90
Hawaii	335.5	$39.80	152.3	$19.50	26.7	$3.40	514.5	$62.70
Statewide	762.6	$131.90	414.1	$73.00	131.9	$28.60	1,308.60	$233.50

Table 6.6 Bike Plan Hawaii Summary of Proposed Mileage and Costs

* Undefined: Includes bikeways on private lands and on roadway systems for which jurisdiction needs to be determined.

Source: State of Hawaii 1994b

6.3.3.3.2 City and County of Honolulu Draft Honolulu Bicycle Master Plan, 1998

The City and County of Honolulu developed a *Draft Honolulu Bicycle Master Plan* (C&C 1998a) in July 1998 and is currently seeking citizen input on the *Plan*. The *Plan* describes a comprehensive set of projects, policies, and programs to incorporate bicycles into Honolulu's future transportation system. The *Plan* has a number of objectives including investing in "sensible alternative transportation modes that are sustainable, that tread lightly on our natural environment, and which yield significant health benefits" (7). While reduction of greenhouse gas emissions is not mentioned as an objective, it is certainly a component of treading lightly on our natural environment.

The *Plan* outlines new bicycle routes and improvements to existing routes to be built over a 20-year period at a cost of almost $80 million. It seeks to accomplish the following goals:

To increase the mode share of bicycle trips.

To enhance cooperation between roadway users.

To encourage an promote bicycling as a safe, convenient, and pleasurable means of travel (38-40).

Benchmarks under these goals include a doubling of commute mode share from 1.4% of commuter trips along major bike routes to 2.8% in the first five years; another doubling from 2.8% to 5% by the tenth year; and reaching 10% of commuter trips by the twentieth year. While sufficient data was not available to estimate the greenhouse gas emissions savings that could result in achieving these goals, it is expected that there would be a significant contribution.

6.3.3.3.3 Neighbor Island Bicycle Plans

The Long-Range Transportation Plans for each of the neighbor islands includes a bicycle component. The *Maui Long-Range Land Transportation Plan* (Kaku Associates 1997) and the *Hawaii Maui Long-Range Land Transportation Plan*

(Harris 1998) were reviewed. Both incorporated their county's component of the 1994 State *Bike Plan Hawaii* discussed above. The *Kauai Long-Range Land Transportation Plan* was not available for review.

6.3.3.4 RECOMMENDATION to Reduce Fuel Use: Use Land Use Planning to Reduce Congestion and Need for Transportation

Mixed-use development plans, in which residential and commercial land uses are allowed in the same neighborhood, can reduce the need for commuting from "residential districts" to "commercial districts." The State of Hawaii and the City and County of Honolulu appear to be moving in directions supportive of this recommendation as outlined in Mayor Harris' *21st Century Oahu - A Shared Vision for the Future, Oahu Vision Presentation* (Mayor Harris 1998). By reducing congestion and the need for transportation, less vehicle fuel will be used and less greenhouse gas emissions will occur.

The redevelopment of the Kakaako District (in Honolulu's urban core) and development of a "second city" called Kapolei, on Oahu, include conscious efforts to encourage mixed-use development, pedestrian paths, and bikeways to reduce the need for motorized transport.

In Kakaako, the state seeks to create an appropriate land mixture of residential, commercial, industrial, and other uses. It is intended that activities shall be located so as to provide primary reliance on public transportation and pedestrian facilities for internal circulation within the district (Mayor Harris 1998).

Kapolei is an area intended to be "mixed use," but which has experienced predominantly residential development. Mayor Harris stated in his 1998 "State of the City" address that, "Kapolei must meet the full definition of a city, a place where people live, work and recreate . . . . Kapolei cannot and will not become our island's largest bedroom community and the source of commuters who move daily between home and their jobs elsewhere on Oahu. Kapolei was meant to be a solution to many of our island's problems, not an expansion of them" (Mayor Harris 1998).

The Mayor envisions future development that is less dependent upon the automobile for transportation. He proposed "that we rethink the basic assumptions of land use planning and go back to the original policies of the General Plan. Instead of continuing to allow urban sprawl in Central Oahu, I propose that we draw rigid and absolute urban boundaries and redirect all future urban growth to the Second City and the Primary Urban Center. By redirecting growth to these two urban areas, we'll stem the increased traffic coming from Central Oahu" (Mayor Harris 1998).

The City is now seeking public input to develop neighborhood plans. The Mayor seeks "plans for towns and neighborhoods that result in a safe pedestrian environment supported by a good public transportation system, centralized parking and other measures to give us viable alternatives to our dependence on the automobile" (Mayor Harris 1998).

6.3.3.5 RECOMMENDATION: Reduce Congestion Through the Use of Transportation Control Measures

6.3.3.5.1 Transportation Control Measures

Transportation control measures (TCMs) are measures that improve the efficiency of the transportation system and measures that reduce transportation demand. Those measures that emphasize improving the operating efficiency and maximizing the capacity of the existing transportation system often address localized concerns and may help reduce congestion. These measures focus on the “supply side” of transportation service (State of Hawaii 1995c, 3-1).

In theory, improved transportation efficiency should result in reduced fuel use However, when congestion is reduced and the system performs better, additional trips are typically generated. Previously, before the system improvements, these trips would have been foregone. In addition, the energy efficiency of internal combustion engine vehicles varies in a nonlinear fashion with vehicle speed. At a speed specific to each vehicle but often around 25-35 mph for a passenger car, maximum fuel efficiency is attained. Therefore, if transportation system management measures result in a change in average speeds, average fuel efficiency could increase or decrease (3-1 to 3-2).

In the *Hawaii Energy Strategy's Transportation Energy Strategy*, it was estimated that 10% of the fuel making up the ground sector transportation energy demand on Oahu was wasted due to congestion (3-2). In 1997, that would have resulted in about 390,000 tons of CO_2 emissions as the idle vehicles burned gasoline and diesel fuel.

Where the transportation control measures reduce the demand for transportation, they can help reduce greenhouse gas emissions as fuels are not used to move people or things, or they do not need moved as great a distance. This includes such measures as land-use planning, telecommuting, schedule changes (e.g., going from a five-day week to a four-day week), etc.

6.3.3.5.2 Transportation Control Measures in Hawaii

Transportation Control Measures in the *2020 Oahu Regional Transportation Plan.* The Plan considered a wide range of TCMs and adopted many of them. (For a more detailed discussion of possible TCMs, please see the *Hawaii Energy Strategy's Transportation Energy Strategy*). The measures planned for implementation through 2000 were as follows:

High Occupancy Vehicle (HOV) Facilities and Enforcement. These include existing HOV lanes on the H-2 and H-1 freeways. The H-1 HOV lane was recently enhanced through the installation of a zipper lane system that deploys a moveable barrier to separate the HOV lane from regular traffic. Additional funds were recommended to enforce the minimum occupancy requirements.

Park-and-Ride Lots were to be added to the existing system to encourage bus use for at least part of each commuter's trip.

Rideshare Programs, including matching services, preferential vanpool/carpool parking, and guaranteed ride home programs were suggested.

Work Behavior Changes would also reduce transportation demand. These would include increased telecommuting, encouragement of flexible work hours and compressed work weeks.

Public Transit Support programs would encourage commuters to switch to TheBus from their cars through transit pass subsidies and public transit marketing.

Trip Reduction Ordinance. While no such ordinance has been passed, the objective would be to reduce demand by mandating preparation and implementation of trip reduction plans by developers and employers.

Bicycle Facilities, which would support the recommendation to improve the bicycle system discussed above, were recommended. These were new bike routes, bike lanes, and bike paths, and bicycle lockers and showers at employment centers and public multi-modal transit centers.

Pedestrian Facilities were also slated for improvement (Kaku Associates 1995, Table A-1c, d)

Beginning in 2001, the TCM measures listed above were to be continued and many were to be expanded. One additional measure was proposed. Parking management measures could attempt to reduce the attractiveness of commuting by automobile by making parking less available and more costly. Components of such a program would include mandating a reduction of parking supply via code changes, elimination of employee parking subsidies, mandating parking cash-out/travel allowance, mandating parking pricing strategies aimed at discouraging commuting, and a residential permit parking program to preclude a shift of parking to residential areas (Table A-2c, 3c).

The Oahu Plan was incorporated into the State of Hawaii Transportation Departments plans. It should be noted that none of the measures were selected specifically to reduce greenhouse gas emissions. However, one of the four goals was to "Develop and maintain Oahu's transportation system in a manner which maintains environmental quality and community cohesiveness" (1-4). Objectives under this goal related to energy use included:

#14: Encourage . . . the development and maintenance of "low energy" transportation facilities, including bikeways, walkways, and other energy efficient elements which can be safely integrated with other transportation modes.

#15: Ensure that energy availability and cost are considered . . . .

#16: Encourage energy conservation in transportation (1-4).

6.3.3.5.3 RECOMMENDATION to Reduce Fuel Use: Develop Estimates of the Energy- and Emission-Saving Effectiveness of TCMs

TCMs were designed to affect travel performance. Energy saving could be a by-product, but is not usually a primary goal. It is quite difficult to determine the energy effectiveness of the many TCMs included in the Plan. Those measures that show the greatest energy-saving potential in the short- and mid-term operate by reducing total regional VMT through travel mode shifts away from single occupant vehicles, or by decreasing the need for travel. Different strategies work best on different sectors of the travel market. For example, home to work trips are perhaps best addressed by measures that encourage non-automobile travel models (e.g., mass transit), and higher utilization rates of automobiles (e.g., ridesharing, HOV facilities). Shopping and errand trips are perhaps best addressed through encouragement of non-automobile modes (e.g., mass transit, walking) and appropriate land use patterns. Home to school trips could be addressed by other options (e.g., HOVs, educational institution actions). Therefore, a complete package to reduce VMT must take into account various trip purposes, the many implementation issues associated with each measure, and the synergies between TCMs.

The energy saving associated with certain combinations of TCMs was estimated in the preparation of the *Plan* according to the *Transportation Energy Strategy*. The analysis indicated that by the year 2020, as much as an 18% energy savings could result from an aggressive suite of TCMs (State of Hawaii 1995c, 3-50). No such claim was made in the *Plan*, however. Additional efforts to analyze and model the measures finally adopted are recommended.

6.3.4 Measures to Reduce Greenhouse Gas Emissions Through the Use of Alternative Fuels

The previous discussions have suggested ways of reducing greenhouse gas emissions in the transportation sector may be accomplished by reducing the demand for transportation energy. In this section, replacing nonrenewable sources of transportation fuel with renewable sources of fuel that produce fewer or no net emissions are proposed.

6.3.4.1 Alternative Fuels

Alternative ground transportation fuels include alcohol fuels (methanol and ethanol; propane; natural gas and synthetic natural gas; electricity; biodiesel; and hydrogen. Of these fuels, propane, natural gas, and synthetic gas are fossil fuels that offer little advantage over gasoline or diesel in terms of greenhouse gas reduction. As a result, they will not be discussed here. Table 6.7 compares the non-fossil fuel options. Electricity is included as it can be produced from renewable energy. Even if provided from fossil fuel sources, there would likely be fewer emissions involved than through use of an equivalent amount of gasoline or diesel.

Table 6.7 Comparison of Alternative Fuels

Fuel	Advantages	Disadvantages
Methanol	Could be produced locally from Hawaii feedstocks. Used for years in racing engines. Extensive data available from California AFV program. Flexible fuel vehicles that can operate on M85 (85% methanol, 15% gasoline) or any combination to 100% gasoline are available. Bus and truck engines that can use 100% methanol are available. High octane. Burns cleaner than gasoline	Not locally available as a fuel. Price of methanol, on per-mile basis in Hawaii, currently would be greater than gasoline. It takes 1.7 to 1.9 gallons of methanol to go as far as 1 gallon of gasoline. Imported methanol would predominantly be made from non-renewable natural gas, reducing its greenhouse gas emissions mitigation value.
Ethanol	Could be produced locally from Hawaii renewable feedstocks. Can be blended (up to 10%) with gasoline and used in existing cars. Blend raises octane about 3%. Flexible fuel vehicles that can operate on E85 (85% ethanol, 15% gasoline) or any combination to 100% gasoline are available. Bus and truck engines that can use 100% ethanol are available. High octane. Burns cleaner than gasoline. Non-toxic.	Not yet locally available as a fuel. Price of ethanol, on per-mile basis, in Hawaii, currently would be greater than gasoline or diesel. It takes 1.3 to 1.5 gallons of ethanol to go as far as 1 gallon of gasoline. Base ethanol fuel may need to be adjusted and blending equipment may need to be installed to blend 10% ethanol in gasoline.

Continued on next page

Table 6.7 Comparison of Alternative Fuels (Continued)

Fuel	Advantages	Disadvantages
Electricity	Electricity can be produced locally from Hawaii resources, including biomass, solar, geothermal, hydro, or wind power. Distribution infrastructure in place. Fuel cost per mile is less than gasoline or diesel. Electric power plants and electric vehicles are more efficient than internal combustion engines. No tailpipe emissions and reduced overall emissions. Charging at night during off-peak hours would provide operational benefits to electric utilities, which currently have an energy demand below their optimum minimum.	Vehicles now available have ranges of only 40 to 200 miles between charges. Standards and infrastructure for battery charging and vehicle servicing are only in early stages of development in Hawaii. Electric vehicles cost more than their gasoline counterparts. Higher volumes of production in the future will reduce this. Current electric-only vehicle technology is not as appropriate for long distance heavy-duty truck and bus applications. Disincentives to daytime charging from the electric utility grid must be put into place to avoid increasing demand for electricity during peak demand periods.
Biodiesel	Can be produced locally from Hawaii resources, including waste cooking oils, a renewable resource. In use on Maui. May be blended with regular diesel and used in existing diesel engines with minimal modification. Biodiesel blends reduce emissions of particulates and smoke. One gallon of biodiesel will go about as far as a gallon of regular diesel.	Still undergoing testing and certification. For use in diesel engines only; not a gasoline replacement. Retail price of biodiesel is higher than for regular diesel.
Hydrogen	Extremely low emissions. Renewable. Can be made from many materials, including water	In research and development. Not commercially available.

Source: State of Hawaii 1995c, Table 4-2, 4-5.

As can be seen on the table, there are a number of very significant issues to consider in looking at alternative fuel options. For the purposes of this Plan, the focus will be on the near term.

6.3.4.2 Hawaii Laws Supporting Use of Alternative Fuels

6.3.4.2.1 RECOMMENDATION: Publicize Incentives for AFV Ownership

There are three provisions of Hawaii laws that make it easier for fleet managers (and the general public) to own and operate AFVs:

1. The state fuel tax on propane is 11¢/gallon (compared to 16¢/gallon for diesel).
2. Vehicles with special "electric vehicle" plates are allowed to park for free at parking meters and use "High Occupancy Vehicle" lanes at any time.

3. "Clean fuel" dispensing equipment is eligible for income tax deductions.

6.3.4.2.2 RECOMMENDATION: Consider Additional Incentives to Encourage AFV Use

Additional provisions should be identified and examined for recommendation to the Legislature to further encourage use of alternative fuels and AFVs.

6.3.4.3 RECOMMENDATION: Encourage Early Production and Sale of 10% Ethanol Blend Gasoline in Hawaii

Alcohol fuels are not currently available in Hawaii. However, there has been a great deal of discussion over the years about producing alcohol fuels (ethanol or methanol) in Hawaii. Cost estimates for an aggressive alcohol fuels program were made as part of the *Hawaii Energy Strategy's Project 5, Transportation Energy Strategy* (State of Hawaii, 1995c).

Based on that work, use of a 10% ethanol - 90% gasoline blend fuel (gasohol), ultimately made in Hawaii from Hawaii biomass was modeled as Transportation Scenario GT2 in the ENERGY 2020 model. This scenario was the fourth most effective non-carbon tax scenario at reducing CO_2 emissions by 2010. Estimated reductions would be 644,690 tons in that year. By 2020, GT2 was the third most effective non-carbon tax scenario, cutting estimated CO_2 emissions by 761,202 tons. (See Chapter 9 for details.)

The State Legislature has already acted to encourage 10% ethanol gasoline in Hawaii. In 1994, legislation was enacted that stated that "gasoline in Hawaii shall contain ten percent ethanol by volume" and designated that specific phase-in schedules, provisions for exemptions, and other details be addressed via a formal rulemaking process under the direction of the Department of Business, Economic, Development, and Tourism (Hawaii Revised Statues, Chapter 486-J10). The preliminary work is underway in preparation for the necessary formal rule making (Tome 1998).

6.3.4.4 RECOMMENDATION: Encourage Early Deployment of Electric Vehicles in Hawaii

Honolulu will become the first "electric vehicle-ready" city in the United States when Hawaiian Electric Company installs a network of up to 20 electric Rapid-Charger stations where electric vehicles will be able to be recharged in less than nine minutes. The network of rapid charger stations is a public-private partnership with funding from the federal Defense Advanced Research Projects Agency and contributions from HECO, AeroVironment, Inc., Electricore, and Hawaii Electric Vehicles, Inc. The Hawaii Electric Vehicle Demonstration Project is the overall coordinator. The Rapid-Charger network was announced on October 27, 1998. This will be an important element of infrastructure to support deployment of electric vehicles. Chargers will be deployed on neighbor islands in the future (HECO 1998b).

Early deployment of electric vehicles will help reduce greenhouse gas emissions. In addition, nighttime charging of electric vehicles could contribute to the efficiency of the electric utility systems by increasing base load levels. Base load utility operations produce less greenhouse gas emissions per kWh generated. The Public Utilities Commission recently approved a nighttime rate of 7.5 cents per kWh, about half regular residential rates, to encourage this practice. A 10 kWh overnight EV charge would be about 75 cents (HECO 1998b).

6.3.4.4.1 RECOMMENDATION: Encourage Electric Vehicle Manufacturers to Offer Electric Vehicles for Sale

In addition to soon being "electric vehicle-ready," Hawaii offers an ideal place for electric vehicle use. The temperate climate reduces thermal management problems and the geographic limits of islands guarantee that no driver could ever stray beyond a network of charging stations (HECO 1998b).

Hawaii residents could benefit from cleaner air through electric vehicle use. The charging station network will make operation anywhere on Oahu possible. Most commuter's round trips are within the range offered by current battery technology. Without the need for a car capable of interstate vacation trips, Hawaii motorists may purchase electric vehicles as their primary vehicle.

Hawaii also offers a potential marketing opportunity for rental car agencies and electric vehicle manufacturers. Rental car agencies can offer a unique and exciting vehicle option to vacationers. Manufacturers can gain exposure to new customers (HECO 1998b).

Electric vehicle-related companies, such as those involved in the Rapid-Charger network and the state should actively seek to encourage electric vehicle manufacturers to offer their vehicles for sale or lease in Hawaii.

6.3.4.4.2 RECOMMENDATION: Expand Hawaii Electric Vehicle Development Program

The Hawaii Electric Vehicle Demonstration Project (HEVDP) is a consortium established initially through a federal grant from the United States Department of Defense, Advanced Research Projects Agency (ARPA) to facilitate the development of electric vehicle technologies in the state for both commercial and military applications. The Hawaii Consortium was one of seven entities selected nationwide by ARPA to participate in this program. The High Technology Development Corporation (HTDC) manages HEVDP. HEVDP's mission is to:

- Energize the transportation technologies industries in Hawaii to create high quality jobs and improve economic competitiveness;
- Maximize the number of commercial and military electric vehicles on the road;
- Broaden the range of EV types and sizes to fit an increasing array of applications;
- Develop an electric vehicle infrastructure such as electric vehicle centers and special charging stations;
- Provide data acquisition and analysis such as vehicle component sensors, data acquisition systems, and requisite software;
- Enhance technical opportunities in the areas of electric vehicle conversion and training; and
- Support military and commercial electric vehicles by providing warranties and service centers (HEVDP 1997).

HEVDP has deployed nearly 40 electric vehicles on Hawaii's roads. These were operated primarily by the military, the state, and the electric utilities. Vehicles include pickup trucks, automobiles, buses, and a specialized industrial vehicle. In addition, E Noa Tours operates an electric "Waikiki Trolley" (Quinn 1998).

As noted above, HEVDP is coordinating the Rapid Charger program. It may be able to foster further deployments of electric vehicles in other ways.

6.3.4.5 RECOMMENDATION: Assist Fleets in Complying with EPACT Requirements for Alternative Fuel Vehicles

In 1992, the National Energy Policy Act (EPACT) became law. This law required fleets of more than 20 centrally fueled light duty vehicles located in metropolitan areas (in Hawaii, only Oahu is included) to purchase "alternate fueled vehicles." Requirements (% of new vehicles purchased each year which must be alternative fuel vehicles) were as shown on Table 6.8.

Table 6.8 EPACT Requirements for AFV Percentages in Fleets, 1997-2006

Model Year	Federal Gov't	State Gov't	Municipal Gov't & Private Fleets	Fuel Provider
1997	25%	10%		50%
1998	33%	15%		70%
1999	50%	25%		90%
2000	75%	50%		90%
2001	75%	75%		90%
2002	75%	75%	20%	90%
2003	75%	75%	40%	90%
2004	75%	75%	60%	90%
2005	75%	75%	70%	90%
2006	75%	75%	70%	90%

The alternate fuels permitted by EPACT are alcohol fuels, natural gas, liquefied petroleum gas (also known as LPG or propane), hydrogen, biodiesel, coal derived fuels, biological materials derived fuels, and electricity. EPACT also provides tax incentives for AFV purchases, conversions, and installation of "clean fuel" dispensing equipment. (PL 102-486).

In addition to the vehicle purchase requirements listed above, there are reporting requirements, provisions for exemptions, and provisions for "credits" if an agency has purchased more than the required number of vehicles or has purchased alternative fuel vehicles in advance of the requirements. Each "covered fleet" is required to submit reports to the Department of Energy on an annual basis.

Assisting fleets to understand and comply with the EPACT requirements is recommended since such compliance will increase the use and acceptance of alternative fuels and infrastructure.

6.3.4.6 RECOMMENDATION: Support Honolulu Clean Cities Program

Electric, propane, and biodiesel-fueled vehicles are in use in federal, state, county, and private fleets on all islands. Although only several hundred of these vehicles are operating, they represent the basis from which information and confidence may be developed for sharing with other fleet managers who may consider adoption of alternative fueled vehicles.

Honolulu Clean Cities is part of the nation-wide Clean Cities program sponsored by the U.S. Department of Energy intended to promote the use of alternative transportation fuels. The twenty-five organizations participating in the program include county, state, and federal government agencies, fuel suppliers, fleets, and industry and community organizations.

As stated in the Memorandum of Understanding, the objectives are to:

- Develop local industry and create alternative-fuel related industry;
- Develop reasonable cost alternative fuels and supporting infrastructure;
- Reduce operation and maintenance cost of vehicles;
- Reduce state and national dependence on imported petroleum for transportation fuel;
- Reduce air pollution caused by transportation fuel;
- Maintain records and statistics of alternative fuel vehicles to determine best fuel, vehicle, and task fit;
- Educate members and the public on alternative fuels and vehicle technology; and

- Promote efficient management and maximum utilization of existing local energy resources (C&C 1997).

The primary activities of Honolulu Clean Cities include alternative fuel vehicle displays at public events; ride-and-drive events for fleet managers, the media, and decision-makers; publication and distribution of a quarterly newsletter; development of programs to convert vehicles and share information from within participants' own fleets; development of joint fueling arrangements; and training.

6.4 Air Transportation

6.4.1 Overview

Air transportation is vital to Hawaii. Overseas air transportation is essential to Hawaii's tourism-based economy, providing transportation to millions of visitors annually. Overseas transportation is the only regular passenger connection to the Mainland United States and international destinations for Hawaii's citizens. Inter-island air transportation is equally critical. It is the only passenger connection between Hawaii's islands for residents and visitors alike. In its 1996 10K filing with the Securities Exchange Commission, Hawaiian Airlines aptly noted that, "One-third of this market is represented by residents of Hawaii who rely on Inter-island flights in much the same way as Mainland residents rely on a state highway system" (Hawaiian Airlines 1997). This fact makes interstate air transportation more critical for Hawaii than any other state, except, perhaps, Alaska.

The importance of air transportation in Hawaii is borne out by a look at its 1995 jet fuel use in relation to other states. Hawaii ranked 40th in the Nation in population, but 8th in the amount of jet fuel used. On a per capita basis, Hawaii (14.76 Bbl/capita) ranked second to Alaska (28.03 Bbl/capita) (State of Hawaii 1997c and EIA 1997b).

The significance of air transportation is further highlighted by the fact that four Hawaii city-pairs ranked in the top 22 airline markets in the United States in 1996. Honolulu-Kahului was ranked 2nd, Honolulu-Lihue was 15th, Honolulu-Kona was 21st, and Honolulu-Hilo was 22nd. With regard to overseas routes, Honolulu-Los Angeles was the 19th busiest domestic city-pair market (Lampl 1997, 48), while Honolulu-Tokyo was the 6th most traveled international market (188).

6.4.1.1 Inter-island Airlines

In this decade, Aloha Airlines and Hawaiian Airlines have served as Hawaii's primary inter-island carriers. Currently, Aloha operates 17 Boeing 737-200 aircraft (Ackerman 1997). Hawaiian uses 13 DC-9-50 aircraft in its inter-island operations (Fujitani 1997). In addition, Hawaiian has eight DC10-10 aircraft used in scheduled service to the Mainland United States and South Pacific destinations. In addition, Mid-Pacific Airlines operated nine YS-11 turboprop airliners inter-island through 1993 and went out of business. Mahalo Air began operation in October 1993, operating six ATR-42 turboprop aircraft, but went into bankruptcy in September 1997and ceased operations. In 1995, in addition to Aloha, Hawaiian, and Mahalo, there were eight other small passenger carriers operating relatively small aircraft (State of Hawaii 1997c). One of these small carriers was Island Air, a subsidiary of Aloha Airlines, which offers daily scheduled flights to Molokai and Kalaupapa, and the resort destinations of Lanai City, Hana, and Kapalua with DeHavilland Dash-6 and Dash-8 turboprop aircraft.

As shown on Table 6.9, inter-island passengers in 1996 were up 7% over 1990 levels at 10,581,825 (State of Hawaii 1994 and Chun 1997). Additional detail is provided on the two major carriers in the inter-island market, Aloha and Hawaiian. Data was not available on Mid-Pacific Airlines, Discovery Airlines, and Mahalo Airlines which operated during this period, but are no longer in service.

Table 6.9 Hawaii Interisland Airline Activity, 1990-1996

	1990	1991	1992	1993	1994	1995	1996
Passengers	9,907,154	9,368,576	9,568,464	9,345,320	9,920,709	10,388,281	10,581,825
Aloha Airlines and Hawaiian Airlines							
ASM (000)	1,978,493	1,849,059	2,029,999	1,817,291	1,915,300	2,032,080	2,002,095
RPM (000)	1,134,404	1,063,201	1,102,609	1,077,184	1,158,940	1,186,409	1,204,002
Load Factor	57.3%	57.5%	54.3%	59.3%	60.5%	58.4%	60.1%
Estimated Fuel Used (Bbl)	1,800,249	1,636,393	1,781,460	1,489,651	1,578,553	1,696,847	1,747,129
ASM/Gallon	**26.2**	**26.9**	**27.1**	**29.0**	**28.9**	**28.5**	**27.3**

Sources: Ackerman 1997; Chun 1997; Fujitani 1997; HAL 1994, 1995; State of Hawaii 1994)

The two major airlines provided 1% more available seat miles (ASM in thousands) in 1996 than in 1990. Their overall operation was more efficient, however, in that 6% more revenue passenger miles were flown (RPM in thousands). The load factor on the two principal inter-island carriers was estimated by comparing total available seat miles for their inter-island flights with revenue passenger miles on those flights. Thus, the aggregate load factor for the two airlines in inter-island operations increased from 57.3% in 1990 to 60.1% in 1996, a 5% increase.

Based upon extrapolations of fuel use data provided by the two airlines, it is estimated that about 3% less fuel was used to provide the increased service, increasing the average available seat miles per gallon (ASM/gallon) to 27.3, a 4% increase in fuel efficiency.

While Mainland airlines with newer equipment and longer routes may achieve over twice the ASM per gallon, the shorter flights of the inter-island carriers are inherently less efficient. These short flights require high fuel use for takeoff and climb to cruising altitude that is not amortized by long cruise and descent segments which characterize many longer Mainland routes operating similar equipment. As Table 6.10 shows, the lengths of inter-island flights range from 54 to 214 statute miles (State of Hawaii 1997c). As noted above, the 98-mile Honolulu-Kahului city-pair had the second highest volume of all city-pairs in the United States (Lampl 1997).

Table 6.10 Great Circle Distances from Honolulu International Airport	
Airport	Statute Miles
Hilo Airport, Hawaii	214
Kona Int'l Airport, Hawaii	168
Kahului Airport, Maui	98
Lanai Airport, Lanai	72
Molokai Airport, Molokai	54
Lihue Airport, Kauai	103

State of Hawaii 1997c

6.4.1.2 Overseas Airlines

As of 1995, there were 26 carriers conducting overseas operations, including Hawaiian Airlines. Twelve were domestic carriers and fourteen were foreign carriers (State of Hawaii 1997c).

Overseas air carriers operating between Hawaii and the Mainland United States and a variety of international destinations appeared to have made dramatic improvements in efficiency in the first half of this decade as shown on Table 6.11. The number of available seats between overseas destinations and Hawaii declined 21% from 1990 to 1996, but passenger arrivals grew 5% in the period, resulting in a 33% increase in load factor. At the same time, the relative percentage of eastbound flights grew from 37% in 1990 to 43%. It should be noted that two different sources of data were used to estimate available seats and there may be inconsistencies in data collection methodology.

Table 6.11 Estimated Scheduled Airline Overseas Seat Capacity, Arrivals, and Load Factors, 1990-1996

Year	Westbound Seats	Westbound Arrivals	Westbound Load Factor	Eastbound Seats	Eastbound Arrivals	Eastbound Load Factor	Average Load Factor
1990	7,367,305	5,692,950	77%	4,412,297	2,814,380	64%	72%
1991	7,157,210	5,444,070	76%	4,694,690	2,882,690	61%	70%
1992	6,362,440	5,295,770	83%	5,062,160	3,109,970	61%	74%
1993	5,882,450	5,039,640	86%	4,870,130	2,839,310	58%	73%
1994	5,551,880	5,197,640	94%	4,694,950	2,711,610	58%	77%
1995	5,214,698	5,056,770	97%	3,841,255	2,900,450	76%	88%
1996	5,408,371	5,078,740	94%	3,888,992	2,971,240	76%	87%

Seats 1990-1994, State of Hawaii 1996, Table 18.38, 459, from HVB estimates

Seats 1995-1996, Hawaii Visitors and Convention Bureau, Reed Travel Group, 1.

Arrivals 1990-1996, State of Hawaii 1997c, Table 7.01, 197

6.4.2 Air Transportation Greenhouse Gas Emissions, 1990-1996

As noted above, in the *Inventory of Hawaii Greenhouse Gas Emissions, Inventory for 1990*, estimated emissions from inter-island, overseas, and military jet fuel were reported. Based upon the availability of new data, estimates of jet fuel use were recalculated in this plan on the basis of domestic, bonded, and military use. Domestic jet fuel use includes civilian scheduled airline jet fuel used in domestic operations, including inter-island flights, and flights between Hawaii and the Mainland United States. Piston-engine aircraft operating in Hawaii used domestic aviation gasoline (avgas). Bonded jet fuel includes fuel used by foreign and domestic carriers in international operations. Military jet fuel and avgas includes all aviation fuel sold by Hawaii refiners or distributors to the U.S. military. For the purposes of this report, only domestic jet fuel and aviation gasoline were used in calculating total Hawaii greenhouse gas emissions. Table 6.12 reports estimated jet fuel use or sales in each of these categories for the years 1990-1996.

Table 6.12 Estimated Aviation Fuel Use and Sales from Hawaii Sources (Bbl), 1990-1996

Fuel	1990	1991	1992	1993	1994	1995	1996
Domestic Jet	8,592,397	7,948,266	7,950,386	7,359,913	8,220,593	8,203,185	8,635,095
Bonded Jet	9,744,361	9,855,053	9,966,179	9,411,294	8,691,605	9,025,344	8,846,322
Military Jet	255,579	33,912	1,223,252	1,219,115	1,434,394	1,233,902	252,056
Military JP-4	1,329,953	1,760,963	118,299	none	none	none	none
Jet Fuel Total	19,922,290	19,598,194	19,258,116	17,990,322	18,346,592	18,462,431	17,733,473
Domestic Avgas	43,278	44,000	40,154	35,730	37,176	37,291	31,692
Military Avgas	1,546	1,533	1,136	1,247	913	none	none
Avgas Total	44,824	45,533	41,290	36,977	38,089	37,291	31,692

During the period 1990-1996, domestic jet fuel use increased 0.5% while bonded jet fuel use declined 9.2%. Overall, civilian jet fuel use declined by 4.6%. It should be noted that military jet fuel sales varied greatly from year to year as some of the military's needs were met from sources outside Hawaii. Data on such imports is not available. In addition, the fuel sold to the military by Hawaii refiners was not necessarily used for military air operations originating in Hawaii.

Figure 6.13, on the following page, depicts the greenhouse gas emissions from aviation gasoline and jet fuel sold or distributed in Hawaii. For the purposes of this plan, the focus will be on emissions from domestic operations. As pointed out in Michaelis (1997a), allocation of aviation emissions under the Framework Convention on Climate Change is ambiguous. Under IPCC guidelines for producing national inventories of greenhouse gas emissions, international aviation and marine bunker fuel were to be recorded as separate categories and were not included under the national total (20). This Plan follows that practice.

Table 6.13 Estimated Greenhouse Gas Emissions from Aviation Fuels from Hawaii Sources (Tons), 1990-1996							
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**
Domestic Jet Fuel							
CO_2	3,846,478	3,558,126	3,559,075	3,294,744	3,680,036	3,672,243	3,865,592
CH_4	107	99	99	92	103	102	108
Domestic Aviation Gasoline							
CO_2	16,495	16,770	15,304	13,618	14,169	14,213	12,079
CH_4	15	15	13	12	12	13	11
N_2O	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Domestic Subtotal							
CO_2	3,862,973	3,574,897	3,574,379	3,308,362	3,694,206	3,686,457	3,877,671
CH_4	122	114	113	104	115	115	118
N_2O	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Bonded (International) Jet Fuel							
CO_2	4,362,167	4,411,719	4,461,467	4,213,066	3,890,890	4,040,292	3,960,151
CH_4	122	123	124	117	108	113	110
Military Jet Fuel							
CO_2	676,704	759,700	597,618	545,750	642,122	552,369	112,836
CH_4	19	21	17	15	18	15	3
Military Aviation Gasoline							
CO_2	589	584	433	475	348	-	-
CH_4	1	1	0.4	0.4	0.3	-	-
N_2O	0.01	0.01	0.01	0.01	0.005	-	-
Total							
CO_2	8,902,434	8,746,900	8,633,897	8,067,653	8,227,565	8,279,118	7,950,658
CH_4	263	259	254	237	242	243	232
N_2O	0.2	0.2	0.2	0.2	0.2	0.2	0.2

6.4.3 Current Activities That Reduce Air Transportation Greenhouse Gas Emissions

Airlines have considerable incentive to reduce fuel use. Fuel amounts to approximately 15% of total operating expenses, the second largest operating expense. As a result, airlines and aircraft manufacturers have made increased fuel efficiency a top industry priority for many years (ATA 1997).

6.4.3.1 Improved Load Factors

As discussed above, airlines in Hawaii operations improved load factors in the 1990s. During the period, the number of flights to and from Hawaii decreased as airlines streamlined operations. By filling higher percentages of available seats with passengers, overall efficiency improved. The load factor for inter-island flights improved about 3% from 1991 to 1996, reaching 60%. A more dramatic improvement was seen in the increase in load factor on overseas flights from 72% in 1990 to 87% in 1996. Higher load factors reduced fuel use and emissions from levels that would have been produced if the flights had carried similar numbers of passengers at the lower load factors seen earlier in the decade.

6.4.3.2 Operational Changes

Aloha Airlines provided information that its flight operations department began a fuel efficiency program in 1993. The flight plans between all islands were changed to incorporate a parabolic profile. Aloha's aircraft climb to higher altitudes and begin descent earlier at lower airspeed to conserve fuel. An aircraft washing program also minimizes dirt on the aircraft removing a source of drag (Ackerman 1997). Apparently, this program, coupled with increased load factors, has improved Aloha's fuel efficiency. Aloha improved its 1996 load factor by just over 2% in comparison to 1990, increasing revenue passenger miles by 11% while fuel use increased only 2.8% over 1990 levels. This yielded an average fuel efficiency of 17.6 revenue passenger miles per gallon, an 8.5% improvement (Based on Lampl 1997 and Ackerman 1997). This fuel efficiency for 1996 can be also expressed as 27.8 available seat miles per gallon. The current U.S. commercial fleet has an average efficiency of about 48 seat-miles per gallon (SMPG). Hawaiian Airlines did not provide information as to any operational changes that it may have made.

As noted above, the short lengths of inter-island flights and the less efficient engines used on their older aircraft reduce both Aloha's and Hawaiian Air's operating efficiency. Available information on Hawaiian Airlines aggregated inter-island and overseas fuel use, making a comparison between difficult. The estimated fuel use data presented in Table 6.12, above, was based upon ASM at a fuel efficiency rate assumed to be similar to Aloha's. The two airlines operate different types of aircraft, but both types used in inter-island service are equipped with similar engines and are of similar vintage.

6.4.4 Potential Measures to Reduce Emissions from Air Transportation

6.4.4.1 Near-term Measures for Hawaii's Airlines

To the extent that some of the following measures may not be used by Hawaii's airlines, they are recommended for consideration as means to reduce greenhouse gas emissions.

6.4.4.1.1 RECOMMENDATION: Adopt Operating Measures for Fuel Efficiency

Generally, measures that reduce fuel use will reduce greenhouse gas emissions. Measures generally in use by U.S. airlines which could be considered by Hawaii's airlines, to the extent that they have not already been implemented, include:

Reducing cruising speeds;

Determine optimum fuel loads and select altitudes and routes that minimize fuel burn;

Using flight simulators rather than real aircraft for pilot training;

Holding aircraft at gates, with engines shut down, when weather or other problems delay takeoff;

Using only one engine to taxi;

Keeping aircraft exteriors clean to minimize aerodynamic drag (ATA 1997).

Reduce auxiliary power unit use; use ground (utility) electrical power instead; and

Convert airport vehicle fleets and ground service equipment to alternative fuels (NRDC 1996).

6.4.4.1.2 RECOMMENDATION: Examine Ways to Increase Load Factors on Inter-island Flights

The nature of competition in the inter-island market reduces the opportunity for increased efficiency through higher load factors. One of the competitive factors is flight availability and schedule frequency.

Load factors in overseas operations are at such high levels that increases may not be practical. Since availability of flights to Hawaii for visitors is critical to Hawaii's economy, there is some concern that lack of available flights may have reduced visitor counts over the past few years. Higher load factors could have serious negative economic effects.

6.4.4.1.3 RECOMMENDATION: Re-equip Inter-island Airlines with Newer, More Efficient Aircraft

Using newer aircraft on inter-island routes could make a major improvement in fuel efficiency. The average age of Aloha's Boeing 737-200 fleet is 16 years (extrapolated from Lampl 1997, 34), the average age of Hawaiian's DC-9-50 fleet is 20 years, and the DC10-10s on Hawaiian's overseas routes are 25 years old (extrapolated from HAL 1997, 4).

Both Aloha and Hawaiian currently enjoy an exemption from federal legislation passed in 1990 that required phasing out the use of Stage 2 aircraft on the Mainland by December 31, 1999, with certain waivers until December 31, 2003, when a full phase out is required. "Congress provided an exemption for air carriers operating in Hawaii . . . to operate as many Stage 2 aircraft of a certain weight as they operated on November 5, 1990" (Hawaiian Airlines 1997). The Stage 2 standard most directly relates to aircraft engine noise, but Stage 2 aircraft are older than Stage 3 aircraft and use engines which are not only noisier, but less fuel-efficient.

According to the Air Transport Association of America, “The McDonnell-Douglas MD-80, Airbus A-320, and Boeing 737-300, for example, transport twice as many passengers per gallon of fuel than the DC-9 and earlier versions of the 737. In addition, they emit smaller amounts of the gases of concern to scientists studying global warming and other environmental trends” (ATA 1997). In response to a query, Aloha Airlines suggested that the fuel savings which would result from conversion to newer Stage 3 aircraft may be on the order of “about 8 to 10 percent” (Ackerman 1997), perhaps reflecting the short lengths of inter-island flights.

As Hawaiian Airlines pointed out in their 1996 *Annual Report*, there are important financial and competitive considerations involved in replacing the current inter-island fleet. “Because Stage 2 aircraft are less expensive to acquire than Stage 3 aircraft, this exemption provides limited protection against the entry of another carrier [into the inter-island market], which would be required to operate an all Stage 3 fleet” (7). At the same time “this advantage is partially offset by the fact that Stage 3 aircraft are generally less expensive to operate and maintain, as well as the fact that in any event over time, carriers will move toward having an all Stage 3 fleet” (7). Stage 3 aircraft are also about 50% quieter (ATA 1997).

Both airlines will face equipment replacement decisions early in the next decade. Aloha indicated that it is studying a number of potential aircraft to replace its current fleet of Boeing 737-200s. However, it expects to operate them until approximately 2004 (Ackerman 1997). Hawaiian reported that it owns two of its DC-9s, leases seven under operating leases, and four under capital leases that expire at various times through the year 2004 (Hawaiian Airlines 1997). While the airlines could enjoy improved fuel efficiency and reduced maintenance costs, they must meet the capital requirements necessary to replace their current fleets.

It is recommended that Hawaii’s inter-island carriers, and any other carriers that may enter the inter-island market, give maximum consideration to reducing fuel costs and maximizing reduction of greenhouse gas emissions through selection of the most fuel-efficient aircraft available. Such new equipment should offer more economical operation while reducing the effects of inter-island air travel on the global climate.

6.4.4.2 Near-term Measures for Domestic Overseas Airline Operations

6.4.4.2.1 RECOMMENDATION: Encourage Use of Efficient Aircraft on Routes between Hawaii and the Mainland

While Hawaiian Airlines also operates to Mainland and overseas destinations, other carriers provide the bulk of the travel between Hawaii and the Mainland.

These carriers operate a variety of aircraft of varying vintage. The details of the overseas domestic fleet were not collected for this report. Generally, however, the operating measures discussed above can improve fuel efficiency. Operation of newer equipment can also reduce fuel requirements. Carriers should be encouraged to use the most efficient aircraft available on Hawaii routes.

The Natural Resources Defense Council suggests differential landing fees based upon emissions of aircraft to encourage airlines to use their least-polluting aircraft as one possible action (NRDC 1996).

6.4.4.3 Longer Term Measures Reducing Emissions from Air Transportation

Future gains in commercial aviation energy efficiency could be obtained through technological improvements to engines and airframes, and, in the more distant future, new technologies for aircraft propulsion. Much of the following discussion is based upon Chapter 10, Commercial Air Transport Energy Use and Emissions: Is Technology Enough?" in *Transportation, Energy, and Environment: How Far Can Technology Take Us?* (DeCicco 1997), by David Green of the U.S. Department of Energy's Oak Ridge National Laboratory. These measures are beyond the control of Hawaii, but will set the standard as to what may be achievable in future reductions of greenhouse gas emissions from air transportation.

6.4.4.3.1 RECOMMENDATION: Support Potential Technological Improvements in Aircraft

Since the first commercial jet aircraft were introduced in the 1950s, fuel use in the cruising mode for short- to medium-range flights decreased by 65%, and by 55% for long-range aircraft. Seat miles per gallon increased from 26.2 to 48.6 nationally. The main factors behind these improvements are technological improvements in aircraft, a 30% increase in load factors, and an average 40% increase in aircraft size (DeCicco 1997, 210).

In 1992, the National Academy of Sciences set a goal of reducing fuel burn per seat mile by 40% over the next two decades compared to current aircraft. The Academy forecast a 25% reduction from improved engine performance and 15% from aerodynamic and weight improvements (211).

Propulsion Technology Improvements. Since the 1960s, commercial aircraft engines progressed from turbojet to turbofan to high-bypass turbofans. Turbojets produced all of their thrust by means of the expanding hot air passing out of the core combustor. Current high-bypass turbofans augment the combustor by accelerating five to six times the volume of air around the core engine using fans driven by the core engine. The bypass ratio of an engine is the ratio of the volume of air passing around the engine compared to the amount passing through the core combustor. Current bypass-ratios are 5-6. The goal for 2005 is 8-10 reducing fuel consumption by 15-10%, and 15-20 by 2015, reducing fuel burned by 30%. Such engines will require new materials and designs to offset weight and drag penalties posed by increasing the diameter of jet engines to increase the bypass ratio.

Another 10% improvement may be achievable using unducted propfan propulsion systems. These are similar to turboprop aircraft, but advances in propeller design could allow higher speeds. Higher costs, noise, vibration, and maintenance concerns have thus far prevented commercialization (211-212).

Advanced Aerodynamics. "Aerodynamic efficiency can be represented by the ratio of lift (the force pushing an aircraft directly upward) to drag (the force opposing its forward motion). Reductions in aerodynamic drag on the order of 35% are possible by various improvements to the L/D ratio of current aircraft" (212). Most of this improvement could be achieved by using a higher aspect ratio wing (with a narrow chord, or width, of the wing relative to its span, or length). Additional efficiencies could come from improved airfoils, laminar flow control, turbulence control, and reductions in induced drag (213).

Weight Reduction. As a rule of thumb, a 1% reduction in the gross weight of an empty aircraft will reduce fuel consumption by 0.25 to 0.5%. Weight reduction has a synergistic effect as lighter aircraft require less wing area, thus less structure, and do not require as large engines as a heavier aircraft. As a result, a initial 1-lb. decrease in structural weight might result in an ultimate 2- to 10-lb. decrease in aircraft empty weight. Commercial aircraft are currently about 97% metallic with lightweight composite materials used for only a few components. In the next century, it is forecast that they will be up to 80% composite with an overall 30% reduction in aircraft empty weight for equivalent range and payload. As a result, fuel consumption could decrease by 7.5 to 10% (214-215).

Technological Potential for Reducing Emissions In addition to emissions reduction through fuel savings, there is a possibility of the reduction of the photochemically active precursor greenhouse gases, including NO_x, CO, and NMVOCs. CO_2 and CO emissions are directly proportional to fuel use, so their reduction will come through efficiency improvements. On the other hand, NO_x emissions depend on altitude, thrust level, engine design, and combustor type. Fuel-efficient engine designs tend to increase formation of NO_x. NASA's Experimental Clean Combustor program has demonstrated that about a 25% reduction of NO_x could be achieved thorough design changes in future engines. As discussed above, however, the main source of reduction will be through improvements in fuel efficiency per passenger mile (217).

6.4.4.3.2 RECOMMENDATION: Maintain High Load Factors

Greene cites forecasts of improved load factors and increased use of larger aircraft to deal with problems of airport congestion nationally. He notes that conventional wisdom used to hold that load factors could not practically be increased beyond

67% nationally. Major aircraft manufacturers project 0.24-0.30% increases in load factors per year over the next two decades (216). As reported above, in 1996, inter-island airlines were operating at about 60% and overseas airlines to Hawaii were at a very high 87% load factor. There may be some improvement in inter-island load factors through schedule refinement, but the competitive value of frequent flights tends to mitigate against great increases unless fuel prices rise significantly to inflict a major cost penalty for low load factors. It is difficult to imagine much greater improvement on overseas flights. As noted above, lack of available seats could be part of the reason behind slow growth in tourist traffic to Hawaii since 1991.

6.4.4.3.3 RECOMMENDATION: Be Alert to Possible Alternative Aviation Fuels Substitution Opportunities

As Greene points out, “High energy density, in terms of both weight and volume, together with ease of handling and storage, is critical to the practicality of a fuel for commercial jet aircraft. Kerosene jet fuel has among the highest volumetric densities of petroleum-based liquid fuels” (218). Propane and butane are next at 75% the energy content per gallon of jet fuel. Alcohol fuels have only 45-60% the energy density on the basis of weight or volume. He cites the example of a conventional jet airliner carrying 775,000 lbs. of kerosene jet fuel as needing 1,760,000 lbs. of methanol, compromising both design and payload (218).

Gaseous fuels, such as hydrogen and methane would have to be stored cryogenically in liquid form to achieve any reasonable energy density. Methane (natural gas) is 60% the energy density of jet fuel on a volume basis and hydrogen is only 25%. On a weight basis, however, methane has 10% more energy density, and hydrogen has 250% of the energy density of jet fuel. The problems of cryogenic storage and handling, and the greater volume necessary, create major technical problems. The National Academy of Sciences believes these fuels would not be available for aircraft before 2020 (219).

Cryogenic Hydrogen Aircraft Fuel and Hawaii. Of alternative fuels under consideration, European work on hydrogen and liquefied natural gas as jet aircraft fuels may offer the two most promising alternatives for possible use beginning sometime between 2020 and 2040. Hawaii offers some potential as a location for establishment of a hydrogen fueled inter-island airline operation.

Sixteen European aerospace companies, including aircraft manufacturers Airbus Industrie and Daimler-Benz, along with the Russian aircraft company, Tupelov, and engine manufacturer, Trud (formerly Kuznetsov), are currently working together on a “Cryoplane” project. Tupelov began work in this area in 1986 and the bi-national program began in 1990. The program expects to fly a modified Dornier 328JET technology demonstrator by the year 2000 (Braybrook 1997, 281).

The consortium believes that a combination of declining reserves of oil and concerns about greenhouse gas emissions will require an alternative fueled airliner by 2020 to 2040. In considering the various possibilities, it was decided that alcohol does not provide a viable amount of energy per mass. Natural gas and hydrogen meet requirements in that respect but gaseous storage would require unacceptably large or heavy tanks. Liquefied forms of hydrogen at very low temperature appear to be the solution (282).

Liquefied natural gas (LNG) is stored at –160 degrees C and provides 20% more energy per weight than jet fuel. This fuel is especially attractive to Russia, where there are ample reserves. The Russians have conducted flight trials with a testbed engine mounted on an experimental aircraft modified to run on LNG, hydrogen, or methane since 1988. Russia is converting three Tu154M aircraft into LNG freighters that were expected to fly in 1997 or 1998 (282). No further information has been found as to the outcome of these tests.

Liquid hydrogen provides 2.8 times the heat value of jet fuel per weight, but increases fuel volume by a factor of four. Designs for a modified Airbus A310 place the cryogenic fuel above the full length of the cabin in a bulbous housing. Burning hydrogen in a jet airliner will produce only water vapor and a small amount of nitrogen oxide. In part due to engine design, it appears that a hydrogen airliner would produce about 5% of the amount of N_2O produced by a current turbofan jet-fueled engine (284).

The use of hydrogen fuel may cause concerns about safety among some, however, leaking liquefied hydrogen burns off rapidly and the flame raises quickly due to the low density of the gas. A hydrogen fire burns with little heat radiation, and it is believed that an aluminum airframe would be able to withstand a hydrogen fire and would protect the passengers (284).

A major challenge in using liquefied hydrogen as a jet fuel would be infrastructure. The proposal is to first convert intra-European wide-bodied airliner operations to hydrogen, ultimately involving about 500 aircraft and 70 airports. This would require an increase in hydrogen production by a factor of 200-300. The fuel would be produced by electrolysis, ideally using renewable energy sources. One proposal is to use about 100 MW of hydroelectric power produced by Hydro Quebec in Canada and to transport the fuel to Europe in container vessels similar to those used to transport liquefied natural gas (284).

Liquefied hydrogen currently costs several times more than jet fuel, but estimates are that there will be a crossover in costs in the 2010 to 2020 period. Jet fuel prices would rise due to reductions in production rates and possible imposition of carbon taxes. It is not clear when such a system would be cost-effective for Hawaii.

Hawaii's inter-island air system might offer an excellent potential for a liquefied hydrogen-fueled system. Its hub and spoke operation and relatively short flight distances would contribute to making application of liquefied hydrogen fuel possible. The fuel itself could be produced by a variety of renewable energy sources, especially wind, solar, and geothermal energy on the Big Island. Since the inter-island air hub would likely remain at Honolulu International Airport, it would be necessary to transport the fuel to Oahu. The necessary transfer and storage infrastructure would need to be constructed. Once the necessary aircraft and engine technology is fully developed, the main obstacle to implementing such a system would appear to be the cost of constructing the infrastructure, the costs of a new or modified inter-island aircraft fleet, and potential problems in transitioning from a jet fuel system to a liquefied hydrogen system.

Other Alternative Fuel Prospects. Another possibility for alternative fuel use would be for hypersonic aircraft flying at more than four times the speed of sound (Mach 4). Greene reports that higher speeds require fuels with greater thermal stability, faster combustion rates, and greater ability to absorb heat than traditional jet fuel. Specially processed hydrocarbon fuels may be usable up to Mach 4, but above that speed to Mach 5, cryogenic methane may be useable. Above Mach 8, only cryogenic hydrogen is an option (DeCicco 1997, 219). Such aircraft will not likely be seen until well beyond the period covered by this plan.

6.4.4.3.4 Prospects for Greenhouse Gas Emissions Reduction in Air Transportation through Technology

Greene summarized the expected continuing growth in air travel through 2015 on a worldwide basis. Under his high efficiency scenario, he projected passenger mile increases of 4.2% per year from 1992-1999, and 3.6% annually from 1999-2015 in the U.S., and 5.4% and 4.5% respectively in the rest of the world. Efficiency was estimated to increase by 2.5% annually, while load factors increased by 0.24% annually in the U.S., and 0.30% in the rest of the world.

Under these assumptions, U.S. air travel was projected to more than double and world air travel to triple. Even the most rapid rate of efficiency improvements would be unable to return greenhouse gas emissions to 1990 levels let alone reduce the emissions below that level (224). Without going into further detail on the national and international level, it is clear that Hawaii air transportation faces similar limitations in reducing greenhouse gas emissions.

Greene concluded his chapter by stating, "Even under the most optimistic assumptions about energy efficiency improvement, air passenger transport will not meet the 2015 sustainability goals with technological advances alone. . . . Nonetheless, this exercise serves to underline the critical importance of technological advances in determining the level of environmental impacts . . . . Oil use and CO_2 emissions are more than 50% higher in the low-efficiency scenario than when maximum technological progress is achieved" (226-227).

Market forces, especially fuel prices, will be important in determining the efficiency of the future air transport fleet. Currently, fuel prices are at very low levels. Higher fuel prices create an incentive to retire obsolete, less-efficient aircraft in favor of newer, more-efficient aircraft. Higher fuel prices would also increase the price of tickets, reducing the demand for air travel (227). This latter consequence is clearly undesirable for Hawaii's tourism-based economy and for its airline-based inter-island transportation system.

6.4.4.3.5 RECOMMENDATION: Oppose Carbon Taxes on Air Transportation Fuels Due to Negative Economic Effects

Carbon taxes are often discussed as potential measures for reducing fossil fuel use and greenhouse gas emissions by increasing the cost of fossil fuel use. Carbon taxes may make sense in those energy sectors where there are currently non-fossil fueled options or where there are further efficiency measures that would become cost-effective at the resulting higher energy price. However, in the air transportation sector, the use of carbon taxes would likely have major negative consequences on Hawaii's economy.

The Annex I Expert Group on the United Nations Framework Convention on Climate Change conducted an analysis of the effects of carbon taxes on international aviation fuel published in March 1997 (Michaelis 1997a). The study was part of a broad assessment of the relative potential of a range of cost-effective policies and measures for consideration by international policy-makers. The study compared aviation with a variety of transportation alternatives and noted that it had high CO_2 intensities in comparison to various alternatives such as automobiles, buses, and trains (5). In the context of Hawaii, it must be stressed again that alternatives to both short-haul inter-island and long haul air travel do not exist and more than partial replacement by the only alternative, inter-island marine passenger transportation, is unlikely.

Michaelis modeled carbon taxes at $5, $25, and $125 per tonne of carbon (One tonne is a metric ton equal to 2,200 lbs.). These charges equated to roughly 2%, 10%, and 50% of current jet fuel prices. The increased fuel costs were expected to be passed through to airline customers resulting in lower demand for air transport and, thus, lower emissions. It was also expected that airlines would attempt to mitigate the effects as much as possible by reducing non-fuel costs, reducing fuel consumption through more efficient operation, and by re-equipping with more efficient aircraft or replacing less efficient engines with more efficient engines (7).

The estimates produced by the model were acknowledged as highly uncertain because estimates of price elasticity for air travel vary by more than a factor of three. Table 6.14 shows the estimate of the effects or globally applied fuel charges on international air passenger traffic.

Table 6.14 Estimated Effect of Carbon Tax on Air Passenger Traffic

Charge on Carbon Emissions ($/tonne C)	5	25	125
Percent Increase in Ticket Prices	0.28	1.4	7
Percent Change in Traffic	-0.2 to -0.6	-0.9 to -2.9	-4.4 to -13.3

(Michaelis 1997, 8, 26)

In the past, as noted above, energy intensity reduction in air transportation was highly responsive to fuel price. Michaelis suggests that an international commitment to raise fuel prices at a moderate rate each year (e.g., 2% per year starting in 2000 would reach $125 tonne by 2020) could lead to energy intensity reductions of 3.5% per year, reducing emissions by 30% relative to baseline estimates. This would still be an absolute increase in emissions for air travel.

In Hawaii, increasing the cost of air travel would not have the desired effect of switching passengers to more efficient modes of travel since there are no alternatives. The alternative would be to not travel. Consequently, it is strongly recommended that Hawaii not be subject to any carbon taxes on aviation fuels due to its dependence on air transportation for inter-island, interstate, and international passenger travel. If a national carbon tax is enacted, air travel to, from, and within Hawaii should be exempted. Alternative means of increasing the efficiency of air travel within Hawaii and overseas should instead be fostered as outlined above.

6.4.4.3.6 RECOMMENDATION: Consider Other Long-Term Measures

Some additional measures that could help reduce greenhouse gas emissions should also be considered at the national level:

Long-term energy intensity targets for stabilizing greenhouse gases, including NO_x linked to an airline emissions permit trading system;

Energy efficiency or emissions standards for aircraft (similar in concept to current noise standards);

Eco-labeling of air tickets;

Funding and incentives for R&D on energy efficiency and NO_x reduction; and

Improved air traffic control (Michaelis 1997a, 31).

6.5 Marine Transportation

6.5.1 Marine Transportation and Hawaii

If inter-island air transportation of passengers can be described as analogous to the Mainland interstate highway system, inter-island marine shipping is the analog of intrastate trucking and railroads. Inter-island marine transport, primarily using towed barges, ships most of Hawaii's cargo inter-island.

Interstate transportation of cargo from the Mainland is primarily provided by containerships. International cargo is also primarily seaborne. The only alternative air cargo with its inherent cost, weight, and bulk limitations. Air cargo is currently primarily used for high value, time-sensitive, or perishable items.

6.5.2 Marine Transportation Greenhouse Gas Emissions, 1990-1996

Available data indicates that most fuel used or sold in the marine transportation category was bonded fuel for use in international shipping or international fishing operations or loaded as cargo and exported from Hawaii. Table 6.15 depicts available data on marine fuel use. It appears from the absence of data for in-state residual fuel oil use in 1992 and 1993 that reporting entities may have reported this fuel in other categories. In addition, the great increase in in-state residual fuel use in 1995 and 1996 compared to earlier years was not explained by other information available at this time.

Table 6.15 Marine Fuels Used or Sold in Hawaii (Barrels), 1990-1996

Fuel/Use	1990	1991	1992	1993	1994	1995	1996
Distillate							
In-State	322,175	424,904	421,700	367,174	266,691	207,498	258,859
Overseas	1,735,339	1,568,259	1,672,255	1,655,316	1,444,687	1,506,093	1,063,268
Subtotal	2,057,514	1,993,163	2,093,955	2,022,490	1,711,378	1,713,591	1,322,127
Motor Gasoline							
In-State	3,879	1,238	1,143	833	1,429	1,190	1,380
Subtotal	3,879	1,238	1,143	833	1,429	1,190	1,380
Residual Fuel Oil							
In-State	6,789	17,216	-	-	5,114	191,841	143,337
Overseas	2,056,854	3,598,180	2,573,210	2,019,376	2,303,229	1,992,753	1,838,106
Subtotal	2,063,643	3,615,396	2,573,210	2,019,376	2,308,343	2,184,594	1,981,443

Source: State of Hawaii 1998a

Based upon reported marine fuel use and sales, Table 6.16 on the following page, summarizes estimated greenhouse gas emissions from marine fuels during the years 1990-1996.

CO_2	1,839,958	2,536,103	2,069,864	1,783,915	1,828,451	1,701,132	1,417,492
N_2O	23	32	26	22	23	21	18

6.5.3 Potential Measures to Reduce Greenhouse Gas Emissions from Marine Transportation

6.5.3.1 RECOMMENDATION: Consider Changes in Operating Procedures for Energy Efficiency

Improvements in operating procedures could save energy.

- Require crew training in efficient operations;
- Financial incentives for fuel-efficient operations (Argonne National Laboratory, 1991 cited in State of Hawaii, 1995b);

- Regular propeller maintenance can reduce fuel use by 5% or more;
- Use of anti-fouling paint to ensure hull smoothness and reducing drag can reduce fuel use by 3-4%;
- Routing ships to avoid heavy weather can save 4% in fuel use;
- A 10% reduction in average speed can save 5% in fuel use on older vessels; and
- An adaptive autopilot can reduce fuel use by 2.5% (Michaelis 1997b, 22).

6.5.3.2 RECOMMENDATION: Adopt Technical Improvements to Ships

A number of technical improvements could be made to future ships engaged in overseas trade or inter-island operations.

- Replacement of two-stroke diesel engines with modern four-stroke diesels would reduce fuel consumption by 5 to 10 percent or more;
- Replacing existing engines with less powerful ones could also achieve energy savings since diesels operate most efficiently at full power, and marine engines typically operate well below full power;
- New engine technologies, such as turbo-compounding and rankine bottoming cycles, have demonstrated fuel savings of 5 to 7 percent and 12 percent, respectively (Argonne National Laboratory, 1991 cited in State of Hawaii, 1995b);
- Improved hull form on new ships could save up to 3% in fuel use;
- Improved propeller designs could save small amounts of fuel;
- Wind assistance through installation of auxiliary sails could reduce fuel use by 10-20%;
- Doubling ship size for similar routes could save up to 30% of the fuel otherwise used by two ships of the current size;
- Fuel switching to biofuels could save up to 80% in greenhouse gas emissions compared to a similar fossil fueled ship (Michaelis 1997b, 22).

6.5.3.3 RECOMMENDATION: Oppose Carbon Taxes on Marine Transportation Fuels Due to Negative Economic Effects

As noted above in the section on air transportation, carbon taxes are often discussed as potential measures for reducing fossil fuel use and greenhouse gas emissions by increasing the cost of fossil fuel use. The Annex I Expert Group on the United Nations Framework Convention on Climate Change conducted an analysis of the effects of carbon taxes on international aviation fuel published in March 1997 (Michaelis 1997b). The study was part of a broad assessment of the relative potential of a range of cost-effective policies and measures for consideration by international policy-makers. The main rationale for carbon charges would be to internalize the costs of greenhouse gas emissions from marine transport. As the Expert Group study notes, "a carbon charge on bunker fuel would only be feasible, fair and economically efficient in a context where such a charge is globally imposed, and where other transport modes pay their full social costs" (6). In fact, if the fuel prices of other modes were not raised proportionately, a maritime fuel carbon tax could lead to increased cargo shipment by less fuel-efficient modes with consequent increases in greenhouse gas emissions (7).

A carbon tax on marine fuels might reduce demand and associated greenhouse gas and other emissions by stimulating energy efficiency improvements in ship engines and ship design; changes in operating practices; switching to a different vessel type; switching to alternative fuels; and reductions in maritime traffic (17-18).

In the case of Hawaii, it is unlikely increased airfreight shipments could replace significant amounts of marine shipping due to the very large differences in price. Rail or truck shipments are not an alternative as they would be for Mainland states. The major likely effect would be increased costs for goods brought in by ship from overseas and those shipped inter-island. Increases in efficiency could lag by many years due to the long life of ships in service. Consequently, use of a carbon tax on marine transportation fuel is <u>not</u> recommended. Should such a tax be enacted nationally, Hawaii should be exempted due to the lack of alternatives.

6.5.3.4 RECOMMENDATION: Consider Alternative Measures

These include alternative charges or fees such as port fees related to ship energy efficiency, regulations on ship technology, voluntary agreements with ship-builders and operators, best practice programs, technology prizes, and support for RD&D (Michaelis 1997b, 6).

6.5.3.5 RECOMMENDATION: Improve Data Collection for Use in Estimating Future Marine Fuel Use

Future marine fuel sales are difficult to predict. According to planners at the Harbors Division, during the next 20 years, each of the current inter-island carriers expects to add a weekly voyage. These cargo vessels can be expected to buy fuel wherever it is cheapest, most likely on the Mainland. While cruise ship stopovers in Hawaii are on the increase, cruise ships do not necessarily need to refuel in Hawaii and can take on fuel at locations offering the best prices. Foreign flag cargo vessels have similar flexibility.

Inter-island barge companies plan to add three tugs and two large barges. The tugs would be fueled in Hawaii. Fishing vessel use of Hawaii as a fueling stop is dependent on relative pricing. The Harbors Division notes that at least two organizations have indicated that they are interested in basing two 15-ship fleets in Hawaii, but the necessary facilities are not available (Soma 1998).

CHAPTER 7 ELECTRICITY

7.1 Overview

Hawaii's electricity sector includes electricity generated by the four electric utilities, independent power producers and cogenerators, and the sugar industry that is sold to consumers through Hawaii's four utility systems. Hawaii's four utility systems include Hawaiian Electric Company, Inc. (HECO) serving the City and County of Honolulu (Oahu); Hawaii Electric Light Company, Inc. (HELCO) serving Hawaii County; Kauai Electric Division of Citizens Utilities (KE) serving Kauai County, and Maui Electric Company, Ltd. (MECO) serving Maui County (Maui, Lanai, and Molokai).

Independent power producers also generate electricity and sell power to a utility. Cogenerators produce electric power and process heat for their own or contracted use and sell surplus power to a utility. Hawaii's sugar plantations generate electricity for their use and sell surplus power to a utility. Some have firm power contracts with their local utility. As a result, "electricity sector" and "electric utility sector" throughout this document refer to all elements of the system involved in producing electricity ultimately sold to the customers of Hawaii's regulated electric utilities.

Emissions from the generation by the sugar industry and other cogeneration not sold to a utility, but used for industrial purposes, are covered separately in Chapter 8.

In 1990, emissions from Hawaii's electricity sector were the second greatest contributor to its global warming potential. Electricity generation produced an estimated 45% of CO_2 emissions, 0.14% of CH_4 emissions, and 1.8% of N_2O emissions in Hawaii. Global warming potential combines the relative effects of CO_2, CH_4, and N_2O emissions into a value expressed in the equivalent effects of tons of CO_2. The sector produced a global warming potential of 7,652,966 CO_2-equivalent tons, or 41% of the total.

The following discussion examines current and potential actions to reduce greenhouse gas emissions in the electricity sector. Most of the recommended actions have already begun and are recommended for continuation. With the exception of HECO's Climate Challenge Program and the AES Hawaii carbon offset program, none of the current activities was specifically designed to reduce greenhouse gas emissions. Nevertheless, activities that reduce the demand for electricity and those that reduce emissions in supplying electricity contribute to overall efforts to reduce greenhouse gas emissions.

The chapter first discusses the Hawaii's Electricity Sector, the 1990 Baseline Estimate, and changes in the sector since 1990. This is followed by three sets of recommendations of ways to reduce Hawaii's greenhouse gas emissions. The first set is for crosscutting actions, that is, those that affect both electricity demand and electricity supply. The second set seeks to reduce electricity demand, which cut emissions due to decreased requirements for generation. The third set is intended to reduce greenhouse gas emissions per kWh generated through greater generation efficiency and the use of renewable energy technologies.

7.2 Hawaii's Electricity Sector

7.2.1 1990 Estimated Emissions Baseline

Table 7.1 displays the estimated electricity sector baseline 1990 greenhouse gas emissions calculated for the *Inventory of Hawaii Greenhouse Gas Emissions: Estimates for 1990* (State of Hawaii 1997a). Electricity sector emissions were 86% of all stationary source CO_2 emissions (4-1) and 41% of Hawaii CO_2 emissions (2-7).

Table 7.1 Estimated Hawaii Electric Utility Emissions, 1990 (Tons)

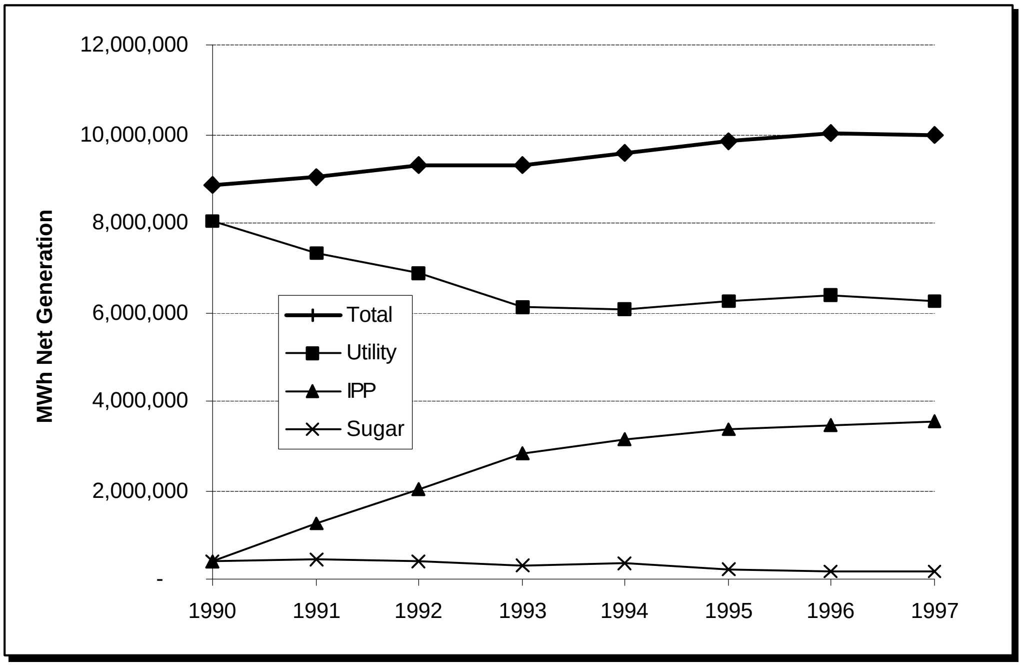
Fuel/Source	CO_2	CH_4	N_20
Distillate			
Engines	473,815	27	13
Combustion Turbines	301,800	23	N/A
Landfill Methane			
Combustion Turbine	7,441	1	N/A
Municipal Solid Waste (MSW)			
Boiler	238,008	N/A	N/A
Residual			
Boilers	6,625,982	58	N/A
Total	7,647,045	109	13

Source: State of Hawaii, 1997a, 4-14

Changes in Hawaii's Electric Industry

Since 1990, there have been major changes in the sources of electricity production in Hawaii. In 1990, Hawaii's utilities produced 90.7% of the electricity sold to customers while independent power producers' (IPPs) and sugar industry cogeneration almost equally accounted for the rest. As Figure 7.1 shows, by 1997, the utility share declined by 22% to 62% of the total and sugar's contribution was down by 62% to 1.5% of the total as several sugar plantations closed, including all on Oahu and the Island of Hawaii. Major power purchase agreements by HECO and HELCO raised the IPP share of net generation by 769% to 36.5% of the statewide total.

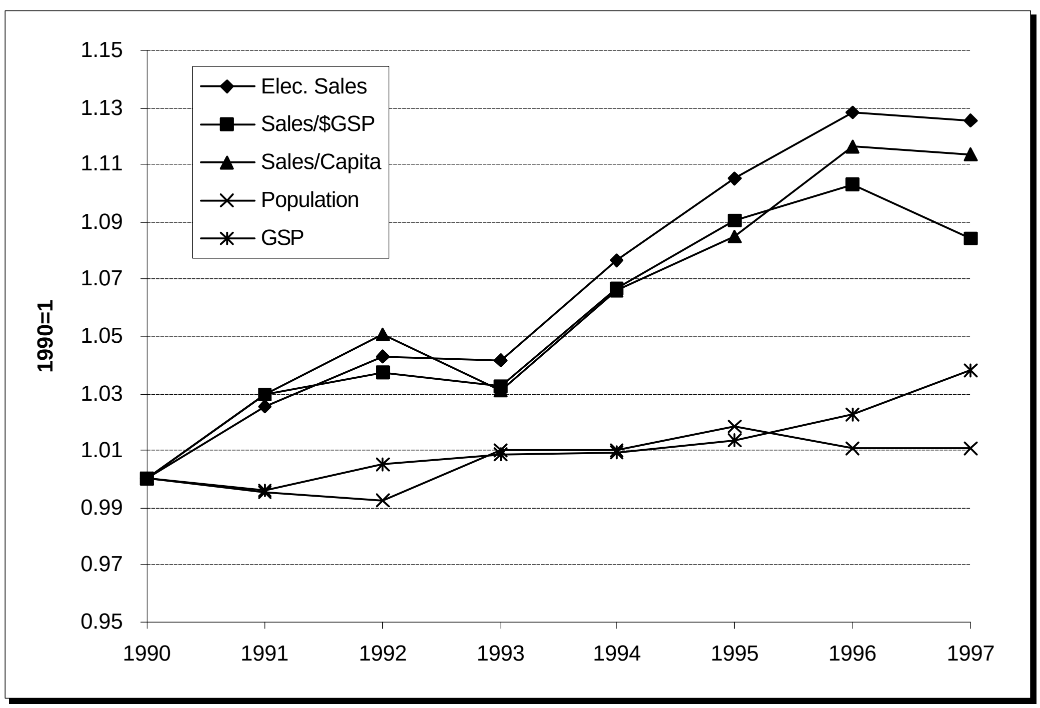
In the *Inventory*, IPP, cogeneration, and sugar industry generation for sale to the electric utilities were reported separately in the industrial sector. At that time, those sources produced a relatively small amount of total electricity generation.



Source: Utility FERC Forms 1 and Annual Reports, 1990-1997

Figure 7.1 Electricity Net Generation (MWh), 1990-1997

7.2.3 Growth in Electricity Sales, 1990-1997



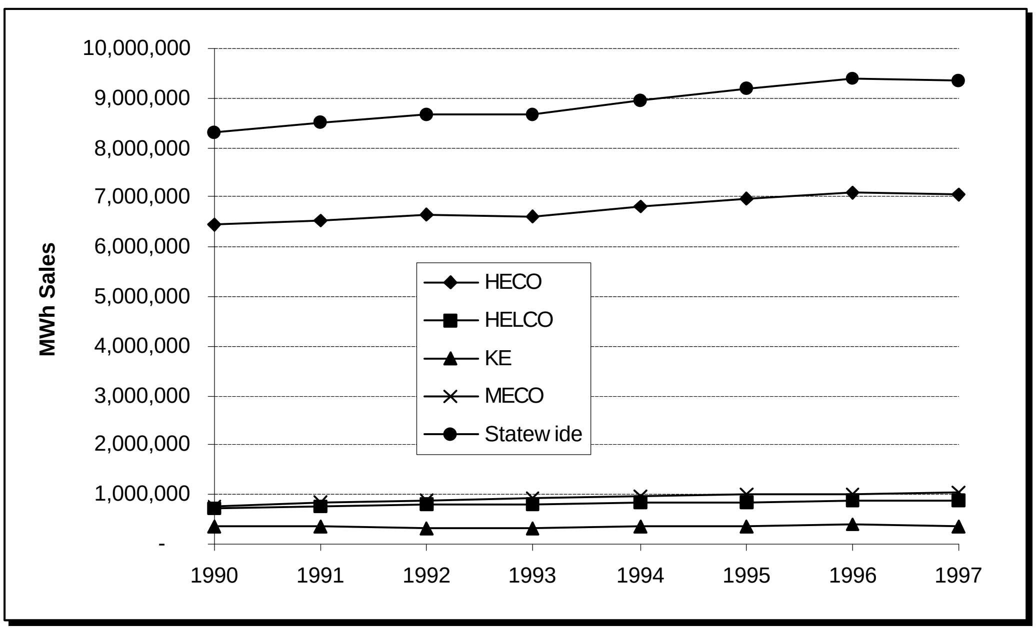
Source: Utility FERC Forms 1 and Annual Reports, 1990-1997, State of Hawaii Data

Figure 7.2 Hawaii Electricity Sales, De Facto Population, and Gross State Product, 1990-1997

Due to the significant increase in independent power production as a source of electricity for sale to utility customers since 1990, all production of power for sale to utility customers was included in the electricity sector in this report.

Growth of electricity sales and increased generation to meet that growth resulted in a greater increase in greenhouse gas emissions in the electricity sector than from any other Hawaii source category. Figure 7.2 shows that increases in electricity sales significantly outpaced growth in Hawaii's population and GSP from 1990 to 1997. By 1997, electricity sales were almost 13% greater than in 1990.

During the same period, defacto population grew about 1.1%, while GSP grew only 3.8%. There was an 11.3% growth in electricity sales per capita and an 8.4% growth in electricity sales per real dollar of GSP. This sharp increase in electricity intensity of Hawaii's economy was exaggerated by the slowing of GSP growth since the beginning of the decade. Hawaii's electricity intensity remains at less than 0.3 kWh per dollar of GSP, approximately half the national average (O'Connell 1998). Nevertheless, in the context of this *Hawaii Climate Change Action Plan*, our focus is on developments since the base year 1990.



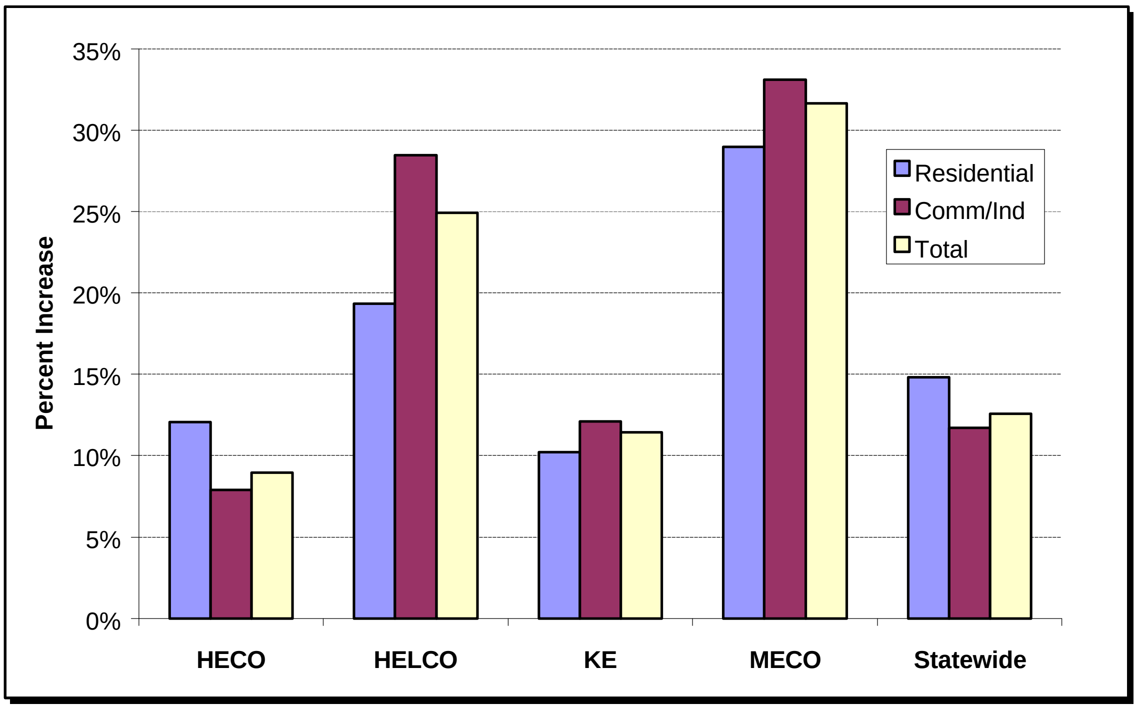
Source: Utility FERC Forms 1 and Annual Reports, 1990-1997

Figure 7.3 Electricity Sales by Hawaii Utilities (MWh), 1990-1997

Figure 7.3 shows sales for each of the four utility systems for the period 1990-1997. MECO sales grew most rapidly over the period, increasing from 781,342 to 1,028,768 MWh, a gain of 32%. HELCO sales increased 25%, from 715,751 to 894,110 MWh. Kauai Electric sales rose 13%, from 342,857 to 387,737 MWh in 1996, but dropped to 382,112 MWh in 1997 for an 11% gain over the eight-year period. Meanwhile, HECO sales increased 10%, from 6,470,857 to

7,091,147 MWh in 1996, but declined in 1997 to 7,049,777 MWh, representing a 9% net increase for the seven-year period.

Figure 7.4 depicts the growth in electricity demand by rate classification from 1990 to 1997 in an effort to determine where to focus electricity demand reduction measures designed to mitigate greenhouse gas emissions. Unfortunately, the rate classifications used by Hawaii utilities only allow a general analysis of the source of demand by residential and commercial/industrial sectors. Some residential use, such as master metered apartments or condominiums, may be included in the commercial/industrial sector as large power users.

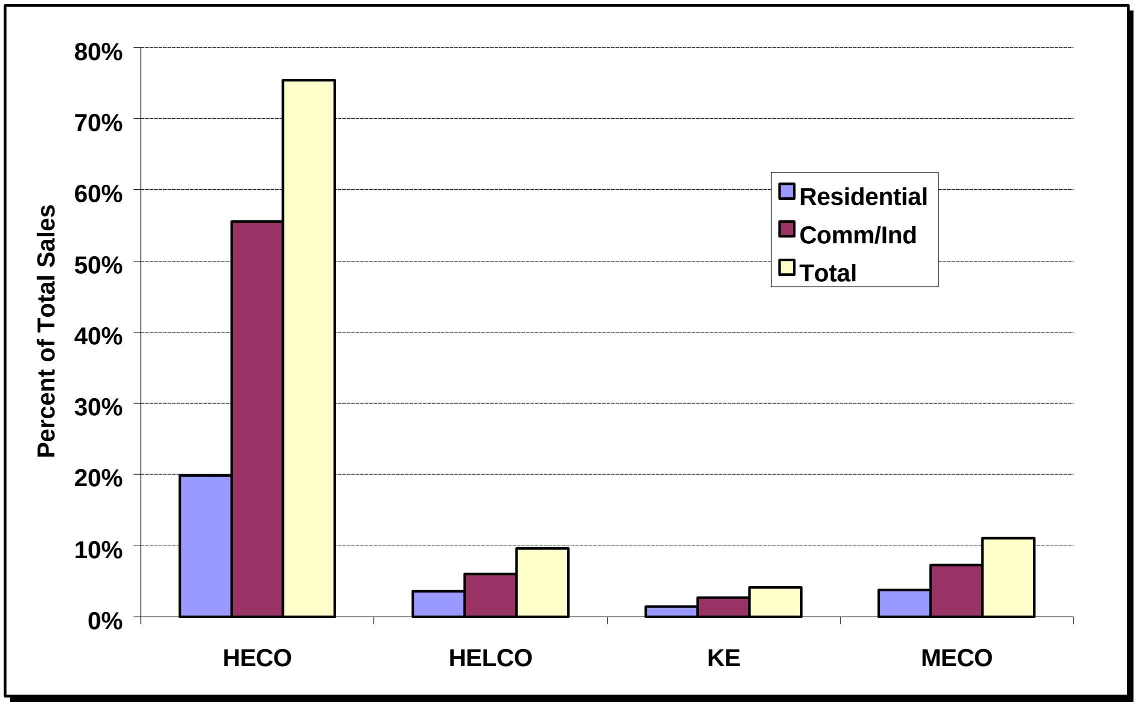


Source: Utility FERC Forms 1 and Annual Reports, 1990-1997

Figure 7.4 Growth in Electricity Demand by Rate Classification, 1990-1997

Total statewide electricity demand grew 13% between 1990 and 1997. The 15% growth in residential demand statewide outpaced the 12% increase in commercial/industrial demand. Demand growth was slowest on Oahu at 9%. Growth was greatest on Maui, where overall demand increased 32%, paced by 33% growth in commercial/industrial demand. While residential demand grew faster than commercial/industrial demand on Oahu, commercial/industrial growth was greater than residential on all of the neighbor islands. Overall demand increased 25% on the Big Island, but Hurricane Iniki and its residual effects resulted in a more modest 11% growth on Kauai. As noted above, electricity demand growth significantly outpaced population growth.

Looking at electricity demand in 1997, Figure 7.5 shows the percentage demand by rate classification and electric utility system. As indicated, despite the more rapid growth in demand on the neighbor islands, HECO on Oahu dominated statewide demand and commercial/industrial sector demand was greater than residential demand for all four utility systems. Clearly, energy efficiency measures should be focused on these areas.



Source: Utility FERC Forms 1 and Annual Reports, 1997

Figure 7.5 Percent of Electricity Demand by Utility and Rate Classification, 1997

7.2.4 Electricity Sector Greenhouse Gas Emissions, 1990-1997

As expected, greenhouse gas emissions grew as electricity generation increased to meet the growth in demand. As noted above, while the *Hawaii Inventory* separately accounted for utility generation and generation of purchased power, the "electric utility system" as depicted in Table 7.2 and elsewhere in this document includes emissions from each utility's own generators. Table 7.2 also includes IPP and sugar industry generators. For sugar industry generation, only emissions from fossil fuel used to produce electricity sold to the utilities were included. Fossil fuel emissions from sugar industry generation used by the plantations were included in industrial sector emissions and are discussed in Chapter 8.

From 1990 to 1997, CO_2 emissions from all generators providing electricity to the utility system grew statewide by 10%. MECO system emissions grew 30%, HECO's grew 8%, HELCO's grew 10%, and KE's declined by 1 percent.

Table 7.2 Estimated Hawaii Electric Utility System CO_2 Emissions (Tons), 1990-1996								
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
HECO	6,411,392	6,173,841	6,357,849	6,774,326	6,527,165	7,237,811	7,361,436	6,909,736
HELCO	800,570	856,322	737,523	734,115	728,755	841,962	882,577	879,730
KE	271,361	298,531	269,935	272,295	271,129	290,350	246,942	267,502
MECO	742,826	805,816	798,638	871,292	830,958	942,520	957,863	969,239
Statewide	8,228,140	8,136,500	8,165,937	8,654,021	8,360,001	9,314,638	9,450,813	9,028,204

Table 7.3 displays estimated CO_2 emissions in pounds per kWh of sales for each utility system and statewide over the 1990-1997 period. This measure provided a comparison of the relative contribution of each utility and its sources of purchased power to CO_2 emissions. Since it was based upon electricity sales, it accounted for station use and losses in transmission and distribution. It included utility-owned generation, independent power producers, and the portion of sugar industry generation sold to the utilities.

Table 7.3 Estimated Hawaii Utility System CO_2 Emissions (Lbs/kWh Sales), 1990-1996								
	1990	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
HECO	1.98	1.89	1.91	2.05	1.92	2.08	2.08	1.96
HELCO	2.24	2.20	1.87	1.83	1.74	1.99	2.02	1.97
KE	1.58	1.61	1.61	1.64	1.53	1.52	1.27	1.40
MECO	1.90	1.93	1.79	1.90	1.73	1.89	1.87	1.88
Statewide	**1.98**	**1.91**	**1.88**	**2.00**	**1.87**	**2.03**	**2.02**	**1.93**

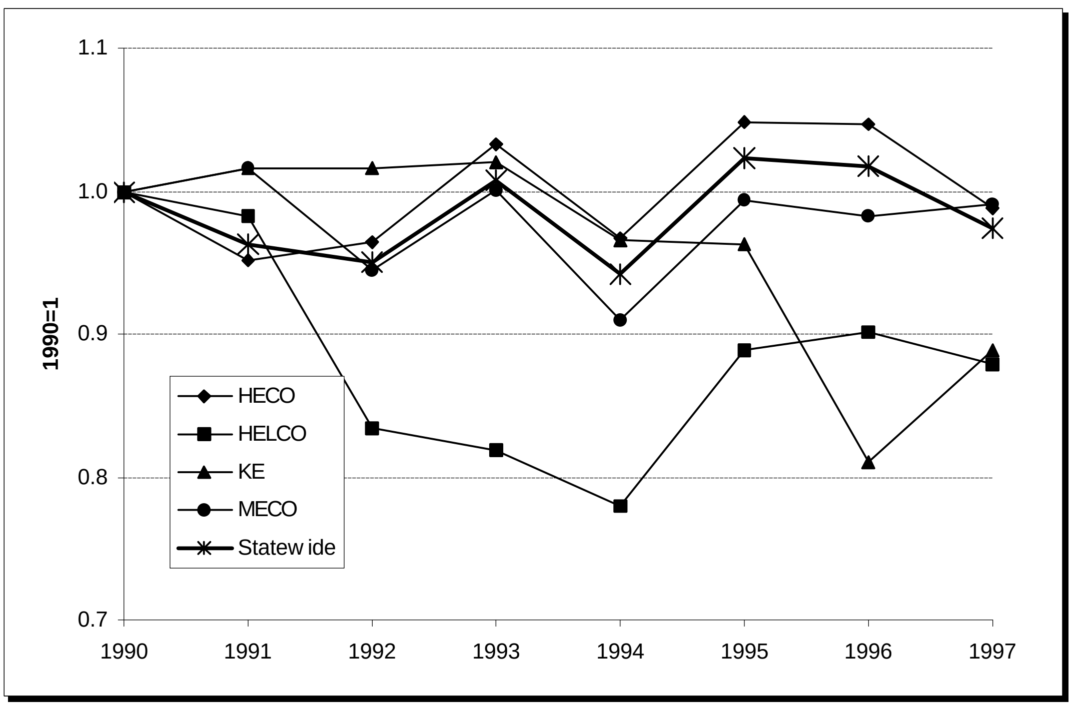


Figure 7.6 Hawaii Electric Utility CO_2 Emissions Indexed to 1990 (lbs./kWh), 1990-1997

Figure 7.6 depicts CO_2 emissions in pounds per kWh sales indexed on 1990 (1990 = 1). As the Figure shows, in 1997 all of Hawaii's utilities reduced CO_2 emissions in pounds per kilowatt hour (kWh) sales compared to 1990.

The HECO system produced greater emissions per kWh of sales than in 1990 in 1993, 1995, and 1996. Due to the size of the HECO system, this pulled up the statewide average. The HECO system's emissions grew starting in 1993 concurrent with purchases of 180 MW of power from the AES Hawaii coal plant and declining sugar industry and wind energy contributions to the Oahu power mix. As discussed in section 7.3.4, below, AES Hawaii voluntarily offset its CO_2 emissions by establishing a forest preserve in Paraguay that serves as a sink for greater quantities of CO_2 than emitted by the plant. However, this offset was not credited in calculating emissions from the HECO system.

By the end of 1996, all Oahu sugar mills were closed and wind energy production by Makani Uwila also ended. However, the H-POWER MSW generation plant and the Kapaa landfill methane generator contributed to the HECO system, also reducing potential CH_4 emissions from MSW landfills. In 1997, HECO sales fell and there was a reduction in No. 6 fuel oil burned in HECO generators and by Kalaeloa Partners IPP plant, which helped reduce emissions per kWh.

HELCO’s CO_2 emissions as measured in lbs./kWh sales went down in 1992 as 30 MW of geothermal energy and the Wailuku hydro project were added to the system. However the closure of sugar plantations in 1995, the use of coal in a former sugar boiler, and a narrowing reserve margin combined to increase CO_2 emissions from the HELCO system. Nevertheless, they remained below 1990 intensity.

KE and MECO system CO_2 emissions were reduced by the contribution of bagasse and hydro-produced electricity from the sugar industry. It should be noted that the utility-only CO_2 emission values presented in the Climate Challenge section below were based upon gross generation and are consequently lower values.

7.2.5 Estimated Electricity Sector Greenhouse Gas Emissions to 2020

The ENERGY 2020 model was used to estimate electricity sector greenhouse gas emissions in Hawaii through 2020. Although the model also estimated CH_4 and N_2O emissions, only the dominant CO_2 emissions will be discussed in this chapter. See Appendix C for an explanation of the ENERGY 2020 model.

7.2.5.1 Projected Growth in Electricity Generation and Sales

Greenhouse gas estimates were driven by estimated growth in electricity demand and generation to meet that demand. The estimates were for greenhouse gas emissions produced by fossil fuels, MSW, and landfill methane generators. Emissions from bagasse-fired generation were not included as equivalent CO_2 is taken up during the sugar cane growing cycle. Emissions from fossil fuel used by sugar plantation generators were included. Figure 7.7 depicts estimated demand and planned generation. Future generation was based upon current utility integrated resource plans. Since the utility plans do not cover the entire period, the ENERGY 2020 model added fossil fuel generation of a type appropriate for the scenario under examination, if needed, for the years not covered. It appears that currently planned generation was sufficient to meet forecast demand through 2020. ENERGY 2020 used its own forecast of energy demands.

Peak demand was projected to increase by 39% from about 1,490 MW to 2,070 MW over the thirty-year period (an average annual increase of 1.1%). Based upon utility plans, ENERGY 2020 estimated that there would be a 60% increase in generation capacity to meet the projected demand from 1,862 MW in 1990 to 2,292 MW in 2020 (an average annual increase of 1.6%).

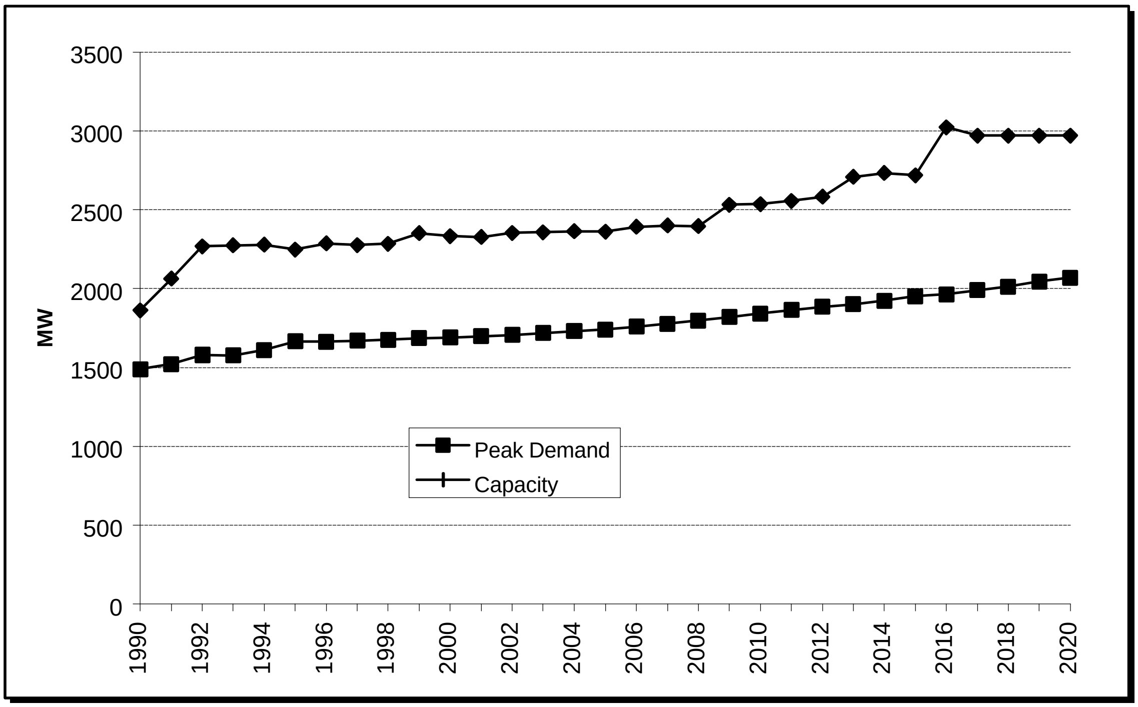


Figure 7.7 Estimated Growth in Peak Electricity Demand and Capacity in Hawaii, 1990-2020

Figure 7.8, below, depicts projected electricity sales for the period. Electricity sales are expected to grow by 42%, from about 8,100 GWh in 1990 to 11,500 GWh in 2020. This represents an estimated average growth rate of 1.2% per year. Projections by sector were calculated by ENERGY 2020 and do not correspond exactly to the rate classifications used by the utilities. They do, however, reflect the model's estimate of end uses by sector. Residential uses were projected by the model to grow at the most rapid rate, 1.7% per year, followed by commercial uses at 1.1%, industrial uses at 0.9%, and other at 0.2%. The ENERGY 2020 model differs from the historical experience using utility rate categories for 1990-1997 because it includes single metered multi-unit residential facilities such as apartments and condominiums in the residential category. These units are usually in utility commercial rate classifications.

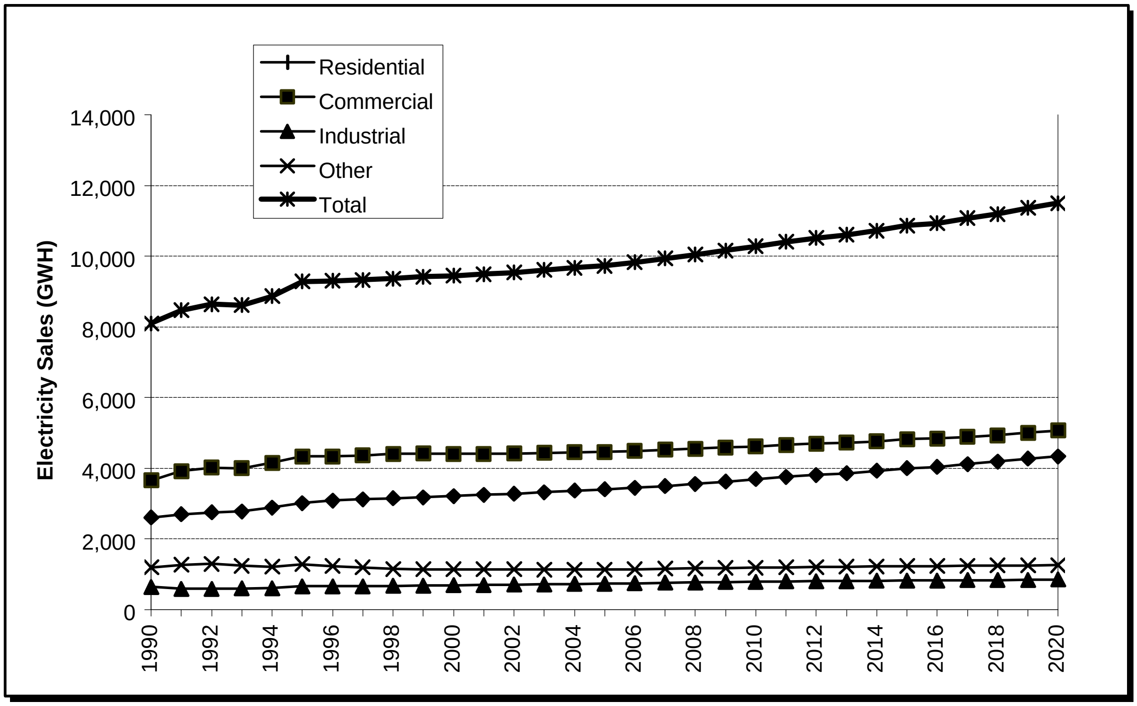


Figure 7.8 Estimated Electricity Sales in Hawaii by Sector, 1990 - 2020

7.2.5.2 Estimated Growth in CO_2 Emissions

Figure 7.9 shows the estimated increase in CO_2 emissions based upon the projected growth in demand and sales. A line representing the Kyoto goal of reducing greenhouse gas emissions 7% below 1990 emissions is provided for reference. **It is not intended to be a specific goal for the electricity sector alone.** Efforts to reduce emissions will involve efforts in all sectors, but each sector will not necessarily be able to separately reach a goal 7% below 1990 levels.

The ENERGY 2020 model estimated that electricity sector emissions under current plans would be 26% higher at 9,860,634 tons CO_2 in 2010 than the 1990 base of 7,813,323 tons. This would be 37% greater than the Kyoto target. Year 2020 emissions were estimated to be 37% greater than 1990, at 10,682,224 tons CO_2, a level 47% greater than the Kyoto target.

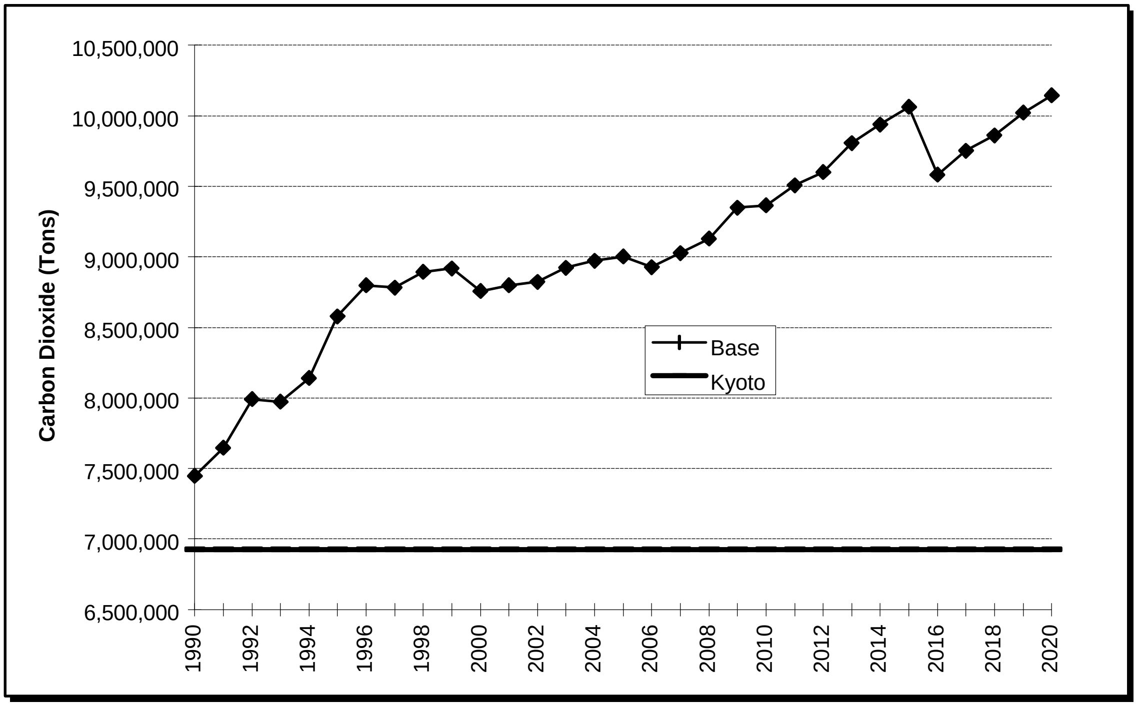


Figure 7.9 Estimated Hawaii Electricity Sector CO_2 Emissions, 1990 - 2000

7.3 Cross-Cutting Actions to Reduce Greenhouse Gas Emissions

Crosscutting actions help create a more efficient electricity system by employing a combination of both demand-side measures and supply-side measures. These include integrated resource planning, HECO's participation in the U.S. Department of Energy's Climate Challenge Program, and possible improvements in electricity system efficiency should the current Hawaii Public Utilities Commission's Docket to examine possible electricity competition ultimately result in such a system.

7.3.1 Actions Under Continued Integrated Resource Planning (IRP)

IRP is an approach to regulated utility planning which evaluates all potential energy options, including supply-side (energy-production by conventional fuels and renewable energy resources) and demand-side management (energy conservation, efficiency and load management) as well as the social, environmental, and economic costs of these options. The goal is to meet consumer energy needs in an efficient and reliable manner at the lowest reasonable cost. While reduction of greenhouse gas emissions was not a specific goal of IRP, effective IRP will tend to reduce greenhouse gas emissions through greater electric and gas utility efficiency, possible increased use of non-fossil, renewable fuels, and demand-side management (DSM) programs.

Although electric industry restructuring may eventually replace IRP with some other planning mechanism, it should be continued in its present form until such restructuring may occur.

7.3.1.1 The Public Utilities Commission Decision and Order No. 11630

In May 1992 the Commission issued *Decision and Order No. 11630 in the Proceeding to Require Energy Utilities in Hawaii to Implement IRP (Docket No. 6617)* (State of Hawaii 1992a). Appended to this order was *A Framework for Integrated Resource Planning* which detailed the goal, governing principles, responsibilities, and requirements for IRP in Hawaii. The *Framework* stated the goal as follows:

> *The goal of integrated resource planning is the identification of the resources or the mix of resources for meeting near and long term consumer energy needs in an efficient and reliable manner at the lowest reasonable cost* (3).

The stress on efficiency is the basis of the IRP contribution to greenhouse gas emission reduction.

7.3.1.2 Implementation of IRP in Hawaii

The first cycle of utility IRP planning under the new framework began with the PUC's May 1992 order. In 1993, the utilities filed their first IRPs for PUC approval. Each utility was to conduct a major review of its IRP every three years, adopting a new 20-year time horizon. Annual evaluation reports were also required. The second round of IRPs was delayed for a variety of reasons, but the second IRP for KE was submitted in April 1997. HECO filed its second IRP in January 1998, HELCO completed its second IRP in September 1998, and MECO will complete its second IRP in September 1999.

Each plan details the utility's needs over the next twenty years to meet the forecasted energy demand for its service area. The plan includes a forecast, supply-side options, demand-side options, a description of the analysis and basis for the plan, and a five-year action plan.

7.3.1.3 IRP and Opportunities for Greenhouse Gas Emissions Reduction

Demand Side Management Programs Initiated. Demand-side management, or DSM, refers to any utility activity aimed at modifying the customer's use of energy to produce desired changes in energy demand. DSM programs under IRP have the effect of reducing greenhouse gas emissions. DSM also offers the potential of lower utility bills for customers over the long term and deferral of major plant investments. DSM plans developed by the utilities under IRP are discussed in Section 7.4 of this chapter.

Renewable Energy Options Were Considered but Not Adopted. One of the hopes of the State and some other IRP Docket intervenors was that IRP would lead to a greater role for renewable energy in Hawaii. This would comply with *Framework* goals of comporting with state plans and reducing impacts on the environment (4). While the utilities examined supply options that included renewable energy in their initial IRPs, renewable supply options were not selected due to utility evaluations of cost, operational factors (the intermittent nature of some renewable technologies, penetration limits, off-peak limits, etc.), reliability, technical, and permitting issues.

The three electric utilities, which have completed their second round of IRPs, considered renewable energy options in their planning, but decided that they would not be cost effective. The utilities remained open to negotiating power purchase agreements with renewable energy developers. For example, HECO, as part of its second IRP, stated that it will issue a renewable request for proposals "to invite renewable energy developers to provide energy to the HECO system in return for payments at or below HECO's avoided energy cost" (HECO 1998, 12-15). HECO will also explore establishing a "Green Pricing" program where consumers are offered energy from renewable resources at an additional cost (12-15).

Carbon Dioxide Emissions Examined. One of the requirements of the *Framework* was for the utilities to consider external costs and benefits in their planning process (4). In the first round of IRP, HELCO used California Energy Commission (CEC) proxy values for carbon dioxide and other air emissions in the process of nominating renewable resources for candidate plans. They were not, however, used as a basis for selecting plans (HELCO 1993b, 4-35). The MECO IRP used similar values, but found the resulting plan incorporating wind and biomass generation was more expensive and that renewable energy use "increases technological risks and decreases flexibility" (MECO 1993, 10-17). HECO used Bonneville Power Authority and CEC adders as proxies in plan nomination and in evaluating a sensitivity analysis (HECO 1993, 5-22; 3-9). The utilities ultimately did not factor external costs and benefits into their resource selection and deferred such treatment until completion of separate studies of externalities.

The *Hawaii Externalities Workbook* was completed by consultants to the HECO companies in June 1997 and submitted to the Commission. The *Workbook* addressed a wide range of external costs and benefits of electricity generation, but expressed uncertainty about the effects of climate change and did not attempt to quantify external costs of greenhouse gas emissions. Moreover, the authors stated, that "because of the global nature of the issue, changes in emissions from a small entity (such as a state) will have virtually no impact on global climate, and only a tiny fraction of whatever change in damages occurs will be borne by the residents of that entity. As a result, it makes little sense for states to develop their own policies" (HECO 1997c, 5-6).

In oral and written comments, made as members of the Externalities Study Advisory Group, DBEDT disagreed with this argument. As discussed earlier in this report, Hawaii residents may be seriously affected by climate change and certainly not just in proportion to local emissions. While Hawaii's portion of overall greenhouse gas emissions is small on a global scale, the potential effects on Hawaii argue for a significant contribution to global emission reduction efforts. Moreover, future greenhouse gas emission control methods could involve increased costs for emission-producing resource options which should be considered in IRP development. Such costs could be in the form of a carbon tax or a need to purchase emissions permits on a national or international market.

In developing subsequent IRPs, HECO and HELCO determined the expected CO_2 emissions of each plan option and considered these values along with many other criteria in making their plan selections. There is no evidence, however, that CO_2 emissions were a major factor in final plan selection and plans with the least CO_2 emissions were not selected over less costly plans with greater CO_2 emissions.

7.3.1.4 RECOMMENDATION: Continue IRP in Hawaii Unless Replaced by an Alternate Form of Planning.

Overall, however, IRP is a positive step towards greenhouse gas emission reduction through the contribution of DSM programs and planning to improve the efficiency of Hawaii's utility systems. It is already clear that the utilities have developed active DSM programs, have more efficient resource plans, and at least formally consider renewable energy options, and determine the amounts CO_2 emissions under various resource options in their planning.

Given the contributions of IRP to the creation of a more efficient electricity system, IRP should be continued until replaced by some other form of planning for future electricity needs. Should wholesale or retail competition be introduced, a new form of planning would likely be required.

7.3.2 U.S. Department of Energy Climate Challenge Program

On March 19, 1997, the Hawaiian Electric Company, Inc., (including its subsidiaries, HELCO and MECO) signed a Climate Challenge Participation Accord with the U.S. Department of Energy. The Participation Accord outlined the voluntary commitments made by the companies to reduce, sequester, or avoid greenhouse gas emissions (HECO 1997a, 1). The HECO companies are also participating in an industry greenhouse gas reduction initiative and a variety of company activities as outlined below.

HECO's "greenhouse gas emission control strategy focuses on three major areas:

- improving the efficiency of fossil fuel generating units;
- reducing energy demand; and
- using renewable energy resources (2)."

7.3.2.1 Improving Fossil Fuel Generating Unit Efficiency

HECO committed to limiting CO_2 emissions from fossil fuel generating units to 1.76 lbs. CO_2/kWh, calculated as a weighted system average. HECO calculates these emissions on the basis of gross generation by company-owned units. This value does not reflect losses of electricity in transmission and distribution nor emissions from IPPs and cogenerators selling power to the HECO utilities. As noted in Section 7.2.4.1, DBEDT calculated utility system emissions on the basis of kWh sold and included utility and non-utility generator emissions to more fully capture the effects of electricity use on Hawaii's greenhouse gas emissions.

HECO stated in its Accord that higher efficiency, new combined cycle turbine units will be phased in to replace older, less efficient units, and that the three utilities will work to reduce fuel use in existing units through control system and instrumentation improvements. These efforts were to be accompanied by a move towards increasingly automated monitoring of unit operating performance.

With the exception of 1992 and 1996, HECO has been able to keep its emission rate below its target and expects to be able to do so through at least 2000 (3).

7.3.2.2 Reducing Energy Demand

In its *Climate Challenge Program* summary (HECO 1997d), HECO projected that its DSM programs will save 431,961 MWh of energy, avoiding 380,000 tons of CO_2 by the end of 2000 (5). This estimate was based upon the first IRP's estimates of DSM program savings. The program was not initiated as early as planned for a variety of reasons and early results were not as great as expected. Nevertheless, based upon more recent data than HECO used in their projections, DBEDT estimated that the HECO companies' DSM programs will save about 350,000 MWh of electricity and 340,000 tons of CO_2 through the end of 2000. The slightly reduced projections were due to delays in receiving Public Utilities Commission approval to initiate programs and lower initial results than in earlier forecasts. The HECO companies' specific DSM plans are discussed in greater detail in subsequent sections of this report. See Section 7.2.4.1 for an explanation of how HECO's and DBEDT's calculation methods differed.

7.3.2.3 Using Renewable Energy Resources

HECO also committed to purchase or produce at least 500,000 MWh of renewable energy per year from waste-to-energy, geothermal, hydroelectric, and wind facilities in the companies' service territories. HECO noted that additional energy might be purchased from biomass facilities operated by sugar companies on Maui, but their continued operation was not assured. Based on HECO's target emission rate, renewable energy purchases were expected to avoid 440,000 tons of CO_2 annually and 2,200,200 tons of CO_2 cumulatively over the period 1996 to 2000 (7).

Between 1990 and 1997, the HECO companies have done better than planned. They purchased or produced 5,397,371,538 kWh of renewable energy (including that purchased from the sugar industry), avoiding 5,264,919 tons of CO_2 emissions. In 1997, the HEI companies avoided 674,605 tons of CO_2 through the use of renewable energy. The discussion of renewable energy below provides more detail on renewable energy resources and purchases of renewable energy for the three HECO companies and Kauai Electric.

7.3.2.4 Utility Forest Carbon Management Program

HECO participates in the Utility Forest Carbon Management Program (UFCMP) which seeks to establish a coordinated plan to manage greenhouse gases through forestry projects. HECO contributed $5,000 to program start-up costs, and will contribute an additional $10,000 to projects through 2000. Based upon projected sequestering of 2.2 million tons per year by all projects in the nationwide program, HECO's $10,000 contribution will provide the equivalent of sequestering an average 12,260 tons per year, or a cumulative 61,300 tons by the end of 2000 (HECO 1997c, 2).

7.3.2.5 Additional Utility Emissions Reduction Projects

HECO also committed to several additional projects with the objective of controlling greenhouse gas emissions. These include:

- Transmission and distribution efficiency improvements;
- Renewable energy studies and promotions;
- Local forestry management programs;
- Transportation programs, including electric vehicle use and mass transit support;
- Education and information programs; and
- Renewable energy research investments (9-14).

7.3.2.6 RECOMMENDATION: Enhance Participation in Climate Challenge Program

The HECO companies are urged to continue their commitment to the Climate Challenge Program and to consider setting more challenging goals for emissions reductions. Kauai Electric Division of Citizens Utilities is encouraged to join the Climate Challenge Program.

7.3.3 Electric Competition and Hawaii

7.3.3.1 Hawaii Public Utilities Commission Docket 96-0493 – A Preliminary Inquiry

Currently, Hawaii's four electric utilities are regulated monopolies with exclusive service to their respective service territories. On December 30, 1996, the Hawaii Public Utilities Commission opened Docket 96-0493, *Instituting a Proceeding on Electric Competition, Including an Investigation of the Electric Utility Infrastructure in the State of Hawaii* (State of Hawaii 1996a). This docket could ultimately result in some form of electric industry competition in Hawaii. Among the objectives of the docket which could have bearing on Hawaii's response to climate change are the following:

- Identification of the State's needs, policies, and objectives that may be supported by competition in the electric utility industry. While this objective focuses on energy development, it could involve economic efficiency, fuel-savings, lower electricity prices and customer choice (8), and consideration of how to reduce greenhouse gas emissions through competition.
- Public Interest Benefits. Environmental protection and research and development programs may be at risk under competition (8). However, in other states, public benefit charges have been established to fund such programs in a competitive environment.
- Long-term Integrated Resource Planning. The existing IRP efforts are intended to consider environmental and other externalities in determining the appropriate mix of generation resources to meet future demand. Ways to enhance or replace current IRP practices, including demand-side management would need to be found (8).
- Renewable resources. Ways to assure the promotion and development of renewable energy resources will be investigated (9).

Nationally, the trend towards competition has resulted from the expectation that electricity competition may drive down cost and prices by reducing inefficiencies. Competitive industries also may be more likely to spur innovations with new technologies (EIA 1996, 35). To the extent that the participants in a competitive electric system achieve greater efficiencies in part by more efficient use of fossil fuels and use of new technologies includes both more efficient fossil fuel generators and renewable resources, competition could help reduce greenhouse gas emissions.

On the mainland, nonutilities are using recently advanced, aeroderivative gas turbine technologies. These are cleaner and use less fuel than older fossil-fueled steam-electric technologies to generate electricity more cheaply. Nonutilities are sometimes able to put advanced generators into operation as an alternative to obsolete existing utility capacity (35).

7.3.3.2 Potential Advantages of Electric Competition

The following are some considerations related to a competitive environment and greenhouse gas reduction in the electricity industry in Hawaii. They include the stimulus of competition for use of advanced technologies, ensuring renewable energy development and energy diversity, energy efficiency, and integrated resource planning.

Using Advanced Technologies. In the 1990s, MECO, HELCO, and independent power producers (IPP) have introduced advanced technologies into Hawaii's generation mix. These have included a geothermal plant, a large (for Hawaii) hydroelectric plant, a waste-to-energy plant, and two cogenerators: a low-sulfur fuel oil-fired dual train combined cycle (DTCC) unit and an atmospheric fluidized-bed coal plant. MECO and HELCO have introduced the use of combined cycle and advanced aeroderivative combustion turbines into their systems. IPPs have also proposed naphtha-fired advanced DTCC units, a plasma arc waste-to-energy facility, and improved renewable energy technologies.

Recently, Hawaii utilities continued to move toward advanced technology. In the IRP process, the utilities were ordered to consider the full range of available technologies. Kauai Electric issued a request for proposals for its next generation unit and selected an advanced DTCC. HECO and HELCO selected phased deployment of advanced DTCCs in their second Integrated Resource Plans. MECO is currently working on its second IRP plans and is considering similar technologies. The utility-owned units are expected to be diesel-fired. Unfortunately, Hawaii's lack of access to natural gas precludes the use of that cleaner fuel.

Renewable Energy and Diversity of Supply. Under competition, such means as system benefits charges or renewable portfolio standards could be used to spur renewables deployment in Hawaii with the attendant reduction of Hawaii's dependence on imported fossil fuel and reduction of environmental effects, including reduction of greenhouse gas emissions. On the mainland, competing organizations have offered "green power" from renewable resources as an incentive to gain environmentally conscious customers.

Greater Energy Efficiency. In light of Hawaii's high electricity prices, energy efficiency can be more cost-effective and should be encouraged for both greenhouse gas reduction and economic growth. Competition could encourage greater efficiency of electricity use. For example, time-of-use pricing has been used on the mainland for at least two decades to stimulate efficiency. This could be utilized at both the commercial and residential level. Time of use pricing would charge higher rates during times of peak demand when the marginal cost of additional electricity is greatest, and lower rates during off-peak periods when the cost of production is lower. This could reduce peak demands and, with real-time pricing, could contribute to improving the efficiency of the electric system. Energy efficiency programs could be bundled with electricity services by competitors.

Should electricity competition result in lower electricity prices as envisioned; such lower prices may have the unintended consequences of encouraging less efficient electricity use. The use of a systems benefit charge to increase energy efficiency programs could help offset such consequences.

7.3.3.3 RECOMMENDATION: Continue Efforts to Restructure Hawaii's Electric Utilities

To the extent possible, efforts to restructure Hawaii's electricity industry should be continued at a rapid pace with the objective of increasing the efficiency of Hawaii's electricity system and reducing costs to customers.

7.3.3.4 RECOMMENDATION: Under a Restructured System, Establish a Renewable Energy Portfolio Standard and Set Maximum Greenhouse Gas Emissions Standards

To ensure that greenhouse gas emissions are reduced under competition, it is recommended that any restructuring of Hawaii's electricity system include a renewable energy portfolio standard and set requirements for demand reduction through demand-side management programs. In addition, consideration should be given to establishing an emission standard to ensure the most efficient generation available is installed, and requiring renewable energy, demand-side management programs, and/or carbon offsets be provided by companies providing generation in a competitive system. The exact specification of such standards would be based upon further, detailed technical and economic analysis.

7.4 Reduce Electricity Sector Greenhouse Gas Emissions through Demand-Side Management and Energy Efficiency Programs

Actions that reduce electricity demand also reduce greenhouse gas emissions. These include utility demand-side management programs, use of solar water heating, and various energy efficiency programs.

7.4.1 Demand-Side Management (DSM)

DSM is defined as any utility activity aimed at modifying the customer's use of energy to reduce demand. It includes conservation, load management, and efficiency programs. DSM offers the potential for lower customer utility bills, deferral of major power plant investments, reduced environmental impacts, and potential diversification of resources (NEOS 1995, ES-1). In the context of this study, DSM measures generally offer reductions in greenhouse gas emissions.

The four electric utilities each proposed DSM programs as part of their initial IRPs and filed their programs for Commission approval and determination of cost recovery. DSM programs were filed in Kauai Electric's and HECO's second round IRP. The following discussion summarizes these programs.

7.4.1.1 Hawaiian Electric Company (HECO) DSM Programs

In its 1996 *Annual Evaluation Report* (HECO, 1996), HECO stated its "basic DSM strategy is to promote and pursue aggressive, achievable and cost effective DSM programs designed to minimize the inefficient use of electricity by our customers, defer the need for the construction of supply-side resources, and reduce the State of Hawaii's dependence on imported oil" (12). Similar objectives were adopted by the other HECO utilities (e.g., see MECO 1997, 11).

As part of HECO's first IRP, the company filed a DSM Action Plan with the Commission on January 18, 1994. The plan included the following programs:

- **Commercial and Industrial Energy Efficiency Program** (Approved April 22, 1996). This program is focused on existing commercial and industrial customers and seeks to promote more efficiency air conditioning, lighting, refrigeration, and motors (HECO, 1997e, 7-14).
- **Commercial and Industrial New Construction Program** (Approved April 22, 1996). Provides design and technical assistance for the design and engineering community for more efficient air conditioning, lighting, motors, and other end uses in the commercial and industrial new construction market (7-19).

- **Commercial and Industrial Customized Rebate Program** (Approved April 22, 1996). Under this program customers can identify energy efficiency opportunities in their facilities, develop a proposal, and present it to HECO. HECO will then evaluate the proposal, determine if it is a cost-effective application, and establish a cost-sharing arrangement with the customer (7-23).
- **Residential Efficient Water Heating Program (Existing Customers)** (Approved June 5, 1996). Promotes the use of high efficiency water heating technologies such as solar water heating and heat pump water heaters. High efficiency resistance water heaters can also be used. Low flow showerheads were also offered to reduce hot water use and to conserve water (7-10).
- **Residential Efficient Water Heating Program (New Construction)** (Approved May 29, 1996). This program promotes solar water heating, heat pump water heaters, and high efficiency resistance water heating to developers of new housing projects (7-6).

In its 1996 *Annual Evaluation Report*, HECO reduced its estimate of the energy and capacity savings from its DSM programs as a result of the adoption of the Hawaii State Model Energy Code by the City and County of Honolulu and the slowdown of the economy. HECO also decided to adopt the results of DBEDT's *Hawaii Demand-Side Management Opportunity Report*, issued in August 1995 as part of the Hawaii Energy Strategy program, as a more timely estimate of the available resource. (HECO 1996, B.2,6)

Table 7.4 Estimated Energy Savings (GWh) and CO_2 Emissions Reductions from HECO DSM Programs

Year	Residential Water Heating (Existing)	Residential Water Heating (New)	Commercial/ Industrial Prescriptive Measures	Commercial/ Industrial New Construction	Commercial/ Industrial Custom Rebate	Annual Total GWh Savings	Annual Total Savings [1] (Tons CO_2)
1996	1.35	0.08	9.38	1.66	0.27	12.74	12,480
1997	5.79	1.28	12.29	5.32	2.09	26.77	26,235
1998	6.58	1.51	15.31	7.08	0.51	30.99	30,370
1999	13.52	3.01	31.62	14.73	1.42	64.30	63,014
2000	20.81	4.67	48.79	22.81	2.33	99.41	97,422
2005	60.90	13.88	145.38	71.97	7.00	299.13	293,147
2010	103.38	24.78	257.35	128.87	98.36	621.16	608,732
2015	123.70	22.95	305.93	183.18	15.76	651.52	638,490
2017	124.40	23.32	311.84	197.08	17.51	674.15	660,667
20-Year Total							
	1,560.94	373.74	3,879.54	1,982.08	1,485.52	9,279.97	9,094,366

(HECO 1998) Values for 2010 are interpolated from more detailed data

[1] CO_2 savings calculated based upon HECO's 1997 system average emissions of 1.96 lbs CO_2 per kWh sales or 980 tons/GWh sales

Table 7.4 summarizes the most recent estimate of energy savings expected from HECO's current DSM programs and the calculated CO_2 emissions reduction. The estimates for 1998 to 2017 are based upon HECO's January 1998 IRP filing. (HECO 1998)

7.4.1.2 Hawaii Electric Light Company (HELCO) DSM Programs

HELCO's DSM programs were approved by the PUC in December 1995. They included a Commercial and Industrial Energy Efficiency Program, Commercial and Industrial New Construction Program, Commercial and Industrial Custom Rebate Program, and Residential Efficient Water Heating Program. These programs are similar to HECO's in concept. In addition, HELCO distributed high efficiency showerheads to customers to reduce water, especially hot water use. Table 7.5 presents the estimated energy savings and CO_2 emissions reductions for HELCO DSM programs based on the August 1998 draft of HELCO's IRP.

Table 7.5 Estimated Energy Savings (GWh) and CO_2 Emissions Reductions from HELCO DSM Programs

Year	Residential Efficient Water Heating	High Efficiency Showerhead	Commercial/ Industrial Energy Efficiency	Commercial/ Industrial New Construction	Commercial/ Industrial Customized Rebate	Annual Total GWh Savings	Annual Total Savings (Tons CO_2)
1999	0.64	3.35	1.66	0.30	0.40	6.35	6,252
2000	1.78	3.35	4.10	1.00	1.48	11.71	11,531
2005	7.66	3.35	15.38	7.90	5.61	39.89	39,294
2010	12.96	-	24.57	18.20	10.65	66.38	65,384
2015	16.10	-	30.93	29.15	16.54	92.73	91,339
2018	16.12	-	32.37	35.00	20.47	103.96	102,401
20-Year Total							
	193	23	375	284	172	1,048	1,134,231

(HELCO 1998) (Odd years 2007-2017 are interpolated)

[1] CO_2 savings calculated based upon HELCO's 1997 average emissions of 1.97 lbs CO_2 per kWh sales or 985 tons/GWh sales

7.4.1.3 Kauai Electric Division, Citizens Utilities Corporation (KE) DSM Programs

Kauai Electric developed six DSM programs in its first IRP in 1993. The six programs were incorporated into the 1994 DSM Action Plan (KE 1997, D-7). The plan included the following programs, which were approved by the Commission in August 1997:

- Residential New Construction Program;
- Residential Direct Install Program;
- Residential Retrofit Program;
- Commercial New Construction Program;
- Commercial Equipment Replacement Program; and
- Commercial Retrofit Program (5-15).

A new plan was developed as part of KE's 1997 IRP filed on April 1, 1997. It included a five-program portfolio.

- **Commercial Retrofit Program**. The program is designed to promote energy efficiency improvements to existing commercial buildings. Primary components of this program are energy audits, customer education, and monetary incentives for measures installed as part of the program (D-12).
- **Commercial New Construction Program**. Provides education, technical assistance, and incentives to commercial new construction owners and trade allies to promote use of energy-efficient equipment in building design. (D-22).
- **Residential Retrofit Program.** Initially, KE use point-of-purchase displays and mail-order channels to encourage residential customers to install energy-efficient lighting and other low-cost measures. Customers will also be encouraged to retrofit their homes with such technologies as heat pump or solar water heaters, and hard-wired fluorescent fixtures. The program involves a combination of trade allies, energy efficiency education, and incentives to encourage customers to adopt the measures (D-26).
- **Residential Direct Install Program.** Targeted on the low-income and renter markets, this program seeks to provide cost-effective efficient lighting and water heating measures. It includes a separate focus on State of Hawaii Housing Authority units. Low-cost measures, such as lighting, hot water pipe and tank insulation, and efficient water flow devices will be provided at no direct cost, or through rebates, and financing options (D-33).
- **Residential New Construction Program.** The program provides energy efficiency technical assistance to residential builders and allies. Incentives will be provided to include solar water heaters, heat pump water heaters, and hard-wired fluorescent fixtures in new units. Financing will be offered to facilitate the customer's contribution (D-39).

The programs outlined in KE's second IRP await PUC approval. Table 7.6 depicts the estimated reduction of greenhouse gas emissions from KE's programs.

Table 7.6 Estimated Energy Savings (MWh) and CO_2 Emissions Reductions from KE DSM Programs

Year	Residential Retrofit	Residential Direct Install	Residential New Construction	Commercial Retrofit	Commercial New Construction	Annual Total MWh Savings	Annual Total Savings 2 (Tons CO_2)
1998	1.01	0.68	-	2.90	-	5	3,214
1999	3.32	2.22	-	9.47	-	15	10,499
2000	6.35	4.24	-	18.06	-	29	20,052
2005	8.36	5.47	1.74	23.22	1.89	41	28,477
2010	5.26	2.66	1.74	18.79	0.57	29	20,313
2015	1.14	0.62	1.33	12.55	0.50	16	11,293
2017	0.13	0.07	0.90	11.79	0.47	13	9,349
20-Year Total							
	103	64	23	354	15	558	390,513

(KE, 1997, Appendix D, Table B. Program Summary Spreadsheets)

[1] Annual energy savings from measures implemented over program's first seven years.

[2] CO_2 savings calculated based upon KE's 1997 average emissions of 1.4 lbs CO_2 per kWh sales or 700 tons per GWh

7.4.1.4 Maui Electric Company (MECO) DSM Programs

On June 2, 1995, MECO filed applications with the PUC for the following DSM programs (MECO 1997,11):

- **Commercial and Industrial Energy Efficiency Program** (Approved September 23, 1996). Seeks to encourage existing commercial and industrial customers to install energy-efficient air conditioning, lighting, and industrial motors (13).
- **Commercial and Industrial New Construction Program** (Approved September 23, 1996). Provides design and technical assistance for the design and engineering community for air conditioning, lighting, industrial motors, and other end uses (14).
- **Commercial and Industrial Customized Rebate Program** (Approved September 23, 1996). This program provides a mechanism for customers to identify energy efficiency opportunities in their facilities, and develop a proposal. MECO will then evaluate the proposal, determine if it is a cost-effective application, and establish a cost-sharing arrangement with the customer (14).
- **Residential Efficient Water Heating Program (Existing and New Customers)** (Approved July 26, 1996). Promotes solar water heating and heat pump water heating to MECO's existing customers and builders of residential homes. For those who cannot install a heat pump or solar system, MECO offers efficient resistance water heaters. Low flow showerheads will be offered to reduce hot water use and conserve water (15).

Year	Residential Efficient Water Heating	Commercial/ Industrial Energy Efficiency	Commercial/ Industrial New Construction	Commercial/ Industrial Customized Rebate	Annual Total GWh Savings	Annual Total Savings [1] (Tons CO_2)
1997	1.60	7.70	0.45	0.29	8	7,934
1998	2.97	12.78	1.30	0.74	18	16,722
1999	7.93	18.49	2.47	1.41	30	28,488
2000	11.94	23.95	3.98	2.23	42	39,559
2005	21.10	31.51	7.66	4.19	64	60,590
2010	21.10	31.51	7.66	4.19	64	60,590
2015	9.17	7.56	3.69	1.96	22	21,031
20-Year Total						
	317	473	115	63	965	907,340

Table 7.7 Estimated Energy Savings (GWh) and CO_2 Emissions Reductions from MECO DSM Programs

(Creveston, 1997, Fax, Aug 12, 1997)

[1] CO_2 savings calculated based upon MECO's 1997 average emissions of 1.88 lbs CO_2 per kWh sales or 940 tons/GWh sales

Table 7.7 summarizes the projected energy savings and CO_2 emissions reductions from MECO DSM programs. MECO reduced its estimate of the energy and capacity savings from its DSM programs as a result of the experience of HECO and HELCO. It should be noted that, while the County of Maui has not yet adopted the Hawaii Model Energy Code, such adoption could reduce the impact of MECO DSM programs.

7.4.1.5 RECOMMENDATION: Continue and Expand Utility DSM Programs

Table 7.8 Statewide CO_2 Emissions Reduction from Utility DSM Programs (Tons)

Year	HECO	HELCO	KE	MECO	Total
1998	30,370		3,214	16,722	50,306
1999	63,014	6,252	10,499	28,488	108,252
2000	97,422	11,531	20,052	39,559	168,564
2005	293,147	39,294	28,477	60,590	421,508
2010	608,732	65,384	20,313	60,590	755,019
2015	638,490	91,339	11,293	21,031	762,152
2016	749,205	95,121	10,123	9,891	864,340
2017	761,323	98,761	9,349		869,433
2018		102,401			102,401
20-Year	9,094,366	1,134,231	390,513	907,340	11,526,450

Table 7.8 summarizes the estimated statewide savings from the utility programs. Current utility DSM programs will provide Hawaii with significant energy and emissions savings. At the same time, they will defer requirements for new generation. Under current plans, savings will peak in 2017 at 869,433 tons of CO_2; however, it is expected that additional programs will supplement the existing programs in future years.

While the utilities have generally continued and expanded DSM programs developed in the first round of IRP, additional options may be cost effective. HECO adopted the DSM Model developed by DBEDT in the HES program. It is recommended that the complete set of potential programs be evaluated in each IRP cycle to determine whether changed conditions or costs have made additional programs cost-effective.

State and County Government Efficiency Programs

This section outlines a number of energy efficiency programs that reduce the need for electricity generation and reduce electricity demand. Each program is recommended for continuation or expansion as indicated below.

7.4.2.1 RECOMMENDATION: Continue to Increase State Government Efforts to Improve Energy Efficiency

Administrative Directive No. 94-06 was issued by then Governor Waihee on November 1, 1994. The Directive established an Energy Management and Efficiency Program for State Facilities to implement the State Energy Functional Plan objective to moderate the growth in energy demand through conservation and energy efficiency (Waihee 1994). Governor Benjamin J. Cayetano conveyed his support for the Directive through *Executive Memorandum No. 96-01, Subject: Fiscal and Energy Management* on January 22, 1996 (Cayetano 1996).

Governor Cayetano's Executive Memorandum noted that the state spends about $50 million annually for energy costs and nearly $3 million annually for gasoline and transportation fuels. The Governor urged all departments and agencies to use public funds judiciously by making energy efficiency a priority (Cayetano 1996). Such efforts, of course, would have the additional effect of reducing greenhouse gas emissions from state government operations.

The Executive Memorandum cited many of the potential energy savings measures discussed in more detail in following sections, including performance contracting, the federally sponsored Green Lights Program, and the Model Energy Code. The University of Hawaii Hilo performance contracting effort was cited as an example.

The program goal, as established in an attachment to the Memorandum, was to reduce electric and gas energy use in state facilities by 15% by 1998 using 1992 as a base year. Each department head was directed to report energy use and costs to DBEDT annually. Such reporting has not occurred on a regular basis and it is not clear whether program goals have been met. The program requires revitalization.

One of the challenges of the program as outlined in the attachment to the Memorandum was that state government agencies operate under varying conditions. As the Governor stated in his memorandum, the Department of Accounting and General Services (DAGS) is responsible for operations and maintenance of buildings under its control and for design and construction of most new buildings and facilities. Also the responsibility for electrical costs varies widely among the departments. . . . Some own and manage their own facilities and pay their own utility costs. Others are located in facilities for which DAGS provides centralized engineering services and payments for utility costs. Others lease offices . . . and may or may not pay the utility costs separately from lease rental" (Cayetano 1996).

Each department was charged with aggressively implementing its opportunities for energy efficiency. Section 7.4.2.2, below, describes some of the successes of state government efficiency efforts in the area of performance contracting. Many opportunities remain for further reductions in energy use and consequent reductions in greenhouse gas emissions from state government operations and facilities.

It is recommended that the Governor consider issuing a new Administrative Directive to further stimulate energy efficiency in state government operations. A new quantitative goal could recognizes the commitment of the United States at Kyoto could be set, requiring reduction of energy use by 7% below a 1990 baseline by 2008-2010 with interim objectives over the time period to that date to ensure continuous progress. Such a goal is less ambitious than the Federal Energy Management Program already underway. This goal could be set at the State level regardless of whether or not the Kyoto agreement is ratified by the Senate. Such action will not only reduce greenhouse gas emissions, but also reduce state spending for energy.

7.4.2.2 RECOMMENDATION: Expand Hawaii State Government Energy Performance Contracting

Performance contracting is an innovative arrangement in which a private company, called an energy service company, or ESCO, finances and installs energy efficiency-related equipment and building improvements for a payment that depends on future energy savings resulting from the improvements. There are several features that distinguish energy performance contracting:

- A single procurement is used to purchase a complete package of services and one contractor is accountable for design, purchase, installation, maintenance, and operation of the equipment;
- The package of services includes financing of all of the project costs. No up-front money is needed by the building owner to implement a performance contract;
- The performance contract is structured so that the total payments with the contract are always less than they would have been

without. This is because the annual energy savings produced by the project are greater than its amortized cost;

- State of the art, energy-efficient lighting, air-conditioning systems, energy management control systems, motor replacements, and variable-speed drives for pumps and fans are common improvements. In larger facilities, cogeneration units may be installed;
- Management and maintenance resources are included in the turnkey service; and
- The risk of energy savings performance is transferred to the ESCO, because payments are contingent on actual savings achieved, which are guaranteed by the ESCO.

DBEDT's ERT Division is coordinating a number of performance contracting efforts within Hawaii's state government. The ERT staff provides assistance to state agencies seeking to obtain the benefits of energy performance contracting under Section 36-41, Hawaii Revised Statutes.

In 1992 and 1993, the ERT conducted surveys of potential facilities, seeking an opportunity to implement a demonstration project in energy performance contracting. Of the fifteen state-owned facilities initially surveyed, the University of Hawaii at Hilo (UHH) was considered to have the most potential. ERT staff worked with UHH staff and the University of Hawaii Procurement, Property and Risk Management Office to develop a solicitation. Evaluation procedures and criteria were developed; and a 10-year performance contract was awarded to Johnson Controls, Inc., in 1994. Following development of a comprehensive energy study of the facility, installation of the energy efficient devices was completed in November 1997.

The UH-Hilo project will:

- Inject $2.9 million income into Hawaii's economy and create 44 new jobs;
- Produce over $6.6 million in energy and other cost savings to the University of Hawaii at Hilo and Hawaii Community College (UH-Hilo) over the term of the contract;
- Provide an average $450,000 annual cost savings from lighting and air-conditioning improvements;
- Provide $96,000 in rebates from HELCO's DSM Program; and
- Reduce CO_2 emissions by an estimated 3,757 tons annually.

Based on the experience in this project, DBEDT ERT developed a *Guide to Energy Performance Contracting, which* is being used to stimulate performance contracting activities in other state organizations. Additional projects under development, if fully implemented, will save the state more than $4 million annually in energy costs, leverage $23 million in private funds for energy improvements, bring in an estimated $11.5 million in income to the economy, and create 350 new jobs.

Table 7.9 shows the estimated potential from performance contracting for the State projects now under development. While planners estimated energy cost savings, energy savings were not reported. These were calculated based upon average electricity rates in the service territory where the facility is located. CO_2 emissions savings were estimated using the nominal 1997 value for lbs. CO_2 per kWh for the local utility. It should be noted that part of the financing of these projects may come from utility DSM programs, so this energy and CO_2 savings may be included in the DSM program savings cited above.

Table 7.9 Estimated Future CO_2 Emissions Savings from State of Hawaii Government Performance Contracting Projects

Project		Estimated Annual Savings ($)	Estimated Annual Electricity Savings (kWh)	Estimated Annual CO_2 Emissions Avoided (Tons)
State of Hawaii				
Community College System	$	924,543	8,374,484	8,207
Department of Education (3 school pilot project)	$	35,391	197,384	193
Hawaii Army Nat'l Guard	$	68,576	321,651	315
Judiciary Facilities	$	448,360	3,043,443	2,983
State Library System	$	200,000	1,550,388	1,519
UH Hilo	$	577,000	3,218,070	3,170
Total	$	2,253,870	16,705,420	16,387

Source: State of Hawaii, 1997d.

ERT is providing technical assistance to interested facility and agency managers throughout the performance contracting process, from developing the RFP through monitoring and verifying savings. The University of Hawaii at Manoa offers a major potential for future savings. It is estimated that $3 million could be cut from UH Manoa's electricity bill, saving 96 million kWh, and about 94,240 tons of CO_2. Performance contracts have been implemented at only three Department of Education public schools. Nine others on neighbor islands are expected to have performance contracts in the future, with estimated annual savings of $190,000, 1.2 million kWh, or 1,176 tons of CO_2.

Some major barriers to the rapid deployment of performance contracting have been encountered. Barriers include constraints on the level of indebtedness that state government may incur, uncertainty about the use of tax exempt financing, burdensome procurement processes and heavy agency staff workload, concern about state liability in cases where savings are not achieved or an energy service company (ESCO) becomes bankrupt, concern that agency energy budgets may be frozen at a reduced allocation, and limitation of contract term by statute to a maximum of ten years. The Division is working to overcome these barriers.

Performance contracting not only reduces greenhouse gas emissions, but also contributes to reducing energy costs, reducing tax revenue requirements, and improving Hawaii's economy.

7.4.2.3 RECOMMENDATION: Continue and Expand County Government Energy Efficiency Programs

County energy staff should be encouraged to expand county government energy efficiency programs. Each county's current efforts are described below.

7.4.2.3.1 City and County of Honolulu

City and County of Honolulu efficiency efforts are focused on installing high efficiency lighting under the EPA's Green Lights program and performance contracting. Under Green Lights, the City and County is replacing inefficient lights in the Civic Center Parking Structure and additional facilities. In the Parking Structure, existing lamps and ballasts are being replaced with more efficient ones. The lead project will save over 120,000 kWh per year and its costs will be paid back in less than three years. Other facilities will be upgraded as funds are available, with about 700,000 kWh in estimated electricity savings (Fujiki 1998).

In addition, the City and County of Honolulu is soliciting proposals for an Energy Savings Performance Contract to upgrade Honolulu Hale (City Hall) with new, energy efficient mechanical and electrical systems. This pilot project should save about 500,000 kWh annually. Its success will likely lead to additional performance contracts (Fujiki 1998). Together, the measures currently planned by Honolulu will reduce CO_2 emissions by an estimated 1,294 tons annually. See Table 7.10 for a summary of the CO_2 reductions expected from City and County of Honolulu projects.

7.4.2.3.2 County of Hawaii

ERT staff provided assistance to Hawaii County in pursuing an energy savings performance contract for the County Building. On October 16, 1996, a $623,000 energy performance contract was signed with Honeywell, Inc., for replacement of existing chilled water plant equipment, energy saving controls, lighting retrofit, and maintenance of the same. Total 10-year savings to the County are estimated to be $738,000. Current average electricity use is 1,081,280 kWh and annual energy savings from the contract are projected at 405,594 kWh. The current annual electricity cost for the building is $179,000 and average annual savings are projected to be $60,600. Installation of the retrofit was completed March 1997. It is estimated that seven direct and indirect jobs were created and $262,312 in direct and indirect income to the economy resulted from this project (State of Hawaii 1997d). The measures underway in County of Hawaii facilities are expected to reduce CO_2 emissions by 8,976 tons annually. See Table 7.10 for a summary of the CO_2 reductions expected from County of Hawaii projects.

7.4.2.3.3 County of Kauai

Kauai County's program will reduce electricity use at a variety of county facilities. It focuses on retrofitting a variety of electric devices, including lighting. The Kauai County facility retrofits are expected to reduce CO_2 emissions by 2,923 tons annually (County of Kauai 1997). See Table 7.10 for a summary of the CO_2 reductions expected from County of Kauai projects.

7.4.2.3.4 County of Maui

The County of Maui has a variety of energy efficiency programs that have or will reduce greenhouse gas emissions. These include retrofits of county buildings, and installation of more efficient street lighting, swimming pool heating, and building cooling systems to be completed over the next two years. In addition, Maui County is participating in the Rebuild Maui County program that will include comprehensive performance contracting for County of Maui facilities. County vehicles are expected to use about 20,000 gallons of biodiesel fuel annually from 1997 to 2002. A community low flow showerhead retrofit program, conducted by the County Wastewater Reclamation Division and the Department of Water Supply in association with Maui Electric Company was also completed in 1997 (Kobayashi 1997). Table 7.10 provides a summary of the estimated annual CO_2 emissions savings from Maui County's energy efficiency projects.

As suggested above in the discussion of state government performance contracting, county government performance contracting can not only reduce greenhouse gas emissions, but can contribute to reducing energy costs, reducing tax revenue requirements, and improving Hawaii's economy.

Table 7.10 Estimated Annual CO_2 Emissions Savings from County Government Projects

Project	Estimated Annual Energy Savings	CO_2 Reduction (Tons/Year)	Project Status
City and County of Honolulu[1]			
Civic Center Parking Structure Lighting	120,000 kWh	118	Completion 1998
Building Dept. Lighting Projects	700,000 kWh	686	Completion 1998-1999
Honolulu Hale Performance Contract	500,000 kWh	490	Completion 1998-1999
City and County of Honolulu Subtotal		1,294	
County of Hawaii[2]			
County Building Retrofit	405,594 kWh	409	Performance Contract
Add'l County Building Retrofits	3,400,000 kWh	3,427	Planned FY98-99
Division of Water Supply	4,700,000 kWh	4,737	Planned FY99-00
Wastewater Division	400,000 kWh	403	Planned FY99-00
County of Hawaii Subtotal		8,976	
County of Kauai[3]			
County Facility Retrofits	4,175,000 kWh	2,923	Completion Summer 98
County of Kauai Subtotal		2,923	
County of Maui[4]			
County Building Retrofit	400,000 kWh	376	Completed 02/94
Swimming Pool Heating and Cooling Retrofit	120 Bbl LPG	33	Initiated 07/97; Possibly 2-5 more pools in FY 98-99
Streetlight Retrofit	473,000 kWh	445	Completion Planned 12/98
"Rebuild Maui County" Projects for County Facilities	6,250,000 kWh	5,875	Completion Planned End 99
Biodiesel Demonstration	476 Bbl Diesel	221	5-yr Project to Spring 02
County of Maui Subtotal		6,950	
County Projects Total		20,142	

[1] Fujiki 1998; [2] Carr 1997; [3] County of Kauai 1997; [4] Kobayashi 1997.

7.4.2.4 RECOMMENDATION: Maintain and Extend the Hawaii Model Energy Code

7.4.2.4.1 Development of the Hawaii Model Energy Code

Over a two-year period through 1993, DBEDT developed the Model Energy Code with the assistance of Eley Associates of San Francisco. The Hawaii Model Energy Code is based on American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 90.1-1989, ASHRAE 90.2P, California's Title 24, and the USDOE standard for non-residential buildings with modifications to make the code more appropriate to Hawaii's climate. Provisions relating to the building envelope and water heating systems were developed in response to the unique conditions of Hawaii and differ somewhat from the parent standard. (State of Hawaii 1993b, 5)

The code sets minimum requirements for the energy-efficient design of new buildings, provides criteria for energy-efficient design, and provides methods for determining compliance with these criteria. (State of Hawaii 1993a, 1) It sets standards for electric power; lighting; building envelope; heating, ventilating, and air conditioning systems and equipment; water heating systems and equipment; and energy management.

7.4.2.4.2 Adoption of the Model Energy Code

In 1994, the State Legislature passed Act 168 which required the counties to adopt an energy code based on ASHRAE 90.1 by October 24, 1994. The Model Energy Code meets this requirement.

On October 27, 1994, the City and County of Honolulu adopted the Model Energy Code. The County of Hawaii adopted the code on November 23, 1994. Kauai County adopted the same code as Honolulu in 1995. All three counties exempted low-rise residential buildings from the code. Maui County was still considering the code as of this writing.

When adopted by all of the counties, the Model Energy Code will also bring Hawaii into compliance with the federal Energy Policy Act of 1992 (EPACT). EPACT required each state to certify whether the state has met or exceeded the requirements of ASHRAE 90.1 for commercial buildings and whether the state has determined the appropriateness of meeting or exceeding the national Model Energy Code for residences by October 24, 1994. Hawaii's Model Energy Code has been determined to meet EPACT requirements.

7.4.2.4.3 Impact of the Model Energy Code

All measures included in the Code are cost-effective. Table 7.11 shows the overall estimated energy cost savings and cost. It should be noted, however, that the *Impact Analysis of the Model Energy Code* was published in December 1993 and assumed adoption by all four counties in 1994. In addition, the construction

Table 7.11 Estimated Annual Model Energy Code Savings and Cost

Building Type	Construction Forecast (Square Feet/Year)	Annual Energy Cost Savings	Compliance Cost	Peak Demand Savings (kW/Year)
Non-Residential New Construction				
57 Office Buildings	620,000	$ 446,000	$ 781,000	992
73 Retail Buildings	340,000	$ 215,000	$ 340,000	510
8 Hotel Buildings	880,000	$ 123,000	$ 528,000	264
82 Misc. Buildings	370,000	$ 22,000	$ -	111
Non-Residential Renovations/Additions				
Office	606,000	$ 128,000	$ 206	484
Retail	660,000	$ 152,000	$ 330	462
	Total	$ 1,086,000	$ 1,649,536	2,823
		Estimated MWh/Year Saved	**10,056**	
		Tons of CO_2 per Year	**9,854**	
		Simple Payback Period (Years)	**1.5**	

Based on State of Hawaii 1993b, Table 2, 15; Table 3, 16 forecast was based upon the state average during the period 1980-1989. However, the slowdown in Hawaii's economy since 1991 resulted in less new construction and less energy savings than originally forecast. As the economy improves in the future, compliance with the Model Energy Code will help reduce greenhouse gas emissions from energy use in newly constructed and renovated buildings.

Table 7.12 shows the cumulative energy savings forecast in the original impact study, supplemented by an estimate of CO_2 emissions reduction.

Table 7.12 Estimated Model Energy Code Energy (MWh/Year), CO_2, and Dollar Savings

Year	New Non-Res. (MWh)	Non-Res. Renov. (MWh)	Total (MWh)	Estimated Tons CO_2 Saved	Energy Cost Savings ($/Year)
1994	8	3	11	11,330	$ 1,100,000
1995	16	6	22	22,660	$ 2,200,000
1996	24	8	32	32,960	$ 3,200,000
1997	32	11	43	44,290	$ 4,300,000
1998	40	14	54	55,620	$ 5,400,000
1999	49	17	66	67,980	$ 6,600,000
2000	57	20	77	79,310	$ 7,700,000
2005	97	33	130	133,900	$ 13,000,000
2010	138	40	178	183,340	$ 17,800,000
2013	162	41	203	191,580	$ 20,300,000
20-yr Total	1,699	529	2,228	2,294,840	$ 222,800,000

Based on State of Hawaii 1993b, Table 4, 17

7.4.2.4.4 Sharing the Hawaii Model Energy Code -- The Tropical Code

Since Hawaii's Model Energy Code addresses air conditioning 12 months a year, the U.S. Department of Energy provided a grant to permit Hawaii to share the MEC with Guam, American Samoa, Puerto Rico, and the Virgin Islands. Guam and American Samoa used Hawaii's MEC as a basis for their own code, a "Tropical Code" specific to hotter, more humid climates. The Code will be shared with the Marianas Islands, Palau, and Caribbean nations. Hawaii is also sharing the MEC with the Philippines as part of the Strategic Technology Marketing and Development Program described in Chapter 14.

7.4.2.4.5 RECOMMENDATION: Adopt Model Energy Code for Maui County (Currently Under Consideration) and Adopt Residential Building Model Energy Code in All Counties

To obtain the MEC's benefits, the County of Maui is currently considering the MEC and is encouraged to adopt it. Since air conditioning appears to be a growing end use for residential buildings in Hawaii, the counties are encouraged to favorably reconsider adoption of the residential building portions of the original model energy code or to adapt them further to their requirements.

7.4.2.4.6 RECOMMENDATION: Encourage Continued Use of HiLight Software Program by Lighting Designers to Ensure Model Energy Code Compliance

HiLight is a software program developed for DBEDT in 1996 by Eley Associates on a cost-shared basis with the U.S. Department of Energy. The program is available at no charge from Eley Associates on the Internet at http://www.ely.com or http://www.hawaii.gov/dbedt/ert/mec/app-b.html. The software helps the lighting designer to evaluate and document the lighting performance of new commercial buildings. Currently in use by most lighting designers in Hawaii, HiLight is a compliance tool for the lighting portion of the Hawaii Model Energy Code. It also allows plan checkers to quickly check plans for Code conformance.

HiLight is a major improvement over a previous software program that had major errors. It also allows designers to print out the results or print calculations directly onto blueprints. The program covers all of the Model Energy Code's lighting requirements, including interior lighting power, interior controls, and exterior lighting power.

The Hawaii Model Energy Code, as noted above, is based on ASHRAE Standard 90.1-1989, but includes more stringent lighting requirements. The lower power limits closely match those in 10CFR435, the standard for federal buildings. HiLight can easily be adapted to other regions, especially those with energy codes based on Standard 90.1. For readers who would like information on versions for other states, contact Eley Associates, 142 Minna Street, San Francisco, CA 94105, telephone: (415) 957-1997, email: info@eley.com (State of Hawaii 1998b).

7.4.2.5 RECOMMENDATION: Design and Constructing Buildings Appropriate to Hawaii's Climate to Reduce Energy Use

This recommendation is to go beyond the minimum standards of the Model Energy Code in designing and constructing buildings. As architects Kent Royle, A.I.A. and Cliff Terry, A.I.A. pointed out in their book, *Hawaiian Design: Strategies for Energy Efficient Architecture* (Royle and Terry, 1990), published by DBEDT, the greatest opportunities for energy conservation are in the programming, schematic design, and design development stages of a project. The architect's work is critical to energy efficiency. Their book presents seven design strategies which can improve the energy efficiency of buildings in Hawaii. They can also contribute to the Hawaiian "sense of place" (A-6)

Royle and Terry presented the following design strategies for energy efficient buildings:

- Consider orientation for solar control, to allow daylighting, and for optimum ventilation (B16-B17);
- Employ solar control through shading and glazing (C20-C22);

- Use daylighting to reduce the need for electric lighting and air conditioning C-26-C27);
- Provide for natural ventilation in placement, location, and type of windows, and supplement with fans (E30-E34);
- Plant landscaping to protect from the sun and to enhance natural ventilation (F-36);
- Select building systems and materials for energy efficiency (G38-G42); and
- Select efficient air conditioning, humidity control, lighting, and building system controls for energy efficiency (H44-H46.

The book also provided guidance for implementing the energy efficient designs.

A technology discussed by Virginia Macdonald, A.I.A., in her paper, *Beyond the Better Light Bulb* (Macdonald 1997), is passive solar design. Passive solar design can provide warming with drying or cooling with drying as appropirate. Electricity savings of 30-80% were reported for passive solar buildings in comparison to conventional structures.

The designs involve creating temperature differences between two volumes of air to create an air flow. The building is designed to have a stack through which sun-heated air is impelled to move upward. Cool air is pulled in from under a raised floor surrounded by a foundation wall, from underground pipes, or through low wall vents shaded by vegetation. According to Macdonald, in Hawaii, even with the air temperature over 90 degrees F, replacement air under a building with a foundation wall is about 69 degrees F (5) Advantages of passive solar design, in addition to the energy savings cited above, include:

- Less or no need for air conditioning with its potential for "sick building syndrome;"
- Skylights used to activate air movement can reduce or eliminate the need for electric lighting during daylight hours;
- Open windows are not required for fresh air, eliminating safety concerns and the need for screens, and improving views;
- By admitting controlled amounts of air, the introduction of dust, heat, and, near the ocean, salt can be reduced (2).

Additional information on passive solar design is available in Ms. Macdonald's book, *Cooling Through Natural Ventilation* and James Leonard's *The House in the Sun, Solar Conscious Architecture for Hawaii and the Tropics*. The latter is available from the DBEDT Energy Branch.

7.4.2.6 RECOMMENDATION: Continue and Enhance Hawaii Participation in U.S. Government-sponsored Energy Efficiency Programs

7.4.2.6.1 Institutional Conservation Program

The Institutional Conservation Program (ICP) was a U.S. Department of Energy-sponsored grant program which granted up to 50% matching funds to non-profit schools and hospitals to conduct engineering studies and undertake retrofits to replace aging, inefficient equipment with state-of-the-art, high-efficiency equipment. Lighting was the most common retrofit.

During the period 1990-1994, about $4.2 million in federal and matching funds were invested in ICP projects in Hawaii. The resulting yearly savings are about $1 million in electricity costs, and the typical life of equipment installed is 15 years. The ICP program should yield total cost savings of $15 million and 165 million kWh. Using estimated 1997 HECO system CO_2 emissions of 1.96 lbs./kWh, this represents about 161,700 tons of CO_2 emissions over the 15-year period.

The most successful project in this program was the installation of heat pipes at Kaiser-Moanalua Medical Center. Heat pipes remove moisture from the air before it enters the air conditioning (AC) system and re-heats the cold air leaving the AC system without using any energy. The project reduced Kaiser's electricity use for AC by 1.3 million kWh per year and is expected to last 20 years for an estimated total savings of 26 million kWh, or about 27,000 tons of CO_2.

7.4.2.6.2 Rebuild America Program

The State of Hawaii is also participating in the U.S. Department of Energy's Rebuild America Program which focuses on stimulating the economy and achieving cost savings through the increased use of energy efficient technologies in the public and private sectors. There are six Hawaii State partners including the Counties of Kauai, Hawaii, and Maui. The program is initially focusing on encouraging energy performance contracting to retrofit government buildings with energy efficient technologies. The program will be expanded to include public sector multi-family housing and small commercial businesses. Savings from the initial government facilities program are described in sections on Hawaii State Government Performance Contracting and County Government Energy Efficiency Programs, above.

7.4.2.6.3 Green Lights Program

The U.S. Environmental Protection Agency's Green Lights Program is a voluntary, non-regulatory program aimed at promoting energy efficiency through investment in energy-saving lighting. The program saves money for participants and reduces pollutants and greenhouse gas emissions.

The State of Hawaii, Bank of Hawaii, First Hawaiian Bank, and the Hawaii Hotel Association are Green Lights Partners. The Hawaiian Electric Company is a Green Lights Ally. As such, these organizations pledged to retrofit 90% of their facilities to energy-efficient lighting systems within five years of joining.

The savings from this program are difficult to attribute as each of the partners are undertaking additional energy conservation programs independently of their Green Lights commitment. An extremely conservative estimate of savings attributable to Green Lights would be $500,000 and 5.5 million kWh and may be closer to $1 million and 11 million kWh annually. This would be 5,390 to 10,780 tons of CO_2 emissions avoided annually. The average life of installed lighting is 15 years. Many of these programs may also fall under utility DSM programs.

7.4.3 RECOMMENDATION: Support Federal Energy Management Program in Hawaii

7.4.3.1 Federal Government Electricity Use in Hawaii

The federal government is a major user of electricity in Hawaii. In particular, Hawaii's large military facilities, especially on Oahu, are major consumers of electricity. In 1996, military facilities used 16.4% of the electricity sold on Oahu (Chang 1997). To generate the electricity purchased by the Department of Defense in 1996, HECO emitted 1,218,880 tons of CO_2. Table 7.13 shows electricity use by the Department of Defense on Oahu from 1990 to 1996.

7.13 U.S. Department of Defense Electricity Use on Oahu (Gwh), 1990-1996

	1990	1991	1992	1993	1994	1995	1996	Growth
DoD	1,076	1,085	1,074	1,065	1,074	1,107	1,172	8.9%
Oahu	6,475	6,480	6,633	6,606	6,791	6,927	7,130	10.1%
DoD Percent of Total	16.6%	16.7%	16.2%	16.1%	15.8%	16.0%	16.4%	
Estimated DoD Tons CO_2	1,065,240	1,025,325	1,025,670	1,091,625	1,031,040	1,151,280	1,218,880	

Source: Chang 1997

It should be noted that, while overall electricity sales grew by 10.1% between 1990 and 1996, military use increased at a slower rate of 8.9%. Some force reductions may have slowed the growth of military electricity use, but the Federal Energy Management Program was a likely additional factor.

7.4.3.2 Federal Energy Management Program

- The mission of the Federal Energy Management Program (FEMP) is to reduce the cost of government by advancing energy efficiency, water conservation, and the use of solar and other renewable energy. Section 543 of the National Energy Conservation Policy Act, as amended by the Energy Policy Act of 1992, required each federal agency achieve:

- 10% reduction in energy consumption in its federal buildings on a Btu per gross square foot basis by FY1995 against a FY1985 baseline; and
- 20% reduction in Btu per gross square foot by FY2000 (USDOE 1998).

In addition, agencies are required to achieve a 30% reduction against the FY1985 baseline by FY2005 per Executive Order 12902 (USDOE 1998). A key element of FEMP activities has been partnership with local electric utilities and demand-side management incentives offered by those utilities.

In his radio address to the nation on July 25, 1998, President Clinton took further action to decrease energy use in Federal buildings and facilities to reduce greenhouse gas emissions and to save taxpayer dollars. He announced the following actions:

- Directed cabinet agencies to work more closely with private contractors to retrofit Federal buildings and other facilities with the best energy saving technology. This would save as much as $700 million and reduce as much as 2 million metric tons of carbon annually;
- Replace 300,000 lightbulbs with energy efficient flourescents over the next three years for a $13.5 million savings and 40,000 metric tons of carbon reduction;
- Directing agencies to bring existing Federal buildings up to the EPA Energy Star efficiency standard; and
- Adopting "sustainable design" guidelines for construction of new buildings for the Department of Defense and six other agencies (Clinton 1998).

Actions being taken by the federal government offer examples that can be imitated at the state and county levels, as well as by private business.

7.4.3.3 Federal Civilian Energy Efficiency Projects in Hawaii

In 1997, renovation of the air conditioning system of the Prince Jonah Kuhio Kalanianaole Building, also known as the Federal Building, was completed. The General Services Administration (GSA), which manages the building, worked with HECO in designing a replacement of the 18-year old system. The project had the following goals: meet Federal energy efficiency mandates, reduce operations and maintenance costs, discontinue the use of ozone depleting refrigerants, and improve comfort.

The renovation was accomplished under a basic ordering agreement between GSA and HECO. It provided new, more efficient chillers, cooling towers with two-speed energy-efficient motors, and energy-efficient pumping system all integrated into a computerized energy management system. (GSA 1997) While data was not provided on savings, the new system represented an improvement and reduced greenhouse gas emissions.

7.4.3.4 Air Force Energy Efficiency Projects in Hawaii

Air Force energy efficiency projects include installation of efficient lighting and occupancy sensors in base industrial facilities. In addition, as part of renovation of Hickam Air Force Base family housing, heat recovery systems on central air conditioning units will provide hot water. Solar water heating is less practical on Hickam as trees shade most housing areas.

An energy services performance contract was recently issued for improvements the Pacific Air Force Headquarters Building, the largest building on base. It is currently in the design stage.

A particular challenge to energy use reduction is the fact that Air Force facilities in Hawaii were below current design standards in energy use per square foot in the FEMP 1985 baseline year in part due to the existence of many unoccupied warehouses since demolished. With increasing use of air conditioning and increased office automation, it is increasingly difficult to reduce energy use in absolute terms. Currently, daylighting of office and workspaces is under investigation (Young 1998).

7.4.3.5 Army Energy Efficiency Projects in Hawaii

U.S. Army Garrison Hawaii operates all Army installations in Hawaii, providing installation management service and logistical support. The Directorate of Public Works Environmental Division has a very active energy savings program as part of a comprehensive pollution prevention program. Fiscal Year 1996 (FY96) was the fourth consecutive year that energy consumption was reduced under this program (USAG-HI 1997).

Total energy consumption was reduced from a 37.6 kBtu/square foot baseline to 33.95 kBtu/square foot in FY96. As Army facilities totaled almost 30 million square feet, this amounted to an estimated savings of 109,500 million Btu, or about 2,239 tons of CO_2 by 1996 as compared to the baseline year 1985. In FY96 alone, there was a savings of 364,276 kWh of electricity. At the 1997 estimated rate of 1.96 lbs. CO_2 emitted per kWh, this was a reduction of 357 tons of CO_2. Electricity costs of $2,873,588 were avoided in FY96 (USAG-HI 1997).

These reductions were achieved through a variety of energy awareness and energy efficiency programs. A relamping contract, developed using FEMP funding, retrofitted over 100 buildings with T8 fluorescent bulbs with electronic ballast, compact fluorescent bulbs, and LED exit signs. The project upgraded lighting in many buildings and removed PCB ballasts. A recycling program was developed to recycle the old fluorescent light tubes, which also contain hazardous materials. The longer lifetimes of the new lighting will reduce future maintenance costs. and disposal costs. Air conditioning costs were reduced due to the lower heat gain from the new lights (USAG-HI 1997).

7.4.3.6 Marine Corps Energy Efficiency Projects in Hawaii

The Energy Management Team at Marine Corps Base Hawaii developed a 25-year performance contract that will implement up to $24 million in energy savings. The contractor will propose, finance, and execute measures guaranteed to produce annual energy ancillary cost savings of approximately $4 million. The objective is to significantly reduce the Marine Corps Base's $8 million annual energy bill and its $9 million maintenance and repair costs. The initial project under consideration in late 1997 was to install high efficiency lighting fixtures in four buildings. Energy and emissions savings were not quantified in available sources. (FEMP 1997)

7.4.3.7 Navy Energy Efficiency Projects in Hawaii

The Navy is involved a major energy efficiency program for implementation under a basic ordering agreement (BOA) with HECO at a number of Navy-operated facilities on Oahu. In FY 97, energy audits were performed at Pearl Harbor Naval Shipyard, Submarine Base Pearl Harbor, and Joint Intelligence Center - Pacific. Additional audits were started in FY98 at the Public Works Center, Lualualei Naval Magazine, and various computer and telecommunications facilities.

The BOA is similar to a performance contract except, upon completion of construction, the customer accepts ownership of the equipment and operation and maintenance (O&M) responsibilities. Under a performance contract, the contractor retains ownership and handles O&M for the life of the contract. Also, results under the BOA are not guaranteed, but were developed by an engineering estimate.

At this time, the Pacific Division, Naval Facilities Engineering Command is administering the contracts for the Navy. Any DoD component can use this agreement to get energy efficient equipment installed at their installation.

The current Navy program is estimated to cost $24.9 million and will result in annual savings of 29 million kWh or about 29,000 tons of CO_2. The energy savings will reduce the Navy's electricity bill by about $3.4 million per year and will earn a rebate from HECO's DSM program of $1.3 million (Kawamoto 1998).

7.5. Reduce Electricity Sector Greenhouse Gas Emissions from the Supply-Side

Greenhouse gases can also be reduced by activities that improve the efficiency of electricity generation or offset emissions from electricity generation. Ongoing activities included the AES Hawaii Carbon Offset program, cogeneration, renewable energy use, and the completion of a Public Utilities Commission Docket on Renewable Energy.

7.5.1 Programs to Offset Carbon Emissions

7.5.1.1 An Example: The AES Hawaii Carbon Offset Program

AES Hawaii is an independent power producer that operates a 180 MW atmospheric fluidized-bed coal plant located in the Campbell Industrial Park at Kapolei, Oahu. The plant began operation in May 1992, selling electricity to HECO under a power purchase agreement and providing steam for process heat to the nearby Chevron USA oil refinery.

According to *AES Carbon Offset Programs Summer Update 1991* (Cooper 1996), AES voluntarily initiated action to offset the carbon which would be produced and emitted into the atmosphere as carbon dioxide even as the plant was under construction. As the *Update* noted,

> Although no regulations exist for the emission of CO_2, AES has taken steps to develop carbon mitigation programs in line with its value of social responsibility. AES Hawaii's carbon offset strategy currently involves balancing carbon released from its power plans with carbon sequestration, the process of increasing the carbon that is stored in forests and other living matter. This strategy is possible because carbon absorbed through photosynthesis and makes up roughly half of the mass of a tree (Cooper 1996).

AES Hawaii estimated that its Barbers Point cogeneration plant would emit about 14.8 million tons of carbon (54,266,665 tons of CO_2) over its nominal 35 year operational life. Under a December 1991 agreement with The Nature Conservancy, AES Hawaii invested $2 million in the 57,700 hectare (142,519 acre or 223 square mile) Mbaracayú Forest Nature Reserve in Paraguay under the condition that 13.1 million metric tons (about 14.41 million tons) of carbon would be sequestered in the biomass of the reserve. A detailed analysis, *Mbaracayú Forest Nature Reserve Forest Biomass Sequestered Carbon Estimates*, indicated that about 27 million metric tons of carbon (about 29.7 million tons of carbon or 108,800,000 tons of CO_2) would be sequestered over the 35-year period. AES Hawaii made the investment and The Nature Conservancy and Fundación Moisés Bertoni purchased and set aside the tract which would otherwise have been developed, reducing its carbon sequestration value (Cooper 1996). This is an example of the type of offset that can be developed anywhere since CO_2 has a global circulation pattern and offsets can be located in any part of the world.

7.5.1.2 RECOMMENDATION: Establish Additional Carbon Offset Programs and/or Participate in Emissions Permit Trading Systems

Electricity producers in Hawaii should be encouraged to establish voluntary carbon offset programs. First priority could be to forestry projects or reforestation in Hawaii, which would also provide local economic benefits. Urban tree planting could contribute to CO_2 absorption as well as reducing energy requirements by shading and heat reduction.

Depending upon the nature of any carbon emission permit trading system which may be created to encourage compliance with international agreements, carbon offset programs could become increasingly cost effective compared to the cost of permits. Participation in these programs will serve to internalize the costs of reducing greenhouse emissions.

7.5.2 Cogeneration

Cogeneration is the generation of electricity and the concurrent use of excess heat produced in the generation process for some additional useful purpose. The effect of cogeneration is to gain more use per Btu of energy used and a reduction in Hawaii's overall greenhouse gas emissions below the level that would have otherwise been produced. Outside the sugar industry, cogeneration avoided an estimated 218,141 tons of CO_2 emissions in 1995.

7.5.2.1 AES Hawaii

AES Hawaii is a 180 MW atmospheric fluidized-bed combustion coal plant located on Oahu. AES Hawaii burned 620,286 tons of coal in 1995, emitting 1,559,690 tons of CO_2. AES Hawaii sold 1,370,161 MWh of electricity to HECO. In addition, 293,972 million Btu of steam were sold to the Chevron refinery for use as process heat, offsetting CO_2 emissions of 25,291 tons (based upon emissions for an equivalent heat value of residual fuel oil) for net CO_2 emissions of 1,534,399 tons (State of Hawaii 1998a).

Further, as discussed above, AES offset its CO_2 emissions beginning in 1992 by establishing a forest preserve in Paraguay which serves as a carbon sink, absorbing an estimated 3,111,000 tons of CO_2 annually. Taking the AES-funded carbon sink into account, the net 1995 CO_2 emissions for the AES Hawaii Plant was a <u>negative</u> 1,576,601 tons CO_2. However, due to the current absence of internationally accepted rules for accounting for offsets, the effects of the sink are not counted in this initial Plan.

7.5.2.2 Kapaa Generating Partners

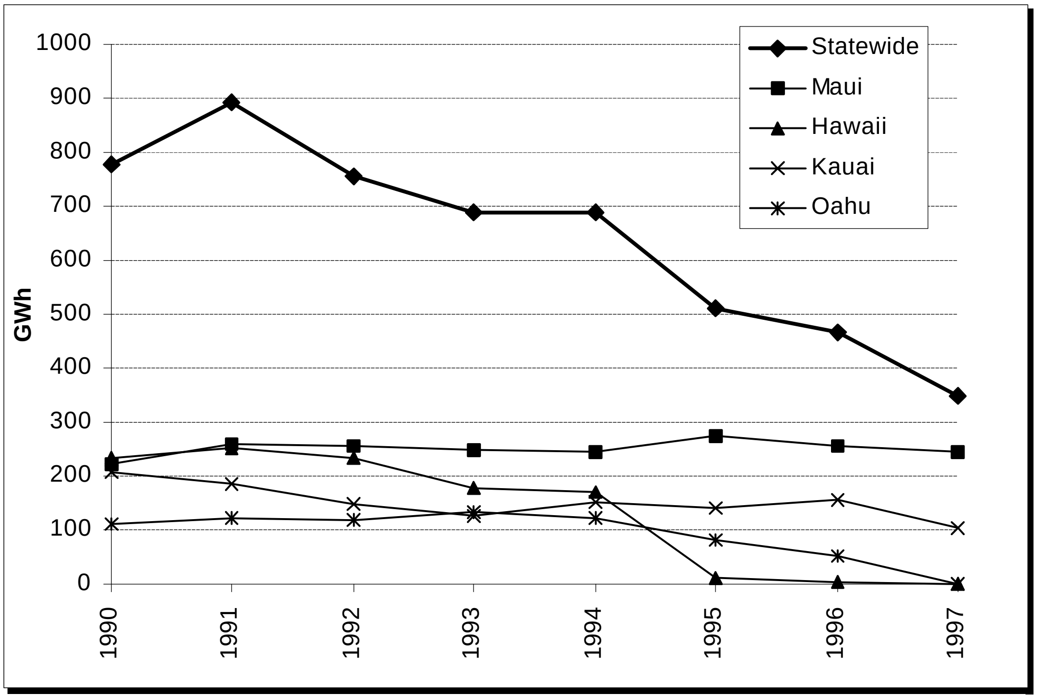
Since 1990, Kapaa Generating Partners has operated a cogeneration unit fueled by landfill methane from the Kapaa Landfill in Kailua, Oahu. A 3.3 MW combustion turbine generator produces electricity and provides process heat to Ameron HCD's collocated quarry operation. The heat is used to dry sand at the quarry, saving 440,000 gallons of diesel fuel annually (Lum 1997, A-2). As 1995 was atypical, 1996 production was used for comparison. In 1996, the facility generated 19,457 MWh of electricity, using 5,877 tons of methane (State of Hawaii 1998a). The use of methane as fuel produced 16,963 tons of CO_2, but use of waste heat saved diesel fuel that, if burned, would have produced 4,020 tons of CO_2. When the GWP of the CO_2 emissions from the generator is compared with the GWP of the methane burned (129,294 tons of CO_2 equivalent), it was calculated that this facility reduced Hawaii's GWP by 116,351 tons of CO_2 equivalent by preventing the escape of the methane into the atmosphere.

7.5.2.3 Kalaeloa Partners

Kalaeloa Partners has operated a 180 MW residual fuel oil-fired dual turbine, single steam turbine combined cycle generator at Campbell Industrial Park on Oahu since 1993. In 1995, this unit used 2,183,909 barrels of residual fuel oil and 8,837 barrels of distillate fuel oil to generate 1,300,380 MWh of electricity for sale to HECO (State of Hawaii 1998a). Total CO_2 emissions were calculated to be 1,181,932 tons. In addition, 889,199 million Btu of steam were sold to the BHP Hawaii refinery, a heat value equivalent to 141,435 barrels of residual fuel oil, offsetting 76,499 tons of CO_2. Net CO_2 emissions were 1,106,194 tons.

7.5.2.4 Sugar Industry

Hawaii's sugar industry historically has been an important source of electricity for electric utilities and for its own needs. As recently as 1962, 18% of Hawaii's electricity was produced by the sugar industry.



Source: Unpublished data, Hawaii Agricultural Research Center.

Figure 7.10 Sugar Industry Electricity Generated for Internal Use and for Sale to Electric Utilities(GWh), 1990-1997

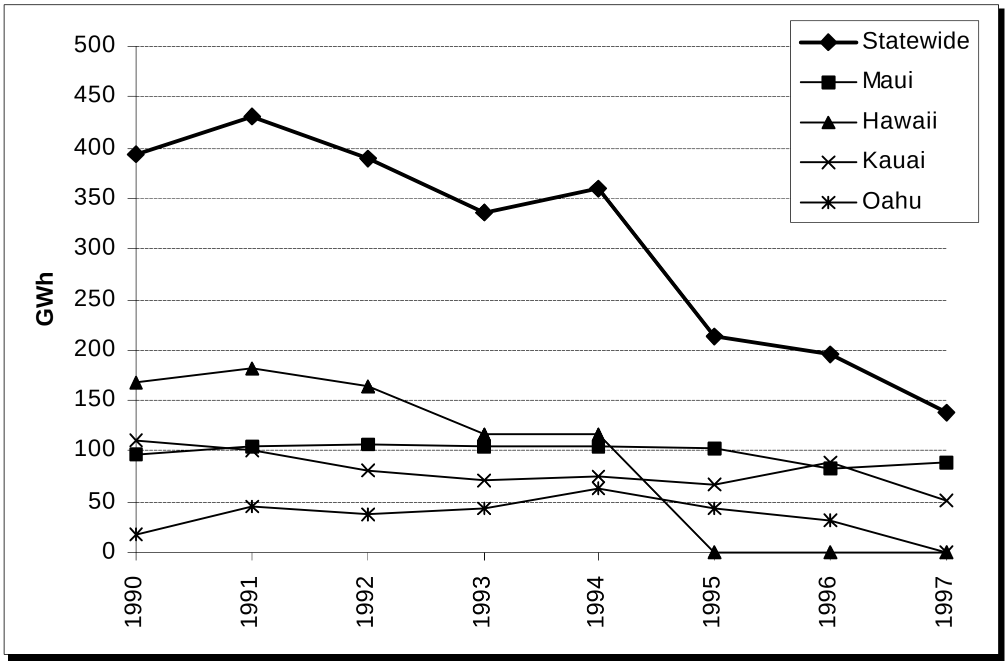
Figure 7.10 shows the decline in electricity produced by sugar plantations between 1990 and 1997. Sugar plantations are important sources of renewable energy, using sugar cane bagasse as their principal boiler fuel for electricity generation and production of process heat. In addition, some plantations operate small hydroelectric generators. Increasingly, however, these renewable sources have been supplemented by burning fossil fuels in sugar mill boilers, including No. 2 and No. 6 fuel oil, waste oil, and coal. A further negative trend has been the closure of many sugar plantations for economic reasons.

All plantations on Oahu and the Island of Hawaii have closed since 1990. Some closures and changes of ownership occurred on Kauai, but plantations remained in operation on Kauai and Maui as of late 1998. The end of sugar production on Oahu and Hawaii reduced the amount of renewable energy available to Hawaii utilities. As Table 7.14 and Figure 7.11 show, since 1990, this was accompanied by a general decline in the proportion and amount of sugar industry generation sold to the utilities except for the sugar plantations on Kauai.

Table 7.14 Percentage of Sugar Industry-Generated Electricity Sold to Utilities

	1990	1991	1992	1993	1994	1995	1996	1997
Hawaii	72%	72%	71%	65%	69%	0%	0%	closed
Kauai	53%	54%	55%	57%	49%	48%	57%	49%
Maui	43%	40%	42%	42%	43%	37%	32%	36%
Oahu	17%	37%	32%	33%	51%	53%	61%	closed
Statewide	51%	48%	52%	49%	52%	42%	42%	40%

Source: Unpublished data, Hawaii Agricultural Research Center



Source: Unpublished data, Hawaii Agricultural Research Center

Figure 7.11 Sugar Industry Electricity Generated and Sold to Utilities, 1990-1997

As seen on Table 7.15, since 1990, 71 to 78% of the electricity generated by the sugar industry was produced using renewable resources, primarily bagasse supplemented with some hydroelectric generation from run-of-the-river plants. This proportion decreased from 78% in 1990 to 71-72% from 1991 to 1993, spiking to 77% in 1994, and again dropping to a range of 71-73% in 1995-1997. This percentage depends largely on rainfall and the size of the sugar harvest. Data is not available to determine the exact amount of renewable resources used to generate electricity sold by the sugar plantations to the utilities compared to that used for generation for the plantation's own use. Therefore, a percentage equal to the overall percentage generated by renewables was assumed to be the amount used to generate electricity for sale to the utilities.

Table 7.15 Percentage of Sugar Industry Electricity Produced from Renewable Resources 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
Hawaii	72%	65%	69%	72%	68%	closed	closed	closed
Kauai	85%	87%	83%	85%	86%	91%	94%	91%
Maui	77%	65%	72%	70%	80%	61%	63%	65%
Oahu	84%	67%	66%	66%	72%	67%	60%	closed
Statewide	78%	71%	72%	72%	77%	71%	73%	72%

Source: Unpublished data, Hawaii Agricultural Research Center

CO_2 savings as a result of renewable energy use in the sugar industry are discussed in Section 7.5.3, below.

7.5.2.5 RECOMMENDATION: Maximize Cost-Effective Cogeneration

From the above discussion, it is clear that maximum efficiency of fuel use and heat by-products of electricity generation can be achieved through cogeneration whenever technically appropriate.

7.5.3 Renewable Energy Use

7.5.3.1 Renewable Energy Use in Hawaii

Table 7.16 summarizes the amount of CO_2 avoided by use of electricity generated from renewable resources in each of Hawaii's electric utility systems.

Table 7.16 CO_2 Emissions Avoided by Renewable Energy Generation for Hawaii Utilities (Tons), 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
HECO	340,674	354,185	352,663	354,056	376,811	390,835	327,517	381,014
HELCO	184,061	171,003	163,276	250,588	293,307	272,264	286,400	312,877
KE	75,112	72,009	54,120	49,284	48,950	46,846	47,650	30,466
MECO	65,434	63,201	72,209	65,999	66,739	73,653	77,417	75,019
Statewide	**665,280**	**660,398**	**642,268**	**719,927**	**785,806**	**783,598**	**738,985**	**799,377**

Use of renewable energy resources to generate electricity ultimately sold to utility customers reduced CO_2 emissions by replacing fossil fuel generation. Non-utility generators and the sugar industry were the primary producers of renewable energy. Between 1990 and 1997, renewable energy resources provided Hawaii's electric utilities 5,870,969,855 kWh of electricity, or 7.8% of the total (State of Hawaii 1998a; HARC 1990-1998), avoiding 5,795,640 tons of CO_2 emissions, for an average reduction of 724,455 tons of CO_2 per year.

In developing these estimates, renewable energy generation sources were considered to be sugar bagasse, wind, hydroelectricity, geothermal, landfill methane, and municipal solid waste. The estimation of sugar industry renewable energy production was based upon the overall percentage of renewable energy (bagasse and hydroelectric) generation by each plantation with kilowatt-hours sold to the utilities. Total energy used by each sugar mill was allocated to internal use and to electricity production for sale on the basis of this percentage. The values in this section do not include electricity generated by plantations for internal use, these emissions are discussed in Chapter 8 in the section on industrial energy use. Bagasse generation was assumed to be CO_2 neutral, that is, an equivalent amount of CO_2 was taken up in growing the bagasse to that emitted when it was burned.

As Tables 7.17 and 7.18 depict, there was a wide variation by utility in the percentage of electricity sales produced by renewable resources.

Table 7.17 Percentage of Utility Electricity from Renewable Sources, 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
HECO	5%	5%	5%	5%	5%	5%	4%	5%
HELCO	21%	19%	19%	31%	37%	32%	33%	35%
KE	25%	22%	18%	16%	16%	15%	18%	11%
MECO	8%	7%	8%	7%	7%	8%	7%	7%
Statewide	7.7%	7.7%	7.0%	8.0%	8.6%	8.0%	7.4%	7.9%

Renewable energy use by HELCO, on the Big Island, increased by 93% between 1990 and 1997. Between 1990 and 1992, most of the renewable energy purchased by HELCO was produced by the sugar industry. However, beginning in 1993, geothermal energy became the major source as the sugar plantations that sold electricity to HELCO began scaling back operations and all closed by 1995.

Kauai Electric's renewable energy came entirely from sugar industry sources, principally sugar bagasse with overall renewable energy sales to the utility declining by 0.5% from 1990 to 1997.

Virtually all of MECO's renewable energy was produced by the sugar industry, except for small amounts of wind and PV solar energy. MECO's use of renewable energy increased by 17%.

On Oahu, municipal solid waste (MSW) produced most of the renewable energy used by the utility throughout the period. HECO also obtained energy from independent power producers burning landfill methane and using wind. The sugar industry provided renewable energy using bagasse until all sugar operations on Oahu closed in 1995. In 1996, the Makani Uwila wind farm also ceased operations. Nevertheless, renewable energy sold to HECO was 13% greater in1997 than in 1990.

Statewide, 1997 renewable energy use in kWh was 16% greater than in 1990. Although the sugar industry started the decade producing the largest percentage of renewable energy for utility sales, it was surpassed in 1991 by MSW, and in 1994 by geothermal. MSW currently provides the largest percentage of the state's renewable energy. Table 7.18 shows the relative contribution of each renewable technology for the period.

Table 7.18 Percentage Contribution to Utility Electricity Sales by Renewable Resources, 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
Sugar Bagasse	3.0%	3.0%	2.7%	2.4%	2.3%	1.5%	1.4%	1.1%
Geothermal	0%	0%	0%	1.5%	1.8%	2.3%	2.3%	2.3%
Hydroelectric	0.7%	0.6%	0.4%	0.4%	0.6%	0.5%	0.5%	0.4%
Wind	0.4%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
LF Methane	0.1%	0.2%	0.2%	0.1%	0.2%	0.1%	0.1%	0.2%
MSW	3.5%	3.6%	3.5%	3.3%	3.5%	3.5%	2.8%	3.8%
Total Renewable	7.7%	7.7%	7.0%	8.0%	8.6%	8.0%	7.4%	7.9%

Finally, Table 7.19 presents a summary of estimated savings of CO_2 emissions by renewable energy source. Sugar industry generation came primarily from bagasse, but included some hydro. CO_2 savings produced by independent wind farms and hydroelectric facilities are reported separately. The "Wind/Hydro" category reported is for electricity generated by those sources owned by HELCO. HELCO reporting did not differentiate between them.

Table 7.19 Estimated Tons of CO_2 Emissions Avoided by Renewable Electricity Generation Sold to Utilities by Source, 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
Sugar Industry	15,466	108,304	87,093	89,062	103,148	83,896	75,625	42,094
Geothermal	-	-	1,176	130,447	152,403	221,788	229,850	225,011
Hydroelectric	-	-	33,298	17,180	40,746	19,687	22,544	50,161
Wind	33,831	28,126	19,441	18,953	15,767	20,642	18,943	14,958
Hydro and Wind	25,784	22,714	9,313	12,808	16,635	16,144	18,345	22,747
LF Methane	8,771	16,318	13,707	10,207	14,364	8,690	15,072	19,903
MSW	304,987	299,542	310,243	309,332	316,652	345,524	289,721	361,111
Total Renewable	**665,280**	**660,398**	**642,268**	**719,927**	**785,806**	**783,598**	**738,985**	**799,377**

7.5.3.2 Near-Term Prospects for Additional Renewable Energy

As of late 1998, developers have proposed new wind projects for Oahu, Maui, and Hawaii, and a large photovoltaic project for Hawaii. It is not clear whether or not they will be built. Power purchase agreements were being negotiated at this writing, but there is no assurance that agreements will be completed.

On Oahu, an effort to use the former Waialua Sugar power plant to produce up to 12 MW of energy from energy crops and waste oil closed in July 1998. The project had encountered difficulty in obtaining green waste as an interim fuel and was only able to sell power at relatively low as available rates. It is clear that further action is needed to encourage a resurgence of renewable energy in Hawaii.

Defense Department agencies are also involved in renewable energy activities. The Navy is planning a 2 kW building integrated photovoltaic system installation on the Boat House on Ford Island. The project team consists of the University of Hawaii School of Architecture, Pearl Harbor, National Renewable Energy Laboratory, and Hawaiian Electric Company (Seki 1998).

In 1996, at Hickam Air Force Base, the Air Force, U.S. Environmental Protection Agency, Electric Power Research Institute, Ascension Technology, Inc., and HECO cooperating to install an 18 kW photovoltaic system on the auto craft shop building. The project is being used to evaluate the potential of building-mounted photovoltaic systems in meeting peak energy demand and energy requirements as part of an air pollution mitigation strategy. The system saves about 31,500 kWh per year. This amounts to annual monetary savings of $3,150. It also saves 53 barrels of oil equivalent and reduces Hawaii's emissions by 55,190 lbs. (27.6 tons) of CO_2 and 182 pounds of NO_x annually (Seki 1998).

Hawaiian Electric Company and the Department of Defense personnel are conducting preliminary site assessments for possible large-scale photovoltaic installations in Hawaii. Currently, it appears that the costs involved will not be economical (Seki 1998).

In addition, the three HECO companies' "Sunpower for Schools" project has installed photovoltaic systems on several Hawaii high schools. The installations are financed by the company and voluntary customer contributions.

On the Big Island, the Mauni Lani Resort installed a 75 kW PV system on its roof in 1998.

The following are recommended actions in the area of renewable energy:

7.5.3.3 RECOMMENDATION: Continue to Encourage Renewable Energy Use Through Renewable Energy Tax Credits

The State of Hawaii began offering renewable energy tax credits in 1977, starting with an energy device tax credit in which a state resident could claim a 10% of the cost of a solar water heater against his or her state income tax. At the time, the state tax credit supplemented a federal tax credit of 30%. In 1979, the state credit was extended to cover installation of up to $30 of insulation material. The following year, the federal tax credit was increased to 40%. The state tax credit was extended to wind energy and home heat pumps in 1981and commercial heat pumps became eligible in 1983. Ice storage became eligible for what became a 15% state energy tax credit in 1986. 1986 was also the first year after the federal tax credit expired. Although the state energy tax credit was 15%, the reduced federal offset had a major negative impact on solar water heater sales. Sales plummeted from 6,740 units in 1985 to 592 in 1986. Ultimately, the state energy tax credit was raised to 20% in 1989 and to the current rates depicted on Table 7.20 (State of Hawaii1996f).

Table 7.20 Hawaii Energy Tax Credits

Technology	State Income Tax Credit	Maximum Amount
Solar Systems (Thermal and Photovoltaic)		
Single Family Home	35%	$1,750
Mulit-Unit Dwelling Unit	35%	$350
Hotels, Commercial, and Industrial Facilities	35%	Actual Cost
Heat Pumps		
Single Family Home	20%	$400
Mulit-Unit Dwelling Unit	20%	$200
Hotels, Commercial, and Industrial Facilities	20%	Actual Cost
Wind System	20%	Actual Cost
Ice Storage System	50%	Actual Cost

(State of Hawaii 1996c)

In 1990, the credits were also extended to December 31, 1998. In 1998, the tax credits were extended another five years, to 2003. Most of the State Energy Tax Credits have gone for solar water heating systems, although some photovoltaic systems and photovoltaic-powered ceiling vent systems have also employed the credit. As the best data is available on solar water heating, it will be the focus of the remaining discussion in this section.

7.5.3.4 RECOMMENDATION: Increase Use of Solar Water Heating

A large base of solar water heating in Hawaii was installed prior to the current residential water heating DSM programs offered by the electric. Table 7.21, on the following page, shows the estimated CO_2 emissions savings due to the use of solar water heating between 1990 and 1995. The utility solar water heating DSM programs have been in effect only since 1996, so the savings depicted on Table 7.21 represent the efforts of homeowners assisted by the State Energy Tax Credit. The emissions savings estimate was based upon kWh savings estimated by Leonard Greer in the *1995 Renewable Energy Data Report* (Greer 1997).

Utility DSM incentives and the renewable energy tax exemption complement each other in encouraging solar water heating installation. Significant additional CO_2 emissions reductions are likely possible from new solar water heating systems. See Section 7.4.1 for more detail on utility solar water heating DSM programs.

Table 7.21 Estimated CO_2 Emissions Avoided by Solar Water Heating Use (Tons), 1990-1995

County	1990	1991	1992	1993	1994	1995
Honolulu	36,286	36,817	37,846	41,874	40,508	44,942
Hawaii	3,861	3,964	3,689	3,976	4,099	4,732
Kauai	1,763	2,005	2,259	1,561	1,530	1,605
Maui	12,438	13,015	13,572	14,042	16,591	16,158
Statewide	54,349	55,801	57,366	61,453	62,728	67,437

(Greer 1997)

7.5.3.5 RECOMMENDATION: Implement Recommendations of Renewable Resource Docket

Hawaii’s 1994 Legislature adopted Senate Concurrent Resolution No. 40, which requested the Public Utilities Commission to initiate an informational docket to facilitate the development and use of renewable resources in the State of Hawaii. The Commission opened Docket No. 94-0226 to accomplish the following objectives:

- Study the policies, statutes, and programs of other jurisdictions, as well as the strategies employed by these jurisdictions to implement the development of renewable energy resources;
- Examine policies presently employed by the State of Hawaii with respect to facilitating the utilization of renewable energy resources;

- Identify barriers to the development of renewables in Hawaii; and
- Formulate strategies to remove the barriers and implement the use of renewables in Hawaii (State of Hawaii 1996e, 1).

The Docket produced a two-part report entitled *Strategies to Facilitate the Development and Use of Renewable Energy Resources in Hawaii* (State of Hawaii 1996e). Part one was a study by the National Renewable Energy Laboratory (NREL), "Renewable Energy Policy Options for the State of Hawaii." The second part, the Collaborative Document, summarized the parties' collaborative efforts to identify barriers and formulate strategies for the use of renewables in Hawaii. There were twenty-one parties to the Collaborative, representing government, electric utilities, non-utility generators, vendors and developers, environmental groups, and other stakeholders. Assessment of Hawaii's renewable resources was deferred to DBEDT which produced an assessment of renewable energy as part of the Hawaii Energy Strategy Program as discussed in Section 7.3.6, above (1-2).

7.5.3.5.1 NREL Report: Renewable Energy Policy Options for Hawaii

NREL cited the following primary impediments to the successful development of renewable energy resources in Hawaii:

- Renewable energy systems require a large initial capital investment;
- Electric utilities fail to incorporate the benefits of renewables in their market decisions; and
- Market power is concentrated in the hands of the electric utility companies, impeding investments in renewables (2).

The report cited three policy measures commonly used to foster renewable energy development in other states, which have been used by the State of Hawaii:

- Financial incentives such as tax credits, tax exemptions, or direct loans and grants, which lower the cost of renewable energy systems;
- Power purchase contract rules which assist non-utility developers in securing contracts for the sale of power to a utility by guiding contract negotiations and the determination of "avoided cost" payments; and
- Integrated resource planning requirements for utilities to consider renewable energy among the range of generation alternatives when developing their least-cost plan (2).

NREL identified a number of basic strategies implemented or considered by other states to further the deployment of renewable energy resources. These included net-metering, renewable energy set-asides, legislative requirements for renewables, direct access to the grid for renewable energy suppliers, risk allocation, targeted financial incentives and disincentives for utilities, system benefits charges, green requests for proposals, and renewables portfolio standards. The following specific strategies were suggested for Hawaii:

- A clear pronouncement by the State that renewable energy development remains an important objective, and the establishment of a concrete goal for renewable energy policies; (Note: This was done through the addition of the statutory energy objective "increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased" by Act 96, Session Laws of Hawaii 1994).
- Establishment by the State of an official preference that all new generating capacity employ renewable energy resources unless it is demonstrated that a specific use is not in the public interest;
- Development of financial incentives to utilities, renewable energy providers, and customers funded from general revenues or by a "system benefit charge" assessed on all electricity customers;
- Establishment of a portfolio standard imposing a minimum renewable energy requirement for the State's electricity mix;
- Development by the utilities of a competitive green power product that allows customers to exercise voluntarily a preference for electricity from renewable energy sources;
- Authorization for alternative renewable energy providers to supply renewable energy service options directly to a utility's wholesale and retail customers; and
- Establishing of a net energy metering policy that allows customers to offset high retail rates with small-scale renewable electric systems (3-4).

7.5.3.5.2 The Collaborative Document

The Collaborative document identified real and perceived barriers to renewable resource development and developed a list of targeted recommendations. Barriers included the following:

- Insufficient avoided cost prices for developer financing;
- Operational limitations on the amount of renewable energy that can be accommodated by the electric utilities;
- Complex and lengthy permitting process and limited availability of sites;

- Form of price offered to renewable developers does not facilitate financing;
- Lack of new renewables in current integrated resource plans;
- Protracted nature of purchase power negotiations;
- Lack of renewable-specific wheeling mechanisms and opportunities for consumer access to renewable power;
- Potential negative environmental and societal impacts of renewable resources;
- Certain renewable and storage technologies may not be sufficiently mature to be economically viable; and
- Fragmented and overlapping efforts by the State in renewable energy research, development, demonstration, and commercialization (4-5).

The Collaborative document listed key strategies for consideration by the Legislature, the Commission, the utilities, DBEDT, the counties, and renewable energy developers. While the Public Utilities Commission has taken no direct action on the report other than provide it to the State Legislature, the recommendations remain valid.

7.5.3.6 Renewable Energy Systems Recommended by Hawaii Energy Strategy Project 3

It is recommend that utilities and independent power producers further consider the recommendations developed by Hawaii Energy Strategy Project 3.

7.5.3.6.1 Renewable Energy Assessment and Development Program

Hawaii Energy Strategy (HES) Project 3 developed a comprehensive assessment of Hawaii’s renewable energy resources and a long-range development strategy. *The Renewable Energy Assessment and Development Program Report* (State of Hawaii 1995b) describes the three-phase project and its detailed results.

The project first developed a Renewable Energy Resources Assessment Plan determining constraints and requirements for wind, solar, biomass, hydroelectric, geothermal, wave, and ocean thermal energy conversion (OTEC) projects. Potential sites were identified and screened and a plan was developed for additional wind and solar monitoring of several potential sites to supplement existing data for other locations.

Renewable energy resource supply curves were developed by compiling cost and performance data on renewable energy systems and analyzing existing data on the

Hawaii resource to develop resource supply curves to allow comparison of the costs of various potential projects.

Concurrently, a year's wind and solar data were collected at selected locations statewide. Once data collection was completed, the resource supply curves were updated to reflect the new data. A plan was then developed to integrate renewable energy into Hawaii's energy supply mix.

7.3.5.6.2 RECOMMENDATION: Implement Elements of the Hawaii Energy Strategy Renewable Energy Implementation Plan

The Hawaii Energy Strategy Project 3 report recommended a renewable energy implementation plan for each of Hawaii's four major islands. The plans were based on the year 2005 resource supply curves and consideration of constraints such as projected load growth on each island, a 20% assumed maximum penetration limit, and the nominal relative cost of energy. Tables 7.22 and 7.23 describe these potential projects by island and basic cost data. While a few of the renewable resource options were modeled in ENERGY 2020 for installation before 2005, most were added later, so the 2005 costs were used as a simplifying assumption.

The list was modified by the addition of options reportedly under negotiation or proposed by IPPs for each island. These are indicated in bold and listed at the top of each county listing. The other renewable energy options on Tables 7.22 and 7.23, except those shown in italics, were used in ENERGY 2020 model runs. All except the options in italics were part of Scenario Run E2, Maximize Renewable energy, which is described in more detail in Chapter 9.

Table 7.22 Estimated Costs of Renewable Energy Options by Island and Site					
Name	**MW**	**Unit Capital Costs (Million $)**	**T&D Costs (Million $)**	**Total Capital Costs (Million $)**	**Capital Costs (1993$/kW)**
Oahu					
Wind at Kahuku	20	20.3	0	20.3	1,017
Wind at Kaena Point	15	15.8	1.5	17.3	1,155
Wind at Kahuku	30	30.8	0	30.8	1,027
Tracking Photovoltaic at Lualualei	50	158.1	2.0	160.1	3,202
Solar Dish Stirling at Pearl Harbor	50	157.1	1.0	158.1	3,162
Hawaii					
Wind at Kahua Ranch	20	24.7	0	24.7	1,236
Photovoltaic (Fixed) at Waikoloa	4	21.9	0	21.9	5,472
Wind at North Kohala	15	17.1	1.5	18.6	1,241
Wind at Lalamilo Wells	10	10.0	0.7	10.6	1,065
Hydro at Umauma Stream	13.8	23.0	1.0	24.0	1,736
Geothermal	15	29.3	0	29.3	1,953
Biomass at Hilo Coast	50	96.9	0	96.9	1,938
Kauai					
MSW plant at Kaumakani	25	53.4	0	53.4	2,136
Wind at North Hanapepe	10	10.7	0	10.7	1,074
Hydro at Wailua River	6.6	10.3	1.0	11.3	1,709
Wind at Port Allen	5	5.4	0	5.4	1,087
Biomass at Kaumakani	25	51.9	0	51.9	2,075
Solar Thermal Dish at Barking Sands	10	20.1	0	20.1	2,005
Maui					
Wind at West Maui	20	21.0	0	21.0	1,050
Biomass at Puunene	25	66.6	0	66.6	2,664
Wind at NW Haleakala	20	23.0	0	23.0	1,150

Source: State of Hawaii 1995b

Table 7.22 shows the capacity of each option in megawatts (MW), the estimated unit capital costs in millions of dollars, additional transmission and distribution (T&D) costs in millions of dollars, total capital costs, and capital costs per kW capacity in 1993 dollars. These values are useful in comparing the costs with fossil fuel generation.

Table 7.23, below, provides an estimate of the electricity production of each resource and the CO_2 savings involved. The capacity of each unit is displayed followed by the availability, or the percentage of the time the unit will provide electricity.

Except for biomass and geothermal, the renewable energy resources recommended are all intermittent resources as indicated by their availability percentage. For this reason, due to the lack of connections between islands to provide reserves when an intermittent renewable system is not available (e.g., the wind is not blowing, or it is night), some of these resources may be incremental to a base fossil fuel system. There will be some probability that they will be available when needed, so 100% fossil-fueled back up will not necessarily be required.

Table 7.23 Estimated CO_2 Reductions from Renewable Energy Options by Island and Site					
Name	**MW**	**Availability**	**Annual Net Generation (GWh)**	**Annual CO_2 Emissions Savings (Tons)**	**Capital Cost per Ton of CO_2 Savings (Project Life)**
Oahu					
Wind at Kahuku	20	22%	38	37,220	$ 18
Wind at Kaena Point	15	24%	32	30,927	$ 19
Wind at Kahuku	30	22%	57	55,837	$ 18
Tracking Photovoltaic at Lualualei	50	23%	100	97,716	$ 55
Solar Dish Stirling at Pearl Harbor	50	18%	81	79,286	$ 66
Oahu Subtotal	**165**		**307**	**300,986**	
Hawaii					
Wind at Kahua Ranch	20	24%	42	41,433	$ 20
Photovoltaic (Fixed) at Waikoloa	4	25%	9	8,467	$ 86
Wind at North Kohala	15	43%	57	56,051	$ 11
Wind at Lalamilo Wells	10	44%	39	38,170	$ 9
Hydro at Umauma Stream	14	33%	40	39,596	$ 12
Geothermal	15	81%	106	104,410	$ 9
Biomass at Hilo Coast	50	70%	307	302,001	$ 11
Hawaii Subtotal	**128**		**599**	**590,128**	
Kauai					
MSW plant at Kaumakani	25	70%	153	107,310	$ 17
Wind at North Hanapepe	10	26%	23	15,821	$ 23
Hydro at Wailua River	7	28%	16	11,505	$ 20
Wind at Port Allen	5	21%	9	6,525	$ 28
Biomass at Kaumakani	25	70%	153	107,310	$ 16
Solar Thermal Dish at Barking Sands	10	20%	17	12,075	$ 55
Kauai Subtotal	**82**		**372**	**260,546**	
Maui					
Wind at West Maui	20	14%	25	23,404	$ 30
Biomass at Puunene	25	70%	153	144,102	$ 15
Wind at NW Haleakala	20	19%	34	32,077	$ 24
Maui Subtotal	**65**		**212**	**199,583**	
Statewide Total	**439**		**1,491**	**1,351,243**	
Source: State of Hawaii 1995b; Estimated CO_2 Emissions for each utility, 1997.					

This concept will require further examination. As Table 7.23 shows, full installation of the full 439 MW of renewables could reduce Hawaii's electrical system CO_2 emissions by as much as 1.35 million tons per year. In Scenario E2, ENERGY 2020 modeled installation of 304 MW (those units not in italics) by 2014. The model calculated CO_2 emissions reductions of 1,046,110 tons CO_2 by 2010, or 10.6% less than the Baseline electric utility sector emissions, but still 21% above the Kyoto goal. By 2020, the annual CO_2 reduction was estimated to be 1,182,053, or 11.1% below the Baseline. For reference, this would be 31% above the Kyoto standard. Thus, it can be seen that additional renewable energy can make significant contributions to CO_2 emissions reductions.

7.5.3.6.3 RECOMMENDATION: Determine Technical Capability of Hawaii Electric Utility Systems to Use Intermittent Renewable Energy

One step that is critical to further development of renewable energy on Hawaii's separate, non-interconnected system is an impartial analysis and identification of the technical capability of each system to use intermittent systems and technologies available to achieve necessary power quality. Some form of fossil energy back up may be needed at present to ensure peak demand is met when intermittent renewables are not available. However, there should continued monitoring of energy storage technology to identify cost-effective non-fossil fuel back-up to allow greater deployment of intermittent systems.

7.6 Electricity Sector CO_2 Emissions Savings Summary

This section summarizes the estimated emissions savings identified in this Chapter from ongoing and projected measures.

7.6.1 Estimated Future Demand-Side Electricity Sector CO_2 Emissions Savings

Table 7.24 is intended to show the potential CO_2 emissions savings from demand-side electricity sector measures that have been initiated and are expected to continue into the future. In Table 7.24, the State and County Efficiency Programs are only those currently identified as underway. It is expected that additional savings will result as performance contracting measures are extended to additional state and county facilities. The State and County Efficiency Programs are in Italics and their savings are assumed to be included in their respective utility DSM programs since these programs also take advantage of DSM program rebates. Accordingly, they were not added into the island subtotals. Federal programs were not included due to lack of data. Due to the FEMP program described above, federal programs can be expected to make increasing contributions to Hawaii's greenhouse gas emissions reductions.

As none of the utility DSM programs was forecast beyond 2018 in their current IRPs, Table 7.24 only goes through 2015 for completeness. In addition to crediting expected saving from DSM programs, emissions reductions from solar water heaters installed prior to inclusion of solar water heating as a DSM program were added to DSM savings to yield island subtotals. Many of these solar water heating systems have been in place for 20 years or more. Accordingly, their emissions reduction value was reduced by 5% per year over the period of the estimate. Many of these solar water heaters will be replaced under utility DSM programs when they "burn out," or fail.

In addition, statewide forecasted emissions reductions as a result of application of the State of Hawaii Model Energy Code are also included on the Table.

Table 7.24 Estimated Future Demand-Side Electricity Sector CO_2 Emissions Savings

	1999	2000	2005	2010	2015
HECO DSM Program	76,401	125,587	348,909	608,732	737,087
State Efficiency Programs	*29,650*	*29,650*	*29,650*	*29,650*	*29,650*
City/County Efficiency Programs	*1,294*	*1,294*	*1,294*	*1,294*	*1,294*
Pre-DSM Solar Water Heaters	44,942	42,695	33,036	25,563	19,780
Oahu Subtotal	121,343	168,282	381,945	634,295	756,867
HELCO DSM Program	6,252	11,531	39,294	65,384	91,339
State Efficiency Programs	*3,169*	*3,169*	*3,169*	*3,169*	*3,169*
County Efficiency Programs	*8,976*	*8,976*	*8,976*	*8,976*	*8,976*
Pre-DSM Solar Water Heaters	4,732	4,495	3,478	2,692	2,083
Hawaii Subtotal	10,984	16,026	42,772	68,076	93,422
KE DSM Program	10,499	20,052	28,477	20,313	11,293
State Efficiency Programs	*Not separately identified. Included in Oahu programs.*				
County Efficiency Programs	*2,923*	*2,923*	*2,923*	*2,923*	*2,923*
Pre-DSM Solar Water Heaters	1,605	1,525	1,180	913	706
Kauai Subtotal	12,104	21,577	29,657	21,226	11,999
MECO DSM Programs	27,578	38,296	58,656	58,656	20,359
State Efficiency Programs	*Not separately identified. Included in Oahu programs.*				
County Efficiency Programs	*6,950*	*6,950*	*6,950*	*6,950*	*6,950*
Pre-DSM Solar Water Heaters	16,158	15,350	11,878	9,191	7,112
Maui Subtotal	43,736	53,646	70,534	67,847	27,471
Model Energy Code (Statewide)	64,680	75,460	127,400	174,440	224,443
Statewide Total	**252,847**	**334,991**	**652,308**	**965,883**	**1,114,202**

Demand-side measures were expected to reduce CO_2 emissions by 252,847 tons in 1999, increasing to 1,114,202 tons in 2015. While impressive, this is Hawaii's starting point. These savings were also estimated on the basis of 1997 CO_2 emissions in pounds per kWh for each utility. The HECO emissions level of 1.96 lbs./kWh was used for statewide values. These savings were accounted for in the Baseline estimate in the ENERGY 2020 model. Additional demand-side savings should be developed through additional utility DSM programs. Should the electric utility industry be restructured, it will be necessary to ensure such programs continue through such measures as systems benefit charges. It is clearly in the self-interest of individuals, business, and government to become more efficient in their electricity use. Additional measures, beyond DSM programs, should be taken with or without the use of performance contracting.

7.6.2 Estimated Future Supply-Side Electricity Sector CO_2 Emissions Savings

Table 7.25 depicts estimated future supply-side electricity sector CO_2 emissions savings. Some of the savings shown on the Table will occur without additional action. Current savings from cogeneration by independent power producers were included. Additional cogeneration may be installed in 1999 at Hamakua, but data was not available to include its potential contribution. In addition, as noted above, emissions were calculated from the number of kWh saved based upon each utility's

1997 performance. As older generators are replaced, system efficiency should improve somewhat, which would actually reduce the CO_2 savings per kWh.

As a simplifying assumption, current renewable energy use is shown to continue at 1997 levels. This is likely to be fairly realistic, although further closures of sugar mills could reduce the amount slightly. Where the demand-side table, Table 7.24, showed only planned measures, Table 7.25 also shows the potential CO_2 emissions reduction that could result from implementation of Scenario E2 as discussed in more detail in Chapter 9.

Table 7.25 Estimated Future Supply-Side Electricity Sector CO_2 Emissions Savings

	1999	2000	2005	2010	2015
Cogeneration					
AES Hawaii	25,291	25,291	25,291	25,291	25,291
Kapaa Partners	116,351	116,351	116,351	116,351	116,351
Kalaeloa	76,499	76,499	76,499	76,499	76,499
Cogeneration Subtotal	218,141	218,141	218,141	218,141	218,141
Renewable Energy					
Current Renewable Energy Use	799,377	799,377	799,377	799,377	799,377
Scenario E2 Savings	62,686	53,016	457,527	1,046,066	1,195,753
Renewable Energy Subtotal	862,063	852,393	1,256,904	1,845,443	1,995,130
Total	**1,080,204**	**1,070,534**	**1,475,045**	**2,063,584**	**2,213,271**

If implementation of Scenario E2 proved feasible, CO_2 emissions could be reduced by an additional million tons by 2010. Unless new fossil-fueled generation technologies that are much more efficient or emit less greenhouse gases are introduced in the near future, additional renewable energy offers the major option for emissions reductions in Hawaii's electricity sector.

CHAPTER 8 RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL ENERGY

8.1 Overview

Chapter 8 examines greenhouse gas emissions in the residential, commercial, and industrial energy sectors. These sectors include use of utility and non-utility gas, self-generation of electricity, non-highway mobile sources such as agricultural and construction vehicles, and a relatively small amount of oil-fired water heating, kiln heating, and steam production. While virtually all of the utility electricity produced in Hawaii is used in these three sectors, Chapter 7 covered the electric utility sector in detail, including electricity demands from these sectors, means to reduce demand, and measures to reduce emissions from electricity generation for sale to utility customers.

Definitions

8.1.2.1 Residential Sector

In this Chapter, the focus is on residential uses of LPG and SNG by single family residences, including separately metered apartment or condominium units. Residential end-uses include water heating, cooking, clothes drying, lighting, etc.

8.1.2.2 Commercial Sector

SNG and LPG users in this sector include master-metered apartments, condominiums, and two or more single-family residences, which occupy the same property and are under single ownership or management. Other commercial users include commercial, institutional, and government customers, including hotels. Due to the difficulty of disaggregating the relatively small number of industrial customers in the large commercial/industrial category, this both commercial and industrial SNG uses are included in this section. There is some direct use of diesel and residual oil for heating and water heating in this sector.

8.1.2.3 Industrial Sector

Industrial uses include direct agricultural, industrial, and construction uses of fossil fuels. Activities involved included principally sugar, construction, cement and paving, quarrying, a few small manufacturers, and agriculture.

8.2 Residential, Commercial, and Industrial Sector Emissions

8.2.1 1990 Estimated Emissions Baseline

Table 8.1 displays the estimated residential, commercial, and industrial sector CO_2 emissions from energy uses calculated for the *Inventory of Hawaii Greenhouse Gas Emissions: Estimates for 1990* (State of Hawaii, 1997a).

Table 8.1 Estimated Hawaii Baseline CO_2 Emissions in Residential, Commercial, and Industrial Sectors by Fuel, 1990

Sector/Fuel	Quantity	Million Btu	Tons CO_2
Residential Sector			
LPG (Bbl)	219,711	881,261	60,461
SNG (Btu)		592,400	34,299
	Subtotal	1,473,661	94,760
Commercial Sector			
Distillate (Bbl)	10,512	61,233	4,890
LPG (Bbl)	381,524	1,530,293	104,989
Residual (Bbl)	3,080	19,364	1,666
SNG (Btu)		2,888,200	167,222
	Subtotal	4,499,090	278,767
Industrial Sector			
Bagasse (Tons)	1,072,015	17,796,000	not included
Coal (Tons)	24,517	527,116	53,576
Distillate (Bbl)	167,874	977,866	78,092
Diesel (off-road) (Bbl)	407,678	2,374,724	189,646
Gasoline (off-road) (Bbl)	34,171	179,500	13,944
LPG (Bbl)	254,349	1,020,194	69,992
LPG (off-road) (Bbl)	25	100	7
Mac Nuts (Tons)	7,500	84,750	not included
Residual (Bbl)	847,449	5,327,911	431,411
Wood Chips (Tons)	16,500	284,483	not included
	Subtotal	28,572,644	836,668
Summary			
Bagasse (Tons)	1,072,015	17,796,000	not included
Coal (Tons)	24,517	527,116	53,576
Distillate (Bbl)	586,064	3,413,823	272,628
Gasoline (Bbl)	34,171	179,500	13,944
LPG (Bbl)	855,609	3,431,848	235,449
Mac Nuts (Tons)	7,500	84,750	not included
Residual (Bbl)	850,529	5,347,275	433,077
SNG (Btu)	3,480,600	3,480,600	34,299
Wood Chips (Tons)	16,500	284,483	not included
	Total	34,545,395	1,042,973

(State of Hawaii, 1997a)

The baseline estimate included stationary source residential, commercial, and industrial emissions and industrial off-road mobile source emissions. Together, these sectors produced about 8% of Hawaii's CO_2 emissions and about 7% of

Hawaii's global warming potential in tons of CO_2 equivalent. Industrial CO_2 emissions were 5% of total CO_2 emissions and about 4% of GWP. Commercial emissions were about 2% of both CO_2 and GWP totals, while residential emissions were about 1% of both categories.

In the *Inventory*, emissions from independent power producers and cogenerators and sugar industry generation sold to the electric utilities were reported in the industrial sector. Due to the significant increase in independent power production as a source of electricity for sale to utility customers since 1990, the discussion of emissions from all production of power for sale to utility customers was included in Chapter 7 in this Plan. Independent power production emissions and emissions resulting from production of cogenerated electricity for sale are not included in the estimate of future emissions below.

8.2.1.1 RECOMMENDATION: Request that Clean Air Branch Collect Fuel Use Data from Air Permits Holders.

One of the key data sources used to estimate fuel use for 1990 was not available for years after 1994 in convenient form. For the *Inventory*, the Air Emissions Reports made by holders of air permits to the State of Hawaii Department of Health (DOH) Clean Air Branch were used to determine the amounts of fossil fuels burned in sources covered under the Clean Air Act and Amendments. While DOH continues to collect data on criteria pollutants, fuel use was not collected on reports after 1994. For consistency, estimates for 1991 and subsequent years were based upon energy refiner and distributor reports to DBEDT, and unpublished data provided by the former Hawaii Sugar Planters' Association, now renamed the Hawaii Agricultural Research Center (HARC). If the Clean Air Branch would resume collecting fuel use data, the data would greatly assist efforts to monitor greenhouse gas emissions in the future.

8.2.2 Estimated Residential, Commercial, and Industrial Greenhouse Gas Emissions to 2000

Figure 8.1 depicts the ENERGY 2020 model's estimate of residential, commercial, and industrial greenhouse gas emissions from 1990 to 2020.

CO_2 emissions in these three sectors were forecast to grow by 2%, from 1.26 million tons in 1990 to 1.28 million tons in 2010. The commercial sector's CO_2 emissions were forecasted to increase by 34% to 362,000 tons. However, a 4% decline in emissions was forecasted in the industrial sector, primarily due to the end of cement kiln operations and closure of several sugar plantations through 1996 reduced that total to 870,000 tons. Residential emissions were forecasted to decline to about 56,000 tons by 2010 if trends of reduced utility gas and LPG sales observed in the early 1990s continue.

By 2020, the forecasted total of CO_2 emissions from the three sectors were 1.4 million tons, or 12% over 1990. Commercial source emissions were expected to be up by 52% at 410,000 tons CO_2. Industrial emissions were also forecasted to increase by 2020 to 4% above 1990 levels at 949,000 tons CO_2. Again, continuing the trend observed in the early nineties, the residential forecast was 42% below 1990 levels at 47,000 tons.

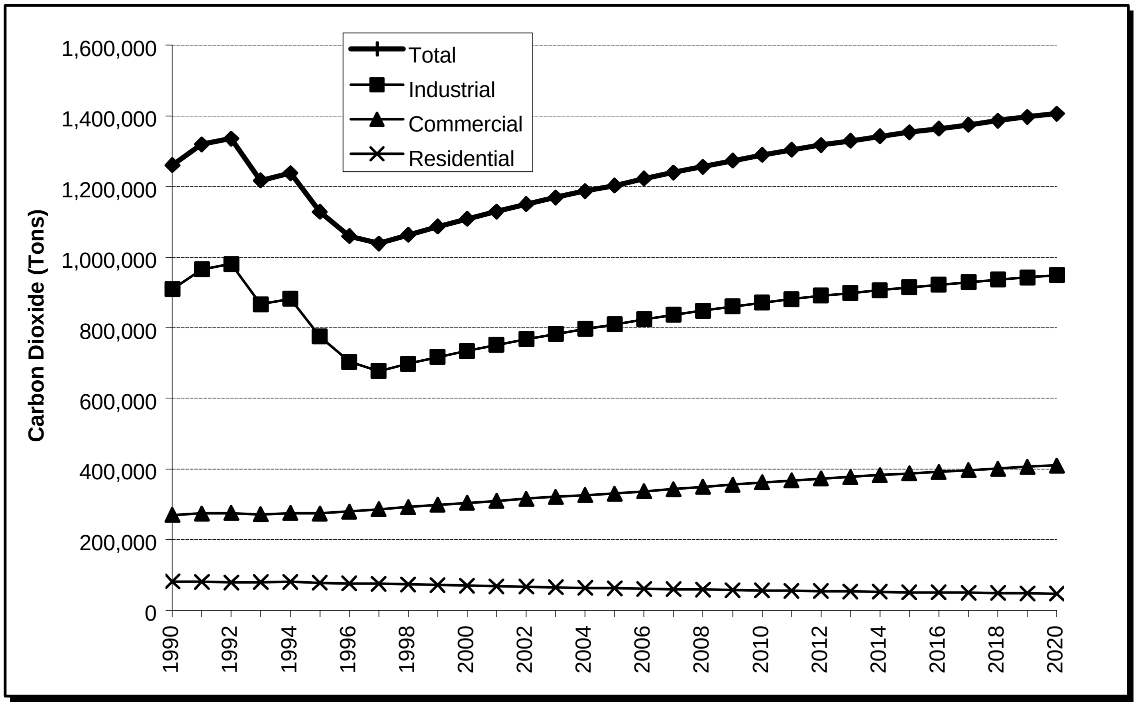


Figure 8.1 Forecast Residential, Commercial, and Industrial Sector CO_2 Emissions in Hawaii (Tons), 1990-2020

8.3 Actions to Reduce Greenhouse Gas Emissions

8.3.1 Utility and Non-Utility Gas

Hawaii has no natural gas resources. Gas service is provided in the form of locally produced synthetic natural gas (SNG) and liquid propane gas (LPG). The Gas Company, a regulated monopoly owned by Citizens Utilities, provides utility gas service. It serves 35,100 customers via underground distribution systems (Aoki 1996, 2). Ninety percent of The Gas Company's customers are on Oahu, with additional service on Hawaii, Kauai, Maui, and Molokai. SNG is provided to Oahu customers in the Honolulu service area (Hawaii Kai to Kapolei), while propane vapor is provided in outlying areas of Oahu and on the neighbor islands (Gasco, 1993, 1-5).

SNG is produced by The Gas Company's SNG plant from low octane hydrocarbons provided by the Tesoro Hawaii Refinery. Propane is primarily purchased from Hawaii's two refineries, supplemented by imports. In addition to the use of propane in the propane vapor utility systems, LPG is also sold to users with stand-alone systems (1-5). This non-utility gas service is not regulated and other firms are participating in this market.

While gas meets a relatively small share of Hawaii's energy needs, it offers the least-cost option for many energy end-uses, the lowest level of greenhouse emissions per unit of fossil energy, and uses by-products of in-state petroleum refining (1-4).

8.3.1.1 RECOMMENDATION: Implement Gas Utility Demand-Side Management Programs

The BHP Gas Company developed an Integrated Resource Plan, which was filed for approval on May 18, 1993. The Hawaii Public Utilities Commission has yet to act on the application for DSM programs. Currently, The Gas Company, now owned by Citizens Utilities, is preparing its second IRP, which will include a new look at DSM programs.

Nevertheless, for this report, we will look at the first DSM proposal. It provides an initial idea as to what could be done in the area of gas utility DSM. Measures in the plan were expected to run ten years. The plan included the following DSM measures:

- **Expanded Residential "Energy Expert" Audit Program.** This was an expansion of an existing program that sought to help residential customers identify and realize savings on their energy bill. It included a conservation education component. In addition to an energy audit, low-cost efficiency measures were included, such as water heater thermostat setback, low-flow showerheads, and minor maintenance of gas appliances (Aoki 1996, Attachment A, 1-3 – 1-4).

- **Efficient Residential Appliance Program.** The program was designed to encourage owners of existing and new homes to select higher-than-standard efficiency appliances, especially water heaters. Rebates of $40 per unit were to be divided between the dealer/installer and the customer purchasing the higher-than-standard efficiency gas water. After a two-year ramp-up period, it was expected that about 470, or 15% of gas water heater purchasers would participate in the program (1-5).

- **Commercial Energy Audit and Custom Energy Efficiency Program for Small Customers.** Small commercial customers include multi-family apartment buildings of 30 or fewer units, small-medium sized restaurants, smaller laundromats and other commercial laundries, and other businesses with gas use of less than

7500 therms per year.

This program involved energy efficiency audits, advice on energy-efficiency options, and assistance with implementation of gas energy-efficiency options. The program was to include direct rebates for equipment purchases and limited assistance in arranging for third party financing or leasing of equipment improvements (1-7).

- **Commercial Energy Audit and Custom Energy Efficiency Program for Medium and Large Customers.** Medium and large commercial customers include hotels and resorts, large multi-family residential buildings, institutions, and industrial facilities. More focus was to be placed on this sector due to the amount of gas used by these customers.

  The program involved on-site auditing, assisting customers with equipment selection and installation, and financial assistance with capital purchases (1-7).

Table 8.2 shows the anticipated savings in therms and savings in tons of CO_2 emissions expected as a result of the proposed programs in the first five years after implementation and over their planned 10-year life. While the CO_2 emissions savings from the DSM programs proposed by BHP Gas Company in 1996 would have been relatively small, The Gas Company, is working on its second IRP and is developing a new set of DSM programs.

Table 8.2 Estimated Gas Savings and CO_2 Emissions Reduction from Planned Utility Gas DSM Programs

Measure	Year 1	Year 2	Year 3	Year 4	Year 5	10-yr Life
Estimated Therm Savings						
"Energy Expert" Residential	15,066	30,114	45,180	60,228	75,294	493,920
Efficient Residential Appliance	2,538	6,426	11,340	16,290	21,312	213,156
Sm. Customer Commerical Energy Audit	7,272	14,562	21,834	29,106	36,378	524,520
Med/Lg Customer Comm. Energy Audit	70,812	141,606	213,228	291,618	370,008	5,247,162
Total	95,688	192,708	291,582	397,242	502,992	6,478,758
Estimated CO_2 Emissions Reduction						
"Energy Expert" Residential	101	202	303	404	504	3,309
Efficient Residential Appliance	17	43	76	109	143	1,428
Sm. Customer Comm. Energy Audit	49	98	146	195	244	3,514
Med/Lg Customer Comm. Energy Audit	474	949	1,429	1,954	2,479	35,156
Total	641	1,291	1,954	2,662	3,370	43,408

Source: Aoki 1996, 2-2, 2-8

8.3.1.2 RECOMMENDATION: Develop Energy Efficiency Programs for Non-Utility Gas Customers

Due to the nature of the non-utility gas industry, and the fact that the market is unregulated, implementation of demand-side management programs appears difficult, if not impossible. Customer education programs in this area may be the only means to effect efficiencies.

8.3.1.3 RECOMMENDATION: Consider Fuel Switching Opportunities between Electricity and Gas

Residential, commercial, and industrial end-uses should be examined to determine opportunities for cost-effective fuel switching as a way to reduce greenhouse gas emissions. Once the optimum technology for each end-use is determined, customer education programs could be implemented to assist customers in choosing between the options.

In the first IRP, the Public Utilities Commission rejected proposals for DSM measures based on fuel switching. These should be reconsidered in light of possible savings opportunities for both energy and greenhouse gas emissions.

8.3.2 Sugar Industry

8.3.2.1 Sugar Industry Emissions from Electricity and Steam Production for Internal Use

As noted above, the emissions from the sugar industry resulting from producing electricity for sale to the utilities were accounted for and discussed in Chapter 7. That electricity was a result of cogeneration of electricity used to power sugar mill operations and boiler steam produced for use as process heat. As a result, there were significant greenhouse gas emissions resulting from power and process heat generation for the mills' own use. This section summarizes those emissions.

Table 8.3 Percentage of Hawaii Sugar Industry Electricity Generation Used Internally, 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
Oahu	83%	63%	68%	67%	48%	47%	39%	0%
Hawaii	29%	28%	29%	35%	31%	100%	0%	0%
Kauai	47%	46%	46%	43%	52%	52%	33%	51%
Maui	57%	60%	58%	58%	57%	63%	32%	64%
Statewide	49%	47%	48%	51%	48%	58%	33%	60%

Source: HARC

Table 8.3 shows the percentage of sugar industry electricity generation used internally from 1990-1997. Sugar operations are now closed on Oahu and Hawaii. On Kauai, AMFAC East (formerly Lihue Plantation), and, on Maui, Hawaii Commercial & Sugar Company's Puunene Mill each have significant power purchase agreements with their respective utilities. The amounts used internally varied with weather and size of the harvest, among other factors. Electricity provided to the utilities under as available contracts was also a factor.

As Table 8.4 indicates, CO_2 emissions from generation of electricity and steam for internal use declined significantly statewide (about 34%), mostly due to closure of the sugar mills on Oahu and Hawaii since 1990. On Kauai, emissions from the remaining mills from generation and process heat production for internal use were only 38% of 1990 levels. On Maui, however, such emissions were up in 1997 to a level 44% greater than 1990.

Table 8.4 Hawaii Sugar Industry CO_2 Emissions from Electricity and Steam Production Used in Internally (Tons), 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
Oahu	35,051	46,810	58,874	69,421	37,756	28,134	20,119	-
Hawaii	48,864	50,782	45,519	49,626	49,726	2,333	-	-
Kauai	24,757	25,313	26,972	20,362	19,373	12,332	5,508	9,436
Maui	79,145	116,090	122,585	105,422	58,958	113,824	98,359	114,163
Statewide	187,817	238,995	253,950	244,832	165,814	156,623	123,986	123,599

Source: HARC

Hawaii's remaining sugar mills are already among the most efficient in the world and continuing cost pressures are expected to maintain high efficiency levels. There are no specific recommendations for improvement.

8.3.2.2 Sugar Industry Emissions from Mechanical Equipment and Vehicles

Sugar industry vehicles and mobile equipment use significant quantities of diesel, gasoline, and LPG as fuel. Of all off-road uses in the industrial sector, data is only available in detail on sugar industry operations.

Table 8.5 CO_2 Emissions from Sugar Industry Mechanical Equipment and Vehicles, 1990-1997

	1990	1991	1992	1993	1994	1995	1996	1997
Oahu	15,514	15,051	14,478	14,135	13,275	6,634	-	-
Hawaii	52,276	51,564	51,673	30,612	31,613	8,875	1,398	-
Kauai	24,387	27,252	19,681	21,708	18,601	16,904	18,218	14,005
Maui	22,991	22,622	22,553	24,772	23,575	22,385	16,378	23,557
Statewide	115,169	116,490	108,384	91,228	87,064	54,798	35,994	37,563

Source: HARC

Table 8.5 depicts emissions from sugar industry mechanical equipment and vehicles from 1990 to 1997. Overall, these emissions were down 67% over the period due to closures and reduction of operations. There are no specific recommendations for efficiency improvements.

8.3.3 Other Industrial Sector Direct Energy Use

Little detail is available on the other emissions-producing uses of energy in the industrial sector. Although Hawaii's other industrial activities are rather limited, this is an area that should be considered for further study.

CHAPTER 9 ENERGY SYSTEM SCENARIO ANALYSIS

9.1 Overview

Chapter 9 examines a number of hypothetical energy sector scenarios designed to reduce Hawaii's greenhouse gas emissions. The scenarios were run on the ENERGY 2020 model of Hawaii's energy system in each of Hawaii's four counties. ENERGY 2020 is linked to the Regional Economic Models, Inc. (REMI) model of the economies of each county. The REMI model was calibrated to conform to the DBEDT Research and Economic Analysis Division's *Population and Economic Projections for the State of Hawaii to 2020 (DBEDT 2020 Series)* (State of Hawaii 1997b). Additional information about the ENERGY 2020 model is provided in Appendix C.

The purpose of these model runs was to evaluate a variety of scenarios as to their potential for reducing greenhouse gas emissions. In addition, the economic costs or benefits of their possible implementation were compared. The scenarios were compared to a Baseline scenario designed, to the extent possible, to replicate the current Hawaii energy system and known plans for additions through the year 2000. The continued use of existing technologies was assumed and their cost s were from utility Integrated Resource Plans (IRP plans). In the case of renewable energy, cost and performance projections for 2005 developed in the Hawaii Energy Strategy program were used as most renewable resources were projected to be added around or after that date.

It should be noted that there were small differences between the emission totals calculated by the ENERGY 2020 and the detailed accounting by individual electricity generator used to establish the 1990 Baseline in the *Inventory of Hawaii Greenhouse Gas Emissions, Estimates for 1990* (State of Hawaii 1997a). The model was calibrated on the basis of fuel use and the DBEDT economic forecast. It is not calibrated to the same level of detail by individual fuel as the *Inventory*. For example, the model did not differentiate between distillate fuel oil and residual fuel oil in the electricity sector. When burned, these identical quantities of these fuels emit different amounts of carbon dioxide and other greenhouse gas emissions. However, in the model, they are the same.

Any model must incorporate simplifications, and these do not negate its utility. The trends and patterns forecasted by the model can be used to examine a variety of possible futures. By applying policy or scenario alternatives, the probable effects of options can be compared against the Baseline to determine estimated effectiveness. The model also yields estimates of economic effects to help evaluate cost or benefits of alternative measures.

While it may not necessarily be possible to implement all of the options examined, the results suggest the areas in which actions could be pursued or at least examined further with the objective of reducing Hawaii's greenhouse gas emissions.

In this study, four groups of scenarios were run on the model. These included electricity scenarios, transportation scenarios, carbon tax scenarios, and composite scenarios. Each is described in more detail in the following sections.

9.2 Electricity Scenarios

9.2.1 Modeling Electricity Options

The following electricity scenarios were developed and run in the ENERGY 2020 model to consider a wide range of actions which could reduce future greenhouse gas emissions. Actions modeled included additional renewable energy and replacement of current generators with new technology.

Baseline. The generation units in this scenario were based upon current operating units and utility plans. It was assumed that utility DSM plans were implemented for 20 years. The effects of all federal appliance standards and the Hawaii Model Energy Code were also included. Table 9.1 summarizes existing Hawaii utility-owned and firm power contract electricity generation as of November 1998. The generation capacity values were rounded.

Table 9.1 Baseline Firm Generation Capacity (Nominal), 1997

HECO	HELCO	KE	MECO
Utility Owned			
1160 MW OFS	71 MW OFS	10 MW OFS	37 MW OFS
102 MW CT	43 MW CT	43 MW CT	60 MW CT/DTCC
	37 MW Diesel	44 MW Diesel	125 MW Diesel
Independent Power Producers			
180 MW DTCC*	22 MW Coal	14 MW Bagasse**	16 MW Bagasse**
180 MW AFBC	30 MW Geothermal		
46 MW MSW			
Total			
1622 MW	203 MW	111 MW	238 MW

OFS = Oil-fired Steam
CT = Combustion Turbine
Diesel = Diesel Engine
DTCC = Dual-Train Combined Cycle
DTCC*= Dual-Train Combined Cycle (No. 6 Fuel Oil)
AFBC = Atmospheric Fluidized Bed Coal
Bagasse ** = Bagasse/Oil (KE) or Bagasse/Oil/Coal (MECO)
MSW = Municipal Solid Waste

Table 9.2 depicts the generation additions and retirements in the base scenario. HECO, HELCO, and KE additions and retirements were from their second IRPs. HECO's and HELCO's second IRPs were filed in 1998, and KE's was filed in 1997. The MECO plan was based upon its first IRP modified by subsequent events and updates. The scenario does not reflect plans under consideration by MECO as it develops its second IRP plan, to be submitted in September 1999. The additions and retirements indicated for the HELCO and MECO systems in this and subsequent scenarios were not installed or retired as of November 1998 due to a variety of delays. They were modeled for installation late in 1998 in ENERGY 2020.

Year	HECO	HELCO	KE	MECO
1998	-12.5 MW Biomass	2x20MW DTCC Ph 1&2 -8.25 MW Diesel		20MW DTCC Ph1
1999		20MW DTCC Ph1 -14.3 MW Diesel -3.4 MW OFS 40 MW DTCC Ph 2&3 -21 MW Diesel -9MW CT -15MW Steam (Standby)		20MW DTCC Ph2
2000		-22MW Coal (IPP)		18MW DTCC Ph3
2001				2.2MW Diesel -8.7MW Diesel
2002			26MW CT	4.4MW Diesel -5.4MW Diesel
2003		15MW Steam Return		-12.32MW Diesel
2004				20MW DTCC Ph1 -12.7MW Diesel
2005		-7.5MW Steam		20MW DTCC Ph2 2.2MW Diesel -12.32MW Diesel -5.9MW Steam
2006		18MW DTCC Ph3		18MW DTCC Ph3 2.2MW Diesel -6MW Steam -0.97MW Diesel
2007		-7.7MW Steam		20MW DTCC Ph1 -5.6MW Diesel
2008				2.2MW Diesel -5.6MW Diesel
2009	107MW DTCC Ph1	21 MW DTCC Ph1		20MW DTCC Ph2 -12.85MW Diesel
2010				18MW DTCC Ph3 -12.85MW Diesel
2011				20MW DTCC Ph1
2012		21MW DTCC Ph2	10MW Diesel	-5.4MW Diesel
2013	107MW DTCC Ph2			20MW DTCC Ph2
2014			24 MW Coal	
2015		-14.1MW Steam		
2016	104MW DTCC Ph3 180MW AFBC	18.7MW DTCC Ph3		
2017	107MW SCCT - 180MW DTCC (IPP)	21MW DTCC Ph1		
2018				
2019				
2020				

Table 9.2 Baseline Scenario Generation Additions and Retirements

Ground transportation efficiency was based upon observed ground transportation fuel efficiency. Air transportation was assumed to improve in efficiency at an average 0.7% per year based upon USDOE base case forecasts. Marine fuel use was assumed to grow at a rate similar to population growth.

Table 9.3 Scenario E2 Generation Additions and Retirements

Year	HECO	HELCO	KE	MECO
1998	-12.5 MW Biomass	2x20MW DTCC Ph 1&2 -8.25 MW Diesel		20MW DTCC Ph1
1999		20MW DTCC Ph1 -14.3 MW Diesel -3.4 MW OFS 40 MW DTCC Ph 2&3 **20MW Wind** -21 MW Diesel -9MW CT -15MW Steam (Standby)		20MW DTCC Ph2
2000		-22MW Coal (IPP) **4MW PV**		18MW DTCC Ph3
2001				2.2MW Diesel -8.7MW Diesel
2002		**15MW Wind**	26MW CT	4.4MW Diesel -5.4MW Diesel
2003		15MW Steam Return **3MW Geothermal**		-12.32MW Diesel
2004		**10MW Wind**		20MW DTCC Ph1 -12.7MW Diesel
2005	**20 MW Wind**	-7.5MW Steam **3MW Geothermal**	**25MW Refuse**	20MW DTCC Ph2 2.2MW Diesel **20MW Wind** -12.32MW Diesel -5.9MW Steam
2006		18MW DTCC Ph3 **13.8 Hydro**		18MW DTCC Ph3 2.2MW Diesel -6MW Steam -0.97MW Diesel
2007	**15 MW Wind**	-7.7MW Steam **3MW Geothermal**	**10MW Wind**	20MW DTCC Ph1 **25MW Biomass** -5.6MW Diesel
2008				2.2MW Diesel -5.6MW Diesel
2009	107MW DTCC Ph1 **30 MW Wind**	21 MW DTCC Ph1 **3MW Geothermal**	**6.6MW Hydro**	20MW DTCC Ph2 **20MW Wind** -12.85MW Diesel
2010				18MW DTCC Ph3 -12.85MW Diesel
2011	**50 MW Tracking PV**	**3MW Geothermal**		20MW DTCC Ph1
2012		21MW DTCC Ph2	10MW Diesel **6MW Wind**	-5.4MW Diesel
2013	107MW DTCC Ph2			
2014			24 MW Coal	
2015		-14.1MW Steam		
2016	104MW DTCC Ph3 180MW AFBC	18.7MW DTCC Ph3		
2017	107MW SCCT - 180MW DTCC (IPP)			
2018				
2019				
2020				

E2 – Maximize Renewable Energy. Under the E2 scenario, depicted on Table 9.3, a maximum amount of renewable energy was used. The additional renewables are highlighted in bold in Table 9.2. Renewable energy resources considered were based upon projects known to be under negotiation as of the summer of 1998 and projects recommended by the Hawaii Energy Strategy Project 3, *Renewable Energy Resource Assessment and Development Program* (State of Hawaii 1995b). Intermittent resources were added to the utility plans and were not assumed to displace fossil fuel generation. Their main effect was to reduce fossil fuel use.

Several renewable units offering firm capacity were included and used to defer similar amounts of fossil fuel generation. No firm capacity renewables were modeled for Oahu and the HECO system. The 15 MW of additional geothermal capacity on the Big Island was assumed to be added in three MW increments capable of separate operation, which deferred installation of the 21 MW DTCC Phase 1 scheduled for 2017 on the HELCO system. On Kauai, a 25 MW refuse-to-energy plant (which could also burn biomass) was added in 2005, as an analog for the proposed plasma-arc plant. It offset the addition of the 24 MW coal steam plant scheduled for 2014. The 25 MW biomass plant modeled for installation on Maui was assumed to defer the second phase 21 MW unit of a DTCC scheduled for 2013 in the first IRP.

E3 – Maximum Efficiency New Oil-Based Generation. As utility IRP plans continue to be predominately fossil-fueled, the E3 scenario looked at the effects of continuing such plans by using only phased installations of diesel-fueled dual-train combined cycle (DTCC) systems sized appropriately to each system to meet future generation needs. Currently, these are the most efficient, lowest emission fossil fuel generation types available for use in Hawaii. The E3 scenario sought to evaluate the effectiveness of choosing this type of generation on CO_2 emission reduction.

In applying scenario E3 to the HECO system, the 180 MW Atmospheric Fluidized Bed Coal (AFBC) plant scheduled for 2016 and the 107 MW Simple-Cycle Combustion Turbine (SCCT) scheduled for 2017 were replaced by a DTCC totaling 318 MW, installed in 2016 and 2017. For Kauai Electric, it was assumed that the 10 MW diesel scheduled for 2012 and the 24 MW coal steam plant were replaced by a nominal 58 MW DTCC installed in three phases from 2011 to 2015. No changes were made to the plans of HELCO and MECO as their current planning calls for retirement of many older steam and diesel systems and their replacement with DTCC. Diesel engine generators were selected for Molokai and Lanai's smaller systems in MECO's plans. The E3 scenario plans are depicted below on Table 9.4.

Table 9.4 Scenario E3 Generation Additions and Retirements

Year	HECO	HELCO	KE	MECO
1998	-12.5 MW Biomass	2x20MW DTCC Ph 1&2 -8.25 MW Diesel		20MW DTCC Ph1
1999		20MW DTCC Ph1 -14.3 MW Diesel -3.4 MW OFS 40 MW DTCC Ph 2&3 -21 MW Diesel -9MW CT -15MW Steam (Standby)		20MW DTCC Ph2
2000		-22MW Coal (IPP)		18MW DTCC Ph3
2001				2.2MW Diesel -8.7MW Diesel
2002			26MW CT	4.4MW Diesel -5.4MW Diesel
2003		15MW Steam Return		-12.32MW Diesel
2004				20MW DTCC Ph1 -12.7MW Diesel
2005		-7.5MW Steam		20MW DTCC Ph2 2.2MW Diesel -12.32MW Diesel -5.9MW Steam
2006		18MW DTCC Ph3		18MW DTCC Ph3 2.2MW Diesel -6MW Steam -0.97MW Diesel
2007		-7.7MW Steam		20MW DTCC Ph1 -5.6MW Diesel
2008				2.2MW Diesel -5.6MW Diesel
2009	107MW DTCC Ph1	21 MW DTCC Ph1		20MW DTCC Ph2 -12.85MW Diesel
2010				18MW DTCC Ph3 -12.85MW Diesel
2011			**20MW DTCC Ph1**	20MW DTCC Ph1
2012		21MW DTCC Ph2		-5.4MW Diesel
2013	107MW DTCC Ph2		**20MW DTCC Ph2**	20MW DTCC Ph2
2014				
2015		-14.1MW Steam		
2016	104MW DTCC Ph3 **107MW DTCC Ph1** **107MW DTCC Ph2**	18.7MW DTCC Ph3		
2017	**104MW DTCC Ph3** - 180MW DTCC (IPP)	21MW DTCC Ph1		
2018				
2019				
2020				

E4 – Five Percent Renewable Energy Portfolio Standard. In the E4 scenario, depicted on Table 9.5, below, the additions of renewable energy simulated a requirement for the utilities under the current regulated system or upon competing power producers under a competitive system to install renewable generation equivalent to 5% of total new generation additions. Where intermittent renewable resources were added, they were not assumed to displace fossil fuel generation, but to reduce fossil fuel use. Several firm capacity renewable were included and deferred similar amounts of fossil fuel generation. 15 MW of additional geothermal generation on the Big Island deferred installation of the 21 MW DTCC Phase 1 scheduled for 2017. On Kauai, a 25 MW refuse-to-energy plant was added in 2005 as an analog for the proposed plasma-arc plant offsetting the 24 MW coal steam plant scheduled for 2014.

Table 9.5 Scenario E4 Generation Additions and Retirements

Year	HECO	HELCO	KE	MECO
1998	-12.5 MW Biomass	2x20MW DTCC Ph 1&2 -8.25 MW Diesel		20MW DTCC Ph1
1999		20MW DTCC Ph1 -14.3 MW Diesel -3.4 MW OFS 40 MW DTCC Ph 2&3 -21 MW Diesel -9MW CT -15MW Steam (Standby)		20MW DTCC Ph2
2000		-22MW Coal (IPP)		18MW DTCC Ph3
2001				2.2MW Diesel -8.7MW Diesel
2002			26MW CT	4.4MW Diesel -5.4MW Diesel
2003		15MW Steam Return **3MW Geothermal**		-12.32MW Diesel
2004				20MW DTCC Ph1 -12.7MW Diesel
2005	**20 MW Wind**	-7.5MW Steam **3MW Geothermal**	**25MW Refuse**	20MW DTCC Ph2 2.2MW Diesel **20MW Wind** -12.32MW Diesel -5.9MW Steam
2006		18MW DTCC Ph3		18MW DTCC Ph3 2.2MW Diesel -6MW Steam -0.97MW Diesel
2007		-7.7MW Steam **3MW Geothermal**		20MW DTCC Ph1 -5.6MW Diesel
2008				2.2MW Diesel -5.6MW Diesel
2009	107MW DTCC Ph1	21 MW DTCC Ph1 **3MW Geothermal**		20MW DTCC Ph2 -12.85MW Diesel
2010				18MW DTCC Ph3 -12.85MW Diesel
2011		**3MW Geothermal**		20MW DTCC Ph1
2012		21MW DTCC Ph2	10MW Diesel	-5.4MW Diesel
2013	107MW DTCC Ph2			20MW DTCC Ph2
2014				
2015		-14.1MW Steam		
2016	104MW DTCC Ph3 180MW AFBC	18.7MW DTCC Ph3		
2017	107MW SCCT - 180MW DTCC (IPP)			
2018				
2019				
2020				

Table 9.6 Scenario E5 Generation Additions and Retirements

Year	HECO	HELCO	KE	MECO
1998	-12.5 MW Biomass	2x20MW DTCC Ph 1&2 -8.25 MW Diesel		20MW DTCC Ph1
1999		20MW DTCC Ph1 -14.3 MW Diesel -3.4 MW OFS 40 MW DTCC Ph 2&3 **20MW Wind** -21 MW Diesel -9MW CT -15MW Steam (Standby)		20MW DTCC Ph2
2000		-22MW Coal (IPP) **4MW PV**		18MW DTCC Ph3
2001				2.2MW Diesel -8.7MW Diesel
2002			26MW CT	4.4MW Diesel -5.4MW Diesel
2003		15MW Steam Return **3MW Geothermal**		-12.32MW Diesel
2004				20MW DTCC Ph1 -12.7MW Diesel
2005	**20 MW Wind**	-7.5MW Steam **3MW Geothermal**	**25MW Refuse**	20MW DTCC Ph2 2.2MW Diesel **20MW Wind** -12.32MW Diesel -5.9MW Steam
2006		18MW DTCC Ph3		18MW DTCC Ph3 2.2MW Diesel -6MW Steam -0.97MW Diesel
2007	**15 MW Wind**	-7.7MW Steam **3MW Geothermal**	**10MW Wind**	20MW DTCC Ph1 **25MW Biomass** -5.6MW Diesel
2008				2.2MW Diesel -5.6MW Diesel
2009	107MW DTCC Ph1 **30 MW Wind**	21 MW DTCC Ph1 **3MW Geothermal**		20MW DTCC Ph2 -12.85MW Diesel
2010				18MW DTCC Ph3 -12.85MW Diesel
2011		**3MW Geothermal**		20MW DTCC Ph1
2012		21MW DTCC Ph2	10MW Diesel	-5.4MW Diesel
2013	107MW DTCC Ph2			
2014				
2015		-14.1MW Steam		
2016	104MW DTCC Ph3 180MW AFBC	18.7MW DTCC Ph3		
2017	107MW SCCT - 180MW DTCC (IPP)			
2018				
2019				
2020				

E5 – Ten Percent Renewable Portfolio Standard. In the E5 scenario, depicted on Table 9.6, above, the additions of renewable energy indicated were selected to simulate a requirement placed upon the utilities under the current regulated monopoly system or upon competing power producers under a system of electricity competition to install renewable generation equivalent to 10% of new generation additions.

The additional renewable energy resources under this scenario compared to scenario E4 were intermittent, except for the 25 MW biomass unit modeled on Maui. The biomass unit offered firm capacity and displaced the 20 MW CT scheduled for 2013.

9.2.2 Results of the Electricity Scenario Runs

9.2.2.1 ENERGY 2020 Run Results

This section compares the estimated reductions in greenhouse gas emissions between the electrical scenario runs. Economic effects of these plans are discussed in Section 9.6, below.

It should be kept in mind that these scenarios are presented to examine the effectiveness of various strategies in reducing electricity sector CO_2 emissions. Any decision for actual construction would require further analysis, including evaluation of updated cost information, technical feasibility of integration of the particular systems into the electricity system, site availability, the likelihood of obtaining necessary permits, etc.. They are, however, based upon the best available information and costs from utility IRPs and DBEDT's renewable energy resource consultant.

9.2.2.2 Estimated Carbon Dioxide Emissions of the Electricity Scenarios

Figure 9.1 shows the CO_2 emissions estimated by the ENERGY 2020 model for the period 1990 – 2020. All of the scenarios modeled reduced greenhouse gas emissions below the Baseline scenario. None of the scenarios met the U.S. Kyoto commitment of 7% reduction of greenhouse gas emissions below 1990 levels.

By 2010, under the Baseline scenario, forecast CO_2 emissions were about 4.4 million tons of CO_2, or 28.5%, above the Kyoto goal. Scenario E2, Maximize Renewable Energy offered the greatest reduction of CO_2, but it was estimated to be still 3.4 million tons, or 21.8%, above the goal in 2010.

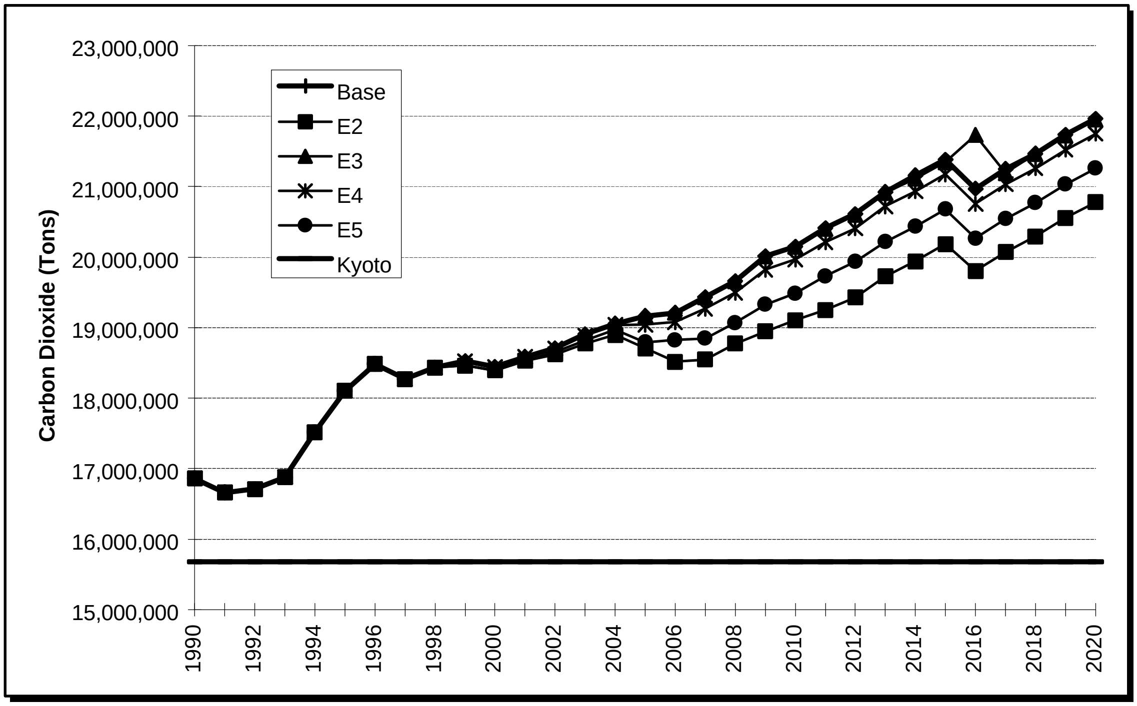


Figure 9.1 Estimated Hawaii CO_2 Emissions under Electricity Sector Scenarios, 1990 - 2020

9.3 Transportation Energy Scenarios

Transportation energy use was responsible for the largest percentage of Hawaii's domestic energy-produced CO_2 emissions. The scenarios were designed to examine potential ways of reducing transportation emissions.

9.3.1 The Base Transportation Scenario

The Baseline for the transportation scenarios was the same Baseline scenario used in the electricity sector analysis above. See the explanation of this scenario in Section 9.2.1.

The transportation-related aspects of the Baseline scenario bear repeating here. Ground transportation vehicle efficiency was assumed to be improving at lower rates than federal CAFE Standard-based projections. This was due to observations of ground transportation fuel efficiency and vehicle purchase patterns in Hawaii and nationwide which have resulted in a less efficient vehicle fleet. Air transportation efficiency was assumed to improve at the average rate of 0.7% per year based upon forecasts by the U.S. Department of Energy. Due to a lack of information, marine transportation improvements were not modeled.

9.3.2 The Ground Transportation Scenarios

GT2 -- 10% Ethanol Blend Gasoline. Under the GT2 scenario, the use of a 10% ethanol/90% gasoline blend was projected to begin in 2000. Initially, most of the ethanol would be imported, but eventually all would be produced in Hawaii from Hawaii-grown crops. Although the model depicted reaching the 10% ethanol level in the first year, in practice, this could take somewhat longer. However, if initiated in 2000, it was expected that the full 10% level would be reached before 2010.

This scenario had the advantage of being possible to implement without major modifications to vehicles and gasoline distribution infrastructure. The 10% ethanol component of the motor gasoline fuel was considered to be without greenhouse gas emissions, as CO_2 would be used in the growing cycle of the feedstock biomass.

GT3 – 50 Cents per Gallon Gasoline Price Increase. Although the GT3 scenario was not an energy efficiency scenario, it was developed to examine the effects of the policy on fuel use that would result if the cost of gasoline was increased by 50 cents per gallon over estimated future prices. The reasons for such an increase could be additional taxes or environmental fees, or as has been discussed in Hawaii, a 50 cents per gallon pay-at-the-pump insurance premium. It should be noted that the examination of this scenario does not indicate that it is recommended to be implemented at this time. It is intended to examine the effects.

GT4 – Increased Use of Alternate Fueled Vehicles. A small percentage of new vehicles were assumed to be alternate fuel vehicles over the period 2000 to 2020 under the GT4 scenario. By 2020, it was projected that 16% of automobiles and 4% of trucks used 85% alcohol fuel, 0.5% of automobiles and 6.7% of trucks used propane fuel, and about 1% of automobiles were electric vehicles. This scenario involves purely hypothetical projections as the future evolution of particular alternate fuel technologies, the relative costs and capabilities of alternate fuel vehicle types, availability of fuels in Hawaii, popular acceptance of different alternate fuels, and a variety of other factors.

GT5 -- Improved Vehicle Efficiency. Based upon available information, it appeared that Hawaii's and the national vehicle fleets did not meet the average current federal Corporate Average Fuel Efficiency (CAFE) standards. The GT5 scenario assumed action was taken at the federal level to raise the fuel efficiency standards required of light trucks and sport utility vehicles that achieved greater compliance with these standards. The model evaluates the effect of improving ground vehicle efficiency by 10% above current CAFE standards.

9.3.3 The Air Transportation Scenario

A2 – Aircraft Efficiency Improvements. The Baseline scenario assumed that civilian aircraft efficiency would improve at an average annual rate of 0.7% per year -- the nominal estimate of the U.S. Department of Energy. The Department of Energy also estimated that efficiency could improve at a rate of up to 2.5% per year. Scenario A2 modeled such improvements beginning in 1998.

In addition to manufacturers producing more efficient aircraft, other factors, such as the vintage and size of aircraft selected for Hawaii routes, passenger load factors, numbers of flights, and operational practices would affect efficiency improvements in Hawaii's aviation sector. This scenario represents a nominal technical potential.

9.3.4 Results of the Transportation Energy Scenarios

Figure 9.2 depicts estimated CO_2 emissions for 1990 to 2020 under the transportation scenarios. As with the electricity sector, no single transportation sector scenario reduced CO_2 emissions to the goal level.

Greater civil aircraft efficiency (Scenario A2) yielded the greatest savings, but resulted in CO_2 emissions 3.7 million tons, or 23.9%, greater than the Kyoto goal. Scenario GT2, the use of 10% ethanol blend gasoline in vehicles, and scenario GT3, a 50 Cents Per Gallon Gasoline Price Increase, closely followed scenario A2. Scenario GT4, increased use of alternative fuel vehicles, and GT5, improved federal vehicle efficiency standards, also reduced CO_2 emissions.

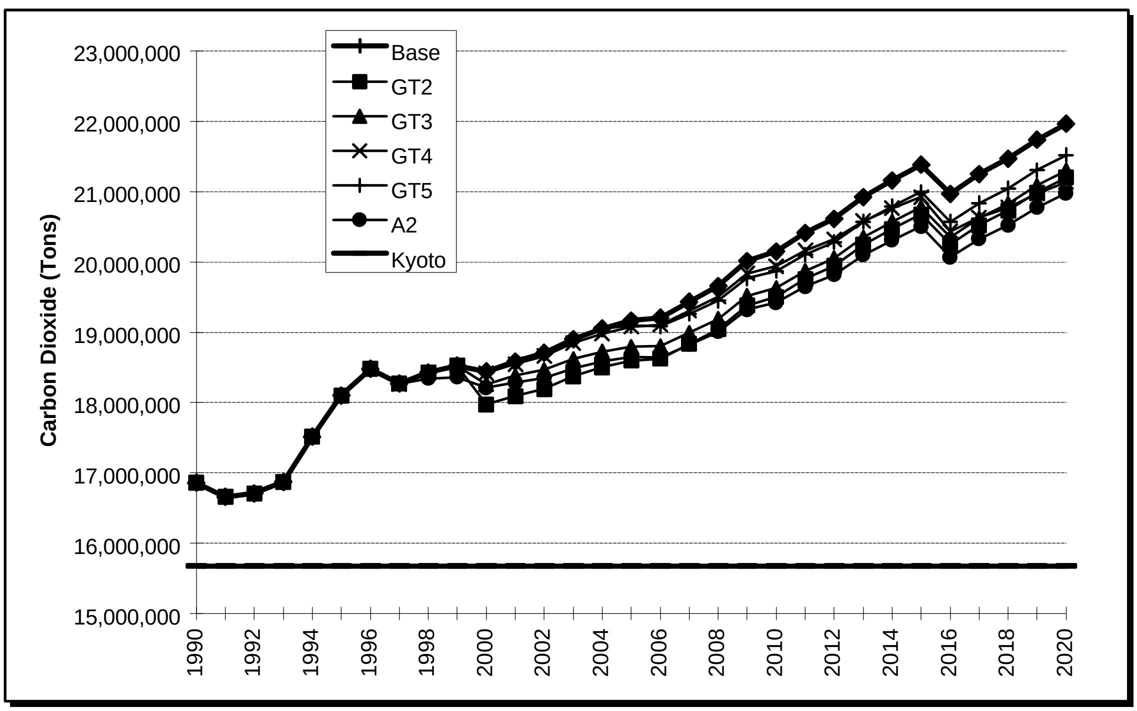


Figure 9.2 Estimated Hawaii CO_2 Emissions under Transportation Sector Scenarios, 1990 - 2020

9.4 Carbon Tax Scenarios

Carbon taxes, based upon the carbon content of fossil fuels, have been discussed as a way of internalizing the costs of fossil fuel use on the environment. In this context, they would increase the cost of fuels, discouraging their use. Under the scenarios here, it was assumed that the taxes were a cost to Hawaii's economy.

The analysis examined the economic consequences of a carbon tax, which turned out to be negative.

Other scenarios could be designed such that the carbon tax would be used to cover costs of federal or state government and other taxes, such as income taxes or the state general excise tax, would be reduced proportionately. Such offsets would likely reduce the negative consequences of carbon taxes while still tending to reduce fuel use. It is not clear whether the fuel use reduction would differ depending upon the ultimate payee of the tax and any offsetting deductions of other taxes. These considerations, in addition to the potential that negative economic consequences might be especially harsh for Hawaii, should be explored in detail before such a tax is considered or enacted. The increased cost of jet fuel when subjected to a carbon tax, for example, could reduce tourist traffic and have a major negative economic impact on Hawaii's tourism-based economy.

9.4.1 The Carbon Tax Scenarios

Three carbon tax scenarios were examined. They were applied to all fossil fuels and were implemented in 2005. They were as follows:

CT2 -- $50 per ton; and

CT3 -- $125 per ton.

Table 9.7 shows the additional expense per million Btu and measure of quantity estimated to result from imposition of each level of carbon tax on the fossil fuels used in Hawaii.

Table 9.7 Additional Costs of Carbon Taxes by Fuel

	CT-2 -- $50/Ton C		CT-3 -- $125/Ton C	
Liquid Fuels	**Cost/10^6 Btu**	**Cost/Gallon**	**Cost/10^6 Btu**	**Cost/Gallon**
Avgas	$ 1.04	$ 0.12	$ 2.60	$ 0.31
Distillate	$ 1.10	$ 0.15	$ 2.75	$ 0.38
Gasoline	$ 1.07	$ 0.13	$ 2.68	$ 0.33
Jet Fuel	$ 1.09	$ 0.15	$ 2.72	$ 0.38
LPG	$ 0.95	$ 0.09	$ 2.36	$ 0.23
Residual	$ 1.19	$ 0.18	$ 2.96	$ 0.44
Solid Fuel	**Cost/10^6 Btu**	**Cost/Ton**	**Cost/10^6 Btu**	**Cost/Ton**
Coal	$ 1.40	$ 0.75	$ 3.50	$ 1.88
Gaseous Fuel	**Cost/10^6 Btu**		**Cost/10^6 Btu**	
SNG	$ 0.80		$ 1.99	

9.4.2 Results of the Carbon Tax Scenarios

As expected, the carbon taxes as modeled in scenarios CT2 ($50/ton) and CT3 ($125/ton) reduced energy use and consequent CO_2 emissions. Figure 9.3 shows the results compared to the Base Scenario.

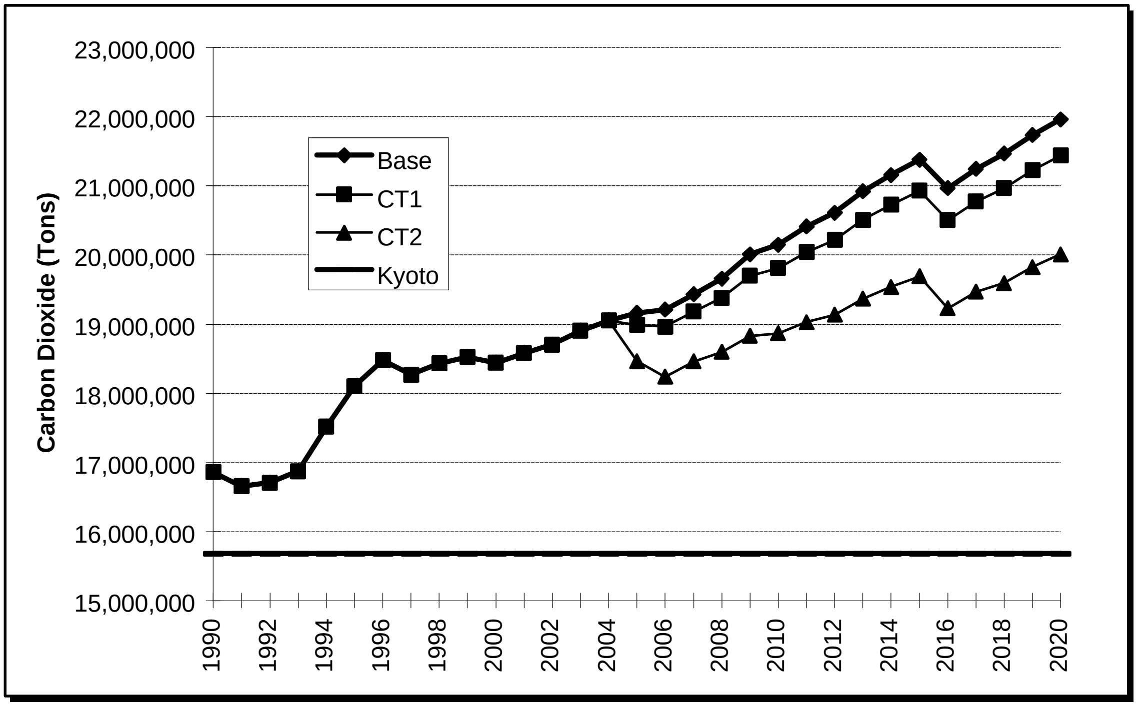


Figure 9.3 Estimated Hawaii CO_2 Emissions under Carbon Tax Scenarios, 1990 – 2020

9.5 Combination Scenarios

In developing the Combination Scenarios, the individual scenarios discussed above were ranked in order of year 2010 CO_2 savings, as shown on Table 9.8.

Table 9.8 Estimated CO_2 Savings in 2010, 2020, and 2000-2020 by Scenario Compared to Base

2010 Rank	Scenario	2010 $C0_2$ Savings	Above Kyoto	2020 Rank	2020 $C0_2$ Savings	Above Kyoto	2000-2020 Rank	2000-2020 $C0_2$ Savings	Above Kyoto
1	CT2 - $125/Ton Carbon Tax	1,278,864	20.4%	1	1,952,443	27.6%	1	23,131,693	21.5%
2	E2 - Max. Renewable Energy	1,046,110	21.8%	2	1,182,053	32.5%	2	17,360,129	23.3%
3	A2 - Aircraft Efficiency	727,943	23.9%	3	983,260	33.8%	3	14,351,708	24.2%
4	E5 - 10% Renewable Portfolio	665,258	24.3%	6	703,955	35.6%	5	83,313,342	25.3%
5	GT2 - 10% Ethanol Gasoline	644,690	24.4%	5	761,202	35.2%	4	13,282,881	24.5%
6	GT3 - $0.50 Gas Price Incr.	602,741	25.2%	7	662,554	35.8%	6	10,000,896	25.5%
7	CT1 - $50 per Ton Carbon Tax	338,762	26.4%	8	522,052	36.7%	8	6,115,677	26.7%
8	GT5 - Impr. Vehicle Efficiency	280,421	26.7%	9	443,660	37.2%	9	4,959,793	27.0%
9	GT4 - Increased AFV Use	212,081	27.2%	4	827,177	34.8%	7	6,263,323	26.6%
10	E4 - 5% Renewable Portfolio	183,023	27.3%	10	213,853	38.7%	10	3,105,937	27.6%
11	E3 - Max Efficiency Oil	-	28.5%	11	14,560	40.0%	11	(551,750)	28.7%
12	Base - Utility IRP and DSM	-	28.5%	12	-	40.1%	12	-	28.5%

Table 9.8 shows CO_2 savings compared to the Baseline scenario and the percentage by which the emissions under the scenario exceed the Kyoto target. Ranking, savings, and percent above the Kyoto target are also depicted for 2020 and for the period 2000-2020. The actions under the scenarios discussed above would each contribute to reducing CO_2 and other emissions with the exception of scenario E3.

Three Combination Scenarios were created to group the scenarios that offered the greatest potential CO_2 reductions. Obviously, some scenarios were mutually exclusive, e.g., the electricity sector scenarios. It was possible to use all of the ground transportation scenarios simultaneously and this was done in creating the combination scenarios. The Combination Scenarios were run in the ENERGY 2020 model to further explore some of the options available to policy-makers and their effectiveness in reducing greenhouse gas emissions.

9.5.1 The Combination Scenarios

The Combination Scenarios were as follows:

C1 – Maximum Reduction Scenario. Scenario C1 combined the electricity scenario with the greatest CO_2 reductions, E2 – Maximize Renewable Energy, with all of the transportation scenarios. These included the following:

GT2 – 10% Ethanol-based Gasoline;
GT3 – 50 Cents per Gallon Increase in Gasoline Price;
GT4 – Improved Vehicle Efficiency Standards;
GT5 -- Increased Alternate Fueled Vehicle Use and
A2 – Aircraft Efficiency Improvements.

Carbon taxes were not included.

C2 – Maximum Reduction Scenario with Maximum Carbon Tax. This scenario included all of the elements of C1 plus the $125/ton carbon tax (CT-2). It was expected to yield even greater CO_2 reductions, but at increased cost.

C3 – Hawaii-based Reductions Scenario. C3 was intended to examine the emission reductions under the control of various entities in Hawaii. The scenario was also based on the E2 – Maximize Renewable Energy electricity scenario. Two ground transportation scenarios, GT2 – 10% Ethanol-based Gasoline and GT3 – 50 Cents per Gallon Increase in Gasoline Price were also included.

9.5.2 Results of the Combination Scenarios

Figure 9.4 depicts the results of the three Combination Scenarios in relation the Base Scenario and the Kyoto target. None of the scenarios reduced CO_2 emissions to below the Kyoto target over the period 1990-2020. The C2 Scenario, Maximum Reduction Scenario with Carbon Tax, achieved the greatest estimated CO_2 emissions reduction, reaching a level only 983,558 tons, or 6%, above the Kyoto target in 2006. In 2006, the Baseline scenario estimate was 23% above the target. C2 would bring CO_2 emissions slightly below 1990 levels in that year. However, CO_2 emissions continued to grow after 2006, and were forecasted to be 1,260,832 tons, 8% above the Kyoto target by 2010. In 2010, the Baseline scenario was 28.5% above the target.

In 2020, emissions estimated for C2 were 1,760,792 tons of CO_2 above the goal, or 11%. By 2020, the Base estimate's CO_2 emissions were 40% above the Kyoto target.

C1 incorporated the same scenarios without the carbon tax. C1 was estimated to have its best performance by 2007, reaching a level 11% above the Kyoto target. By 2010, the ENERGY 2020 model estimated emissions under C1 at 1,970,797 tons, or 13%, above the Kyoto target. By 2020, estimated scenario C1 CO_2 emissions were about 2.8 million tons, or 18%, more than the Kyoto target.

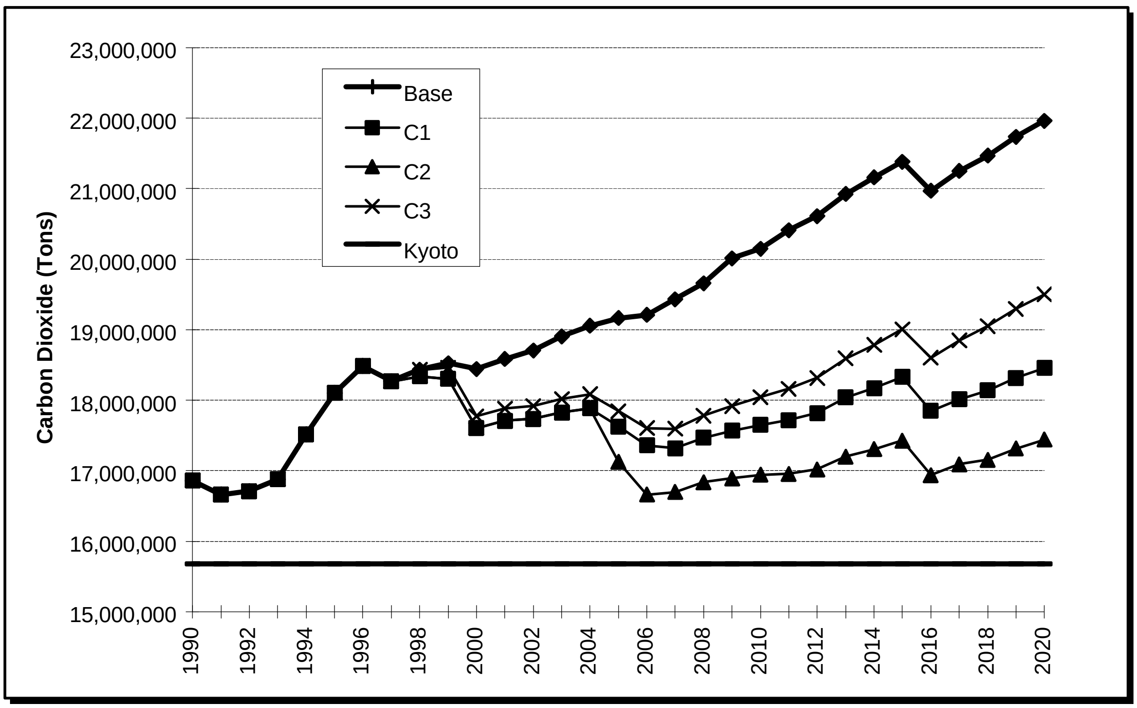


Figure 9.4 Estimated Hawaii CO_2 Emissions under Combination Scenarios, 1990 – 2020

Scenario C3 incorporated only actions that could be taken independently within the state and did not rely on technological advances from elsewhere. Under this scenario, the best performance was reached in 2007, at a level 1.9 million tons of CO_2 greater than the Kyoto target (12% above). By 2010, the estimated that C3 Scenario emissions could reach a level of 2.3 million tons, 15% above the goal. Year 2020 emissions were estimated at 3.8 million tons, or 24%, above the goal.

In each case, although the Combination Scenarios reduced CO_2 emissions significantly, continued growth in energy use caused emissions to continue to rise. Table 9.9 summarizes the results. The economic impact of the individual scenarios and the three Combination Scenarios is evaluated in the next section.

Table 9.9 Comparison of Combination Scenario CO_2 Savings							
Rank	Scenario	2010 $C0_2$ Savings	Above Kyoto	2020 $C0_2$ Savings	Above Kyoto	2000-2020 $C0_2$ Savings	Above Kyoto
1	C2 -- Maximum Reduction With Carbon Tax	3,210,150	8%	4,522,239	11%	61,446,885	10%
2	C1 -- Maximum Reduction	2,500,185	13%	3,503,514	18%	48,595,576	14%
3	C3 -- Hawaii-based Reductions	2,105,729	15%	2,462,189	24%	38,590,859	17%
4	Base - Utility IRP and DSM	0	28.5%	0	40%	-	28.5%

9.6 Estimated Economic Effects of Scenarios

9.6.1 Estimated Effects on GRP and Personal Income

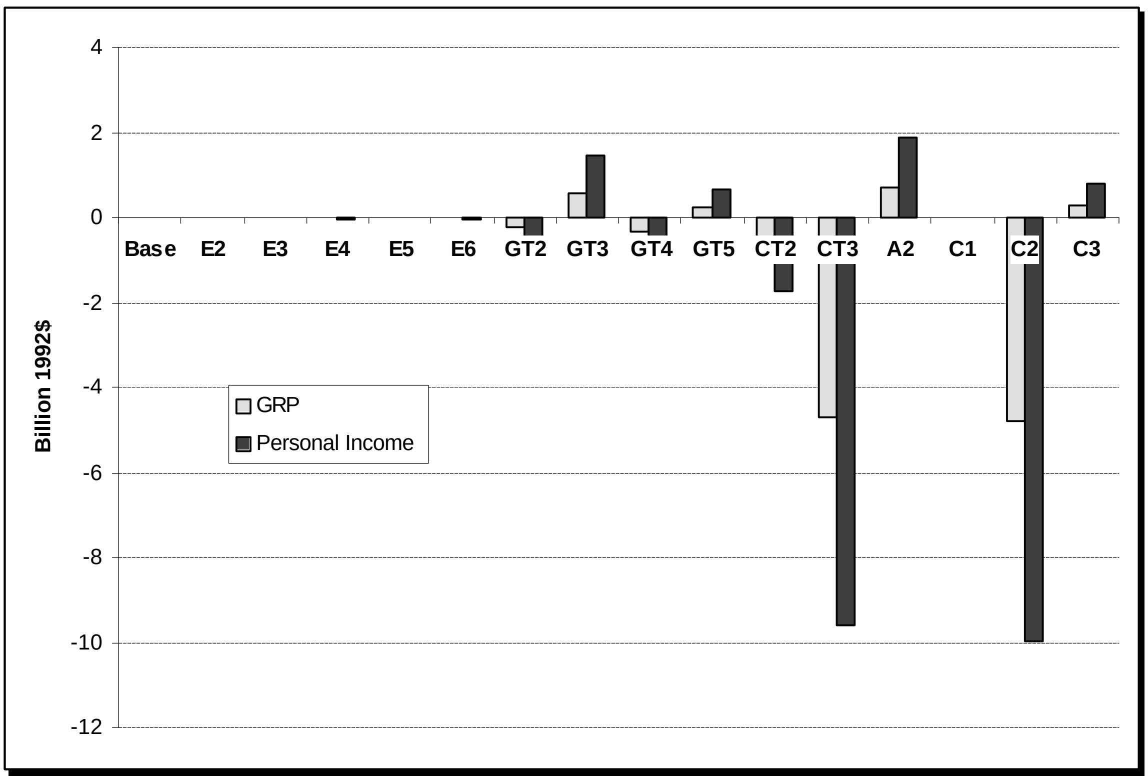


Figure 9.5 Estimated Effects of Energy Scenarios on GRP and Personal Income in Hawaii, 2000 - 2020

Figure 9.5 shows the effects of each of the scenarios on Hawaii's estimated gross regional product (GRP) and personal income over the period 2000-2020. The negative potential effect of carbon taxes on Hawaii's economy is shown by the results of CT2 and CT3, and Combined Scenario C2. CT3 was estimated to reduce GRP by $4.7 billion and over the years 2000 – 2020. This would be 0.56% of total GRP over that period.

Table 9.10 ranks the scenarios by their estimated benefit or cost to GRP per ton of CO_2 savings over the period 2000-2020. The CO_2 savings rank is indicated in the right column of the Table.

Table 9.10 Scenario Ranking by Estimated GRP Benefit (Cost) per Ton CO_2 Saved 2000-2020

Rank	Scenario	CO_2 Savings	GRP Effect	$GRP per Ton CO_2	CO_2 Rank
1	GT3 - $0.50 Gas Increase	10,000,896	$ 543,600,000	$ 54.36	9
2	A2 - Aircraft Efficiency	14,351,708	$ 696,300,000	$ 48.52	6
3	GT5 - Vehicle Efficiency	4,959,793	$ 223,400,000	$ 45.04	12
4	C3 - Hawaii Reductions	38,590,859	$ 275,900,000	$ 7.15	3
5	E4 - 5% Renewable Portfolio	3,105,937	$ 800,000	$ 0.26	13
6	C1 - Maximum Reduction	48,595,576	$ 10,100,000	$ 0.21	2
7	E5 - 10% Renewable Portfolio	10,623,658	$ (16,800,000)	$ (1.58)	8
8	E2 - Maximize Renewable Energy	17,360,129	$ (11,800,000)	$ (0.68)	5
9	GT2 - 10% Ethanol Gasoline	13,282,881	$ (242,500,000)	$ (18.26)	7
10	GT4 - Increased AFV Use	6,263,323	$ (344,700,000)	$ (55.03)	10
11	C2 - Max Reduction & Carbon Tax	61,446,885	$ (4,799,600,000)	$ (78.11)	1
12	CT2 - $50 per Ton Carbon Tax	6,115,677	$ (826,700,000)	$ (135.18)	11
13	CT3 - $125 per Ton Carbon Tax	23,131,693	$ (4,698,900,000)	$ (203.14)	4
14	E3 - Max Efficiency Oil	(551,750)	$ 6,900,000	Increased CO2	15
15	Base	-	-	-	14

Note: All Savings are relative to the Base Estimate

Six scenarios produced small positive economic effects over the 2000-2020 period, and offered positive contributions to GRP per ton of CO_2 emissions reduction. The next four scenarios, which did not include a carbon tax (E5, E2, GT2, and GT4) had relatively small negative effects on GRP. Scenarios C2, CT2, and CT3, which contained a carbon tax had significant negative economic effects. Scenario E3 was ranked 14 as it was not expected to reduce CO_2 emissions over the period.

9.6.2 Effects on Employment

As seen in Figure 9.6 and Table 9.11, there was a similar pattern of effects on employment. The scenarios that included a carbon tax had the major detrimental effect on overall employment. Over the years 2000 – 2020, C2 reduced employment by 78,499 job years (one job for one year), or 0.00056%; and CT3 reduced employment by 76,249 job years, or 0.00054%. CT2 reduced jobs by about 13,846 job years, or 0.00009%. While these numbers are significant in human terms, they were spread over the 21-year period, mitigating their effect somewhat. They do support the argument that a carbon tax and its negative effects should not be considered for Hawaii due to negative economic effects.

On the positive side, Scenario A2 increased employment by 14,476 job years, followed by GT3 at 11, 566 job years. In all, seven scenarios produced estimated increases in employment; however, E3, Maximum Efficiency Oil Generation, is ranked 14th as it was estimated to slightly increase emissions (See Table 9.11 for details).

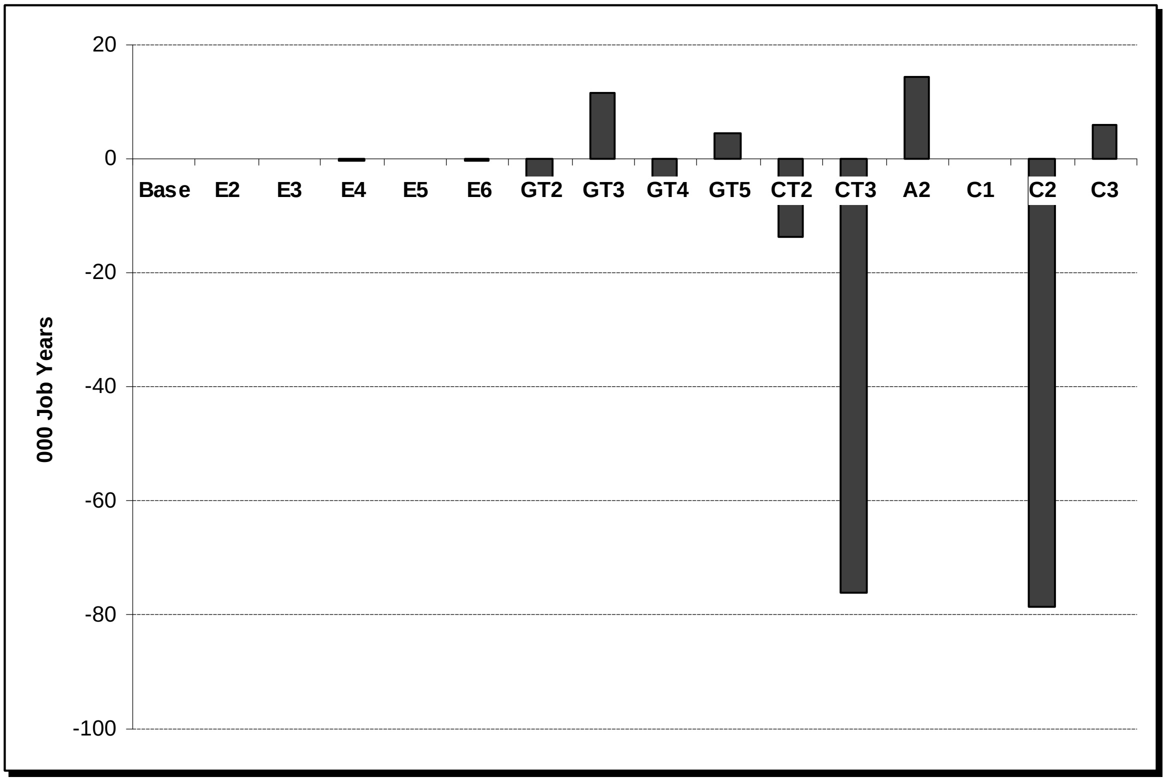


Figure 9.6 Estimated Effects of Energy Scenarios on Employment in Hawaii, 2000 - 2020

Table 9.11 Scenario Ranking by Estimated Job/Years Created or (Lost) per Ton CO_2 Saved 2000-2020

Jobs Rank	Scenario	CO_2 Savings	Job/Years Created or (Lost)	CO_2 Rank
1	A2 - Aircraft Efficiency	14,351,708	14,476	6
2	GT3 - $0.50 Gas Increase	10,000,896	11,566	9
3	C3 - Hawaii Reductions	38,590,859	5,832	3
4	GT5 - Vehicle Efficiency	4,959,793	4,583	12
5	C1 - Maximum Reduction	48,595,576	99	2
6	E5 - 10% Renewable Portfolio	10,623,658	8	8
7	E2 - Maximize Renewable Energy	17,360,129	(155)	5
8	E4 - 5% Renewable Portfolio	3,105,937	(377)	13
9	GT2 - 10% Ethanol Gasoline	13,282,881	(5,329)	7
10	GT4 - Increased AFV Use	6,263,323	(7,118)	10
11	CT2 - $50 per Ton Carbon Tax	6,115,677	(13,846)	11
12	CT3 - $125 per Ton Carbon Tax	23,131,693	(76,249)	4
13	C2 - Max Reduction & Carbon Tax	61,446,885	(78,499)	1
14	E3 - Max Efficiency Oil	(551,750)	129	15
15	Base	-	-	14

Note: All Savings are relative to the Base Estimate

9.7 Scenario-Based Recommendations

The model results suggest that the negative economic effects were most significant in the scenarios with carbon taxes. The differences between other scenarios were so small as to be within likely margins of error for the model. Based upon the estimated effects of carbon taxes as modeled; however, it is recommended that carbon taxes not be part of efforts to reduce CO_2 emissions.

9.7.1 RECOMMENDATION: Consider Implementing Elements of Scenario C3

Since the policies modeled in scenario C3 could be implemented at the state level, they are recommended for consideration for the initial Hawaii Climate Change Action Plan for the energy sector. They included E2, Maximize Renewable Energy in the electricity sector, and in the ground transportation sector, GT2, 10% Ethanol-based Gasoline, and GT3, 50 Cents per Gallon Gasoline Price Increase.

RECOMMENDATION: Support Efforts to Increase Aircraft and Ground Vehicle Fuel Efficiency

It was also clear that, due to the fact that a majority of Hawaii's energy use is in the form of jet fuel and ground transportation fuels, improvements in fleet efficiency would significantly help reduce CO_2 emissions. As the results of scenario A2, Aircraft Efficiency Improvements suggest, Hawaii should support aircraft research and development efforts at the national level, and encourage airlines serving Hawaii to use their most efficient types of aircraft. The results of the ground transportation scenarios, GT4 -- Increased Alternate Fuel Vehicle Use and GT5 -- Increased Vehicle Efficiency, suggest that Hawaii should encourage auto manufacturer efforts to develop and deploy alternative fuel vehicles and high-efficiency vehicles, and to seek federal increases in CAFE standards. Hawaii's citizens should also be made aware of the effects of vehicle use on climate change and should be encouraged to purchase fuel-efficient vehicles and to operate them in an efficient manner.

RECOMMENDATION: Maximize Renewable Energy and Demand-Side Management in the Electricity Sector.

Based upon the scenario runs in ENERGY 2020, Hawaii should continue efforts to maximize the use of renewable energy, and it should conduct research and development and demonstration projects. All of the scenarios employed the electric utilities' 20-year DSM programs. Hawaii's utility DSM programs should be encouraged and supported with appropriate tax credits. The utilities should evaluate the full range of possible DSM programs in each IRP cycle to ensure that any measure, which may become cost-effective in the face of increasing electricity prices is included. There should also be provisions to enhance renewable energy and DSM programs under any electricity restructuring that may be implemented. Possibilities include the use of system benefit charges and/or renewable portfolio standards.

CHAPTER 10 INDUSTRIAL PROCESSES

10.1 Overview

In 1990, Hawaii had only three industries that emitted significant greenhouse gas emissions in the course of their production processes -- the cement industry, oil refining, and synthetic natural gas production. Cement production stopped in Hawaii in 1995. Oil refining and synthetic natural gas production are responsible for a very low percentage of Hawaii's greenhouse gas emissions. Due to a lack of detailed reporting on oil refining and synthetic natural gas production, only the following brief summary is presented.

10-2 1990 Estimated Emissions Baseline

Table 10.1 summarizes the estimated greenhouse gas emissions from industrial processes in Hawaii in 1990.

Table 10.1 Estimated Greenhouse Gas Emissions from Oil, SNG, and Cement Industry Processes in Hawaii, 1990 (Tons)

Industry	CO_2	CH_4
Oil and Synthetic Natural Gas		
Transportation, Storage, and Distribution		156
Refining and Processing		81
Subtotal		237
Cement		
Clinker Production	109,005	
Masonry Cement	269	
Subtotal	109,274	
Total	109,274	237

Sources: Kusunoki 1996, Roberts 1996

10.2.1 Emissions from Oil Refining and Utility Gas Industries

Methane is the primary emission from oil and natural gas systems, although smaller quantities of NMVOCs, CO_2, and CO can be emitted. While CH_4 emissions occur throughout the total fuel cycles of oil and natural gas, Hawaii is involved in only the importing, refining, and distribution phases. Emissions occur in marine vessel operation, storage, and refining. Additional emissions come from venting and flaring of waste gas (USEPA, 1995b, D3-1).

While the *State Workbook* (3-1 – 3-3) provided a methodology for calculating CH_4 emissions from natural gas processing, transportation, and distribution, there is no natural gas use in Hawaii. However, synthetic natural gas (SNG) and propane-air mixtures are produced for use in utility gas systems. The emissions from this system were included in Table 10.1.

Hawaii's non-utility gas needs are met with liquefied petroleum gas (LPG). Emissions from the combustion of these gases are discussed in Chapter 8. Emissions from production of LPG are accounted for with other refinery processing in this chapter.

Fugitive emissions or venting of CH_4 vapors can occur during petroleum tankering. The amount of leakage is strongly dependent upon the original CH_4 content of the crude oil and its preparation for transport. Crude oil can emit CH_4 from some types of storage tanks. During the refining process, CH_4 may be leaked or vented in some processes. Most of such excess CH_4 is flared, or burned, converting the emissions to CO_2 and other products of combustion. Refined products generally contain negligible amounts of CH_4. Consequently, CH_4 emissions are not estimated for transporting and distributing refined products (D3-1). The 1990 CH_4 emissions for Hawaii's refineries were calculated by each of Hawaii's refineries at DBEDT request.

Refinery feedstocks are used to produce synthetic natural gas for use in the main Oahu gas system as utility gas. In the other utility gas service territories, i.e., outlying areas of Oahu and the neighbor islands, propane vapor is the only form of gas distributed. BHP Gas Company calculated the emissions from the utility gas systems at DBEDT request. (BHP Gas Company is now The Gas Company, a division of Citizens Utility.) To preserve the requested confidentiality of individual inputs the data provided by the two refiners and BHP Gas Company were presented in aggregated form.

10.2.2 Emissions from the Cement Industry

CO_2 is emitted during the production of cement. CO_2 is produced when calcium carbonate ($CaCO_3$) is heated in a cement kiln to form lime (calcium oxide or CaO) and CO_2. A total of 109,274 tons of CO_2 was emitted from cement production in Hawaii in 1990.

In August 1995, Hawaiian Cement, Hawaii's only cement producer, stopped manufacturing clinker and now imports all clinker used in the state. Hawaiian Cement plans to build a cement import terminal on Oahu, ultimately eliminating distribution of cement from the dock. This change in operations resulted from the decline in construction in Hawaii and a contraction from sales of 575,000 tons of cement in 1990 to projected sales of 297,000 tons in 1997 (Roig, 1997, B-8).

While clearly an undesired event from the standpoint of Hawaii's economy and jobs, the end of cement production marks the end of this source of greenhouse gas emissions in Hawaii. Nevertheless, the emissions resulting from cement production for Hawaii construction requirements will occur out-of-state.

10.3 Reducing Future Greenhouse Gas Emissions from Oil Refining

BHP Hawaii reported that their efforts to reduce methane emissions include a Leak Detection and Repair (LDAR) program and plans to upgrade seals and fittings on some of the company's storage tanks to lower fugitive emissions of Volatile Organic Compounds which contain some methane. The LDAR program has been implemented on all but one of the BHP refinery's major manufacturing processes and will be implemented on the remaining process in the near future (Kusunoki, 1997). Chevron USA did not respond to two requests for information on its activities in this area.

10.3.1 RECOMMENDATION: Encourage Refiners to Carry Out and Report Actions to Reduce Greenhouse Gas Emissions

Additional information is needed from refiners to assist in maintaining an accurate inventory of Hawaii greenhouse gas emissions and to monitor progress in reducing emissions.

10.4 Reducing Future Greenhouse Gas Emissions from Synthetic Natural Gas Production and Distribution

10.4.1 RECOMMENDATION: Encourage The Gas Company to Carry Out and Report Actions to Reduce Greenhouse Gas Emissions

The Gas Company, a Division of Citizens Utilities, operates a synthetic natural gas production facility on Oahu. The Gas Company was purchased from BHP Hawaii in 1997. This facility is a potential source of greenhouse gas emissions, primarily from fugitive emissions in the production and during transportation of synthetic natural gas through pipelines to the ultimate consumer on Oahu. In addition, The Gas Company operates propane air pipeline systems on Oahu and some neighbor islands that could also emit gas through fugitive emissions. Such leakage is likely to be very small, but it should be estimated and measures taken to reduce such emissions considered in future reporting. While data on greenhouse gas emissions from facility operations was not requested for this report, it should be included in future planning.

CHAPTER 11 MUNICIPAL WASTE MANAGEMENT

11.1 Overview

This chapter examines options for reduction of greenhouse gas emissions produced by municipal solid waste (MSW) management and wastewater treatment in Hawaii. It is an edited version of the recommendations and supporting analysis developed by the University of Hawaii Environmental Center and reported in *Greenhouse Gas Reduction Strategy for Hawaii, Phase II: Forecasts and Mitigation Options for Non-Energy Emission Sources* (Miller 1997) as part of this project. It contains additional information contributed by Gail Suzuki-Jones of DBEDT's Clean Hawaii Center in early 1998.

11.2 Emissions from Municipal Waste Management

11.2.1 1990 Emissions Baseline

Municipal waste management activities in Hawaii emitted 189,684 tons of CO_2 and 53,490 tons of methane in 1990. Table 11.1 summarizes these emissions as calculated for the *Inventory of Hawaii Greenhouse Gas Emissions: Estimates for 1990* (State of Hawaii 1997a). Most of these emissions were produced by MSW. Since methane emissions are estimated to have 22 times the global warming potential (tons CO_2 equivalent) as CO_2 emissions, the methane emissions from landfills and municipal wastewater treatment had the greatest effect on global warming. Municipal solid waste produced 98% of the global warming potential from municipal waste management in Hawaii in 1990.

Table 11.1 Greenhouse and Precursor Gas Emissions from Municipal Waste Management in Hawaii, 1990 (Tons)

Activity	CO_2	CH_4	Tons/CO_2 Equivalent
Municipal Solid Waste			
Landfill	147,098	53,490	1,323,878
Incinerator	42,586		42,586
Subtotal	189,684	53,490	1,366,464
Municipal Wastewater Treatment			
Treatment		1,027	22,594
Municipal Waste Management Total	189,684	54,517	1,389,058

(State of Hawaii, 1997a)

11.2.2 Estimated Growth in Emissions from Municipal Waste

Figure 11.1 depicts the estimated growth in methane emissions from municipal solid waste and municipal wastewater treatment through 2020 that could occur if no additional action is taken to reduce emissions. Figure 11.2 shows the forecast increase in CO_2 emissions. The drop in 1993 and 1994 is due to reduction in incineration and then closure of the Waipahu Incinerator on Oahu.

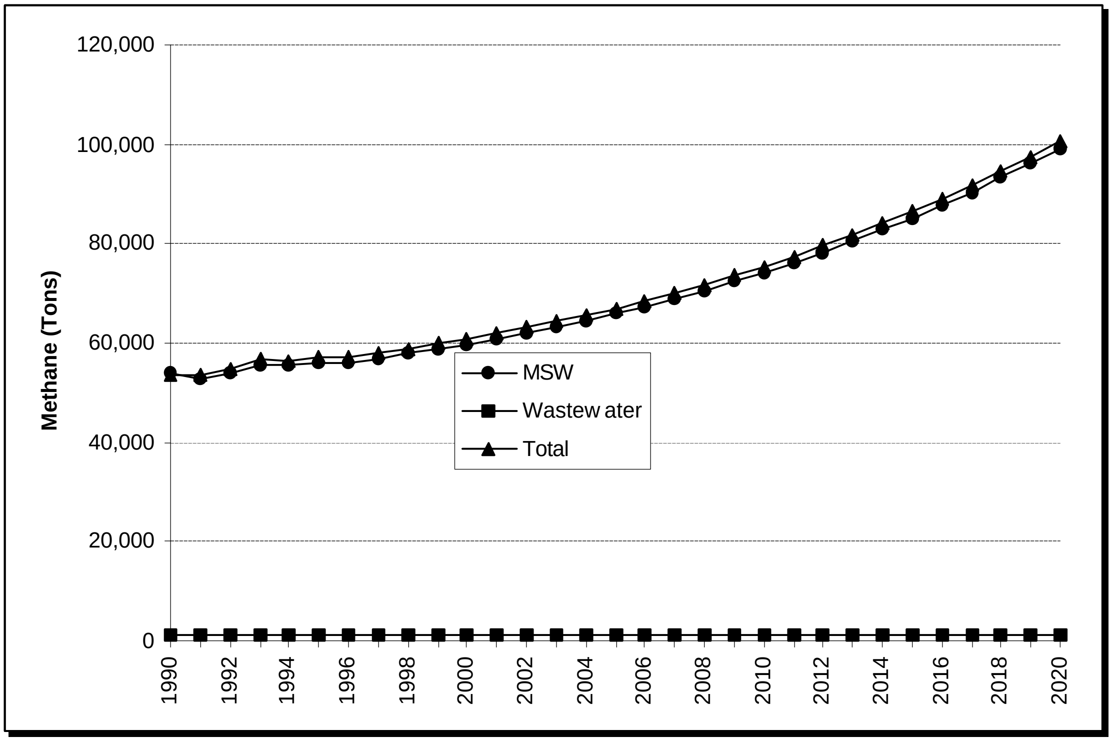


Figure 11.1 Estimated methane Emissions from Municipal Waste, 1990 – 2020

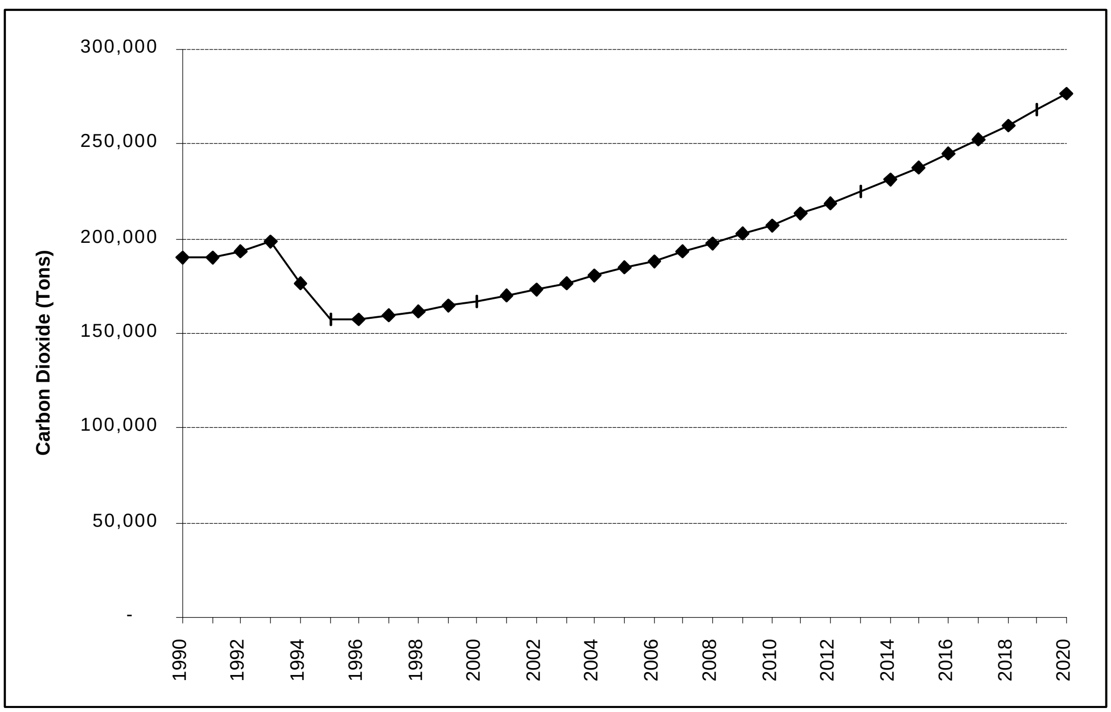


Figure 11.2 Estimated CO_2 Emissions from Municipal Solid Waste, 1990 - 2020

While the H-POWER waste-to-energy plant was in operation by 1990, its CO_2 emissions are accounted for in the energy sector. H-POWER reduced forecast methane emissions through its combustion of a majority of MSW produced on Oahu that would have otherwise gone to landfills and emitted methane over a thirty-year period.

11.2.3 Hawaii's Municipal Solid Waste Situation

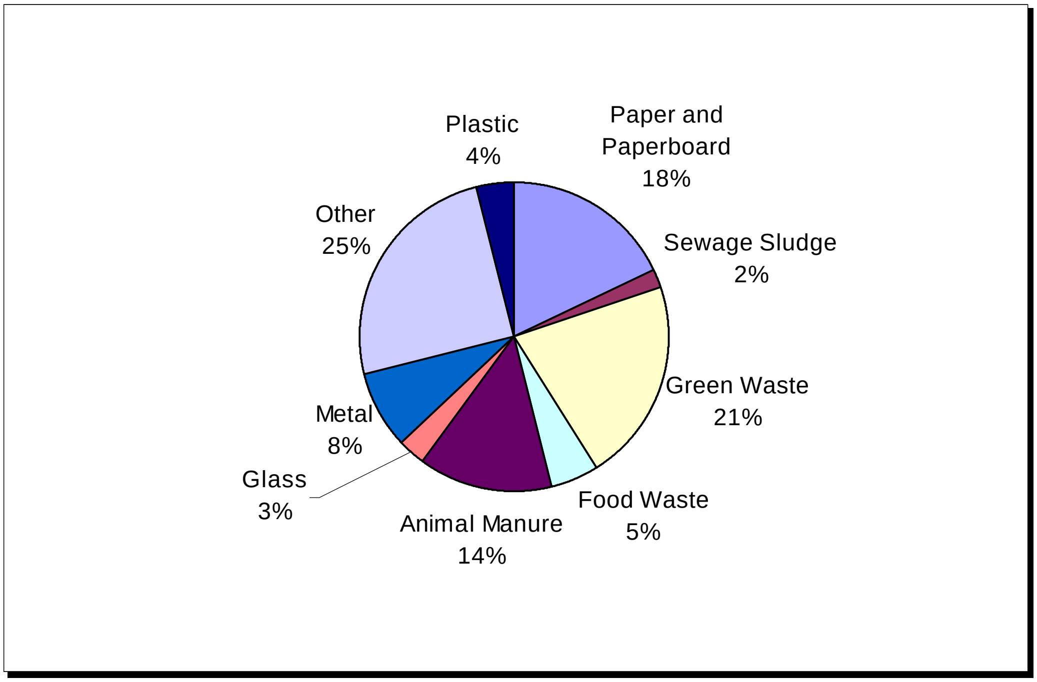
- The 1990 methane emissions from landfills were 72% of the total (State of Hawaii 1997a, 2-8). Nationally, these emissions are on the decline through a combination of pre-consumer and post-consumer solid waste reduction measures, and increased capture of landfill methane emissions (EIA 1995, 35). In 1990, the U.S. Environmental Protection Agency (USEPA) set goals of 25% solid waste reduction nationwide by 1995 and 50% reduction by 2000. As current efforts fall far short of this goal, the USEPA revised its goal recently to a 35% reduction by 2005 (Harder 1997). The USEPA recently prioritized the methods of reducing emissions from landfills as follows: source reduction, recycling, composting, incineration, and landfilling (ICF Inc. 1997, ES-1; see Table 3).

In 1989, of the estimated 1,243,000 tons of MSW generated in Hawaii, about 83% were landfilled, 4% were recycled or composted, and 13% were incinerated (*Biocycle*, March 1990, cited in State of Hawaii 1991, 2-3). The State of Hawaii's 1991 *Waste Management Plan* recommended most of the same emission reduction measures as the USEPA. (The *Plan* was under review in 1998 by a public/private task force.) The 1991 *Plan* prioritized the methods as follows: source reduction, recycling, and bioconversion (composting and mulching).

Source reduction was stressed most strongly "because it reduces costs, conserves energy and resources, and even increases economic competitiveness" (State of Hawaii 1991, ES-1 and G-1). The tonnage of waste being hauled to landfills or to combustion facilities statewide steadily decreased in recent years. On Oahu, nearly 10% less waste went to landfills or waste-to-energy plants in 1997 than in 1991, the historical peak year (Jones 1997).

- Specific waste reduction efforts in Hawaii are being carried out by the four counties. The four counties' waste management plans emphasize, in decreasing order: composting, paper recycling, and source reduction. This is the exact opposite of the order recommended by the state. While the counties have emphasized composting, due mainly to the relative ease with which green waste can be separated from other solid waste at the source, recycling actually reduced the most waste tonnage in recent years (Harder 1997).
- As can be seen in Figure 11.3, given the composition of the waste stream in Hawaii, a combination of paper recycling and

composting can have a major impact on the volume of waste that goes to landfills or waste-to-energy plants. The following sections recommend a set of measures to reduce MSW in Hawaii and the resultant greenhouse gas emissions.



(Source: Hollyer, 1996)

Figure 11.3 Estimated Composition of Waste Generated in Hawaii, 1991

11.3 Recommended Actions to Reduce Emissions from Municipal Solid Waste

The State of Hawaii recently became an USEPA Waste Wise program participant. This commitment involves achieving results in the following areas: waste prevention, recycling collection, and buying recycled products. Using less, recycling materials, purchasing products that create less waste, and separating, collecting, storing, and removing recyclables are some measures the State is using to reduce MSW.

The following measures are recommended to reduce greenhouse gas emissions from MSW: (1) pre-consumer source reduction; (2) post-consumer source reduction; (3) waste-to-energy plants; (4) flaring of methane emitted from landfills; and (5) using methane emitted from landfills as a fuel to generate electricity or steam.

11.3.1 Recommendations for Pre-Consumer Source Reduction (low cost, high benefit)

Source reduction is perhaps the easiest and most straightforward method of reducing methane emissions in Hawaii. Source reduction can occur either prior to the sale of goods to the consumer, or when the consumer discards that refuse. It is estimated that product packaging takes as much as 30% of landfill space nationwide (State of Hawaii 1991, 5-8).

11.3.1.1 Recommendation: State and County Government Leadership in Pre-Consumer Source Reduction

State and county governments can take the lead in pre-consumer source reduction efforts, providing an example for business, by taking the following actions:

a. Educate local commodity producers and importers regarding the desirability of reducing packaging volume for commodities.

b. Buy in bulk and request packaging that uses recycled materials.

c. Educate design and construction professionals on source reduction strategies related to the building process as well as on the use of resource-efficient building products such as recycled-content plastic lumber and glass tile. Under a grant from the Department of Energy, the DBEDT Energy, Resources, and Technology Division is developing a training program in energy- and resource-efficient building strategies, systems, and products for design and construction professional

d. Increase use of recycled paper. Although recycled paper generally costs 1% to 2% more than virgin paper, government should take the lead, despite the price difference. The State Department of Accounting and General Services (DAGS) now ensures that 25% of paper purchases consists of at least partly recycled material. This percentage that may rise to nearly 100% due to a joint effort by several western states to buy recycled paper in cost-effective quantities (McCabe 1997).

e. Require all new copy machines in government offices to be capable of making two-sided copies. This could build on the program already underway to reduce paper used by copy machines and to increase the recycling of the paper that is used.

f. Expand the use of electronic mail.

g. Use and maintain efficient and durable equipment, supplies, and materials.

h. Specify and use landscape materials that use recycled waste in public works and other large projects.

11.3.1.2 Recommendation: Encourage Consumer Actions in Pre-Consumer Source Reduction

Consumer participation in source reduction could be encouraged in the following ways:

a. Reduce junk mail. Provide forms to businesses and residences for use to remove themselves from junk mail lists. Junk mail is a major contributor to paper waste, and its elimination would also improve the efficiency of mailrooms in private and public operations (State of Hawaii, 1991, G-4). This could dovetail with the program already being implemented by the County of Kauai, which specifically recycles junk mail from residences (Tanegawa 1997).

b. Establish and implement a “green packaging” label which signifies that producers have used minimal packaging volume and/or substantial percentages of recycled materials in their packaging (State of Hawaii 1991, p. G-4 and G-5). The State’s 1991 *Waste Management Plan* suggested such a label for local manufacturers (G-6).

c. Reuse products and supplies. Exchange, sell, or donate unneeded goods and materials to nonprofit organizations. Unwanted and wanted reusable items can be listed on the HIMEX (Hawaii Materials Exchange), a computerized listing designed to help divert materials from the waste stream and to extend the life of reused materials.

d. Promote reusable bags for supermarket and commodity store customers. Promotional efforts would likely be necessary to gain customer support for this measure.

11.3.2 Post-Consumer Source Reduction (low to moderate short-term cost, high benefit)

After goods have been used by the consumer and are ready to be discarded, there are several options for reducing the amount of solid waste that goes to landfills. The most obvious is recycling, which is discussed below. Composting will be discussed later in Chapter 12 with fertilizers.

It should be noted, however, that even if Hawaii’s recycling rate continues to increase, there may be little effect on the future organic content of landfill material. The USEPA predicted that, nationally, the organic content of landfill waste will increase slightly in the coming years due to: (a) increased per capita consumption of paper, wood, and other organic components; and (b) increased efforts to recycle noncombustible materials such as aluminum and glass (USEPA, 1993a, 4-26).

Since only about 6% of the organic portion of Hawaii’s waste stream are being recycled at present (Hollyer *et al.* 1996), there is room for fairly substantial increases in organic recycling. Counties are now moving to increase the green waste recycling percentage (McCabe 1997).

As an example, on Oahu, effective May 1998, the allowable amount of cardboard or green waste in loads delivered to any City and County of Honolulu disposal site was reduced from 25% to 10%. This restriction was intended to impose source separation and recycling of these materials.

The amount of construction and demolition (C&D) debris in loads at the only MSW landfill were restricted to 10%. Nanakuli landfill, a private C&D disposal site, accepts these materials. In support of these efforts, the Clean Hawaii Center and State of Hawaii Office of Solid Waste Management have co-sponsored workshops, a developmental forum, and a publication, *Minimizing C&D Waste*.

The following recycling measures are suggested:

11.3.2.1 Recommendation: Support county recycling programs and improve coordination efforts and internal programs of state government offices.

The Clean Hawaii Center within the DBEDT Energy, Resources, and Technology Division produced the *Buy Recycled in Hawaii Directory* of recycled goods and services to raise awareness of local companies that collect, process, and remanufacture recyclable goods. The Center has also conducted a number of "Buy Recycled Workshops" for both the public and private sector on how and why to buy recycled. Maui County has initiated a "Remade on Maui" campaign to promote a variety of value-added products. The City and County of Honolulu promoted the "Made in Hawaii Festival" as part of a national campaign to buy locally recycled products.

11.3.2.1.1 Recycling in Hawaii County

On the Island of Hawaii, all recycling to date has been undertaken by private entities. An estimated 9% and 12% of waste is being recycled. The future trend remains unknown, due in part to uncertainty regarding the initiation of county-run recycling programs. For example, in the early 1990s, the county first started, then suspended a composting (Capelis 1997; McCabe 1997). The Rural Community Assistance Corporation (RCAC) has proposed setting up recycling parks. By increasing recycling at transfer stations, the facilities will become recycling parks, diverting reusable and recyclable material from landfills, and becoming a community resource.

11.3.2.1.2 Recycling in Kauai County

On Kauai, county recycling efforts are estimated to divert approximately 16% of the waste stream, or 200 tons per day, from landfills. The program includes a system of six residential recycling centers for newspaper, cardboard, junk mail, glass, and aluminum. There is also a county program to pick up green waste and tires upon request. This program diverted approximately 29,500 cubic yards of green waste from landfills in 1996, converting it to mulch, which the county gave away to homeowners. Around 90% of this green waste were generated by county operations. Although a county-run composting project was attempted in 1993, it was discontinued in 1994 (Tanegawa 1997).

The county hopes to initiate new mulching and public education programs in the near future. The mulching operation, while privately run, would use county land in Princeville. It would feed a nearby, privately-run composting operation which intends to also compost biosolids. The county is also considering bans on materials such as green waste and cardboard at landfill facilities. The Kauai Resource Exchange Center, a community-based collection program and drop-off for reusable items will also contribute to the diversion of material from Kauai's landfill. Together, these programs should cause Kauai's recycling percentage to resume its upward trend (Tanegawa 1997).

11.3.2.1.3 Recycling in Maui County

Maui's recycling rate reached 24% in 1996 (Hirose 1997). Most materials are recycled via drop boxes, but the private operation, Maui Recycling Service, charges $17 per month for home pickup of all recyclable materials.

Maui initiated island-wide sewage sludge (hereafter biosolids) and green waste composting, and banned disposal of biosolids in landfills in 1996. Green waste is brought to EKO Composting on the site of Maui's Central Landfill where it is co-composted with all of the county's biosolids. Another private company, Maui Composting, plans to start composting green waste and food waste in the near future using state startup funds (Baker 1997). The county composted approximately 28,300 tons of green waste, biosolids, used oil, and shipping pallets in 1996, up sharply from about 18,000 tons only a year before (Cordell 1997). Maui has set itself the ambitious goal of recycling between 50% and 65% of its waste stream by the year 2000, through these and other operations, and through an impending county mandate that will require all businesses to recycle their cardboard and food waste (Baker 1997).

11.3.2.1.4 Recycling in the City and County of Honolulu

On Oahu, the amount of MSW being recycled has been steadily increasing, from 22% in 1995 to 26% in 1996, and is projected to reach 28% by 2000 (Namunart 1997). The increases were mainly due to initiation of new regulatory measures. For example, the City and County of Honolulu now bans any load with more than 10% cardboard, paper and/or green waste from all landfills and the H-POWER plant.

The green waste is mulched or composted, since 1993, mainly by the private company Hawaiian Earth Products, Ltd. Straight mulch is given to homeowners and city parks for free, while composted mulch is sold for $30/lb. to $32/lb. Oahu's state and national parks and monuments have not yet requested this mulch and represent a future market (Namunart 1997; Hawaiian Earth Products 1995; Hawaiian Earth Products 1997).

In areas of Oahu with automated trash pickup, green waste is picked up on specified days. As the percentage of the county receiving automated pickup grows (scheduled to reach 75% to 85% by the year 2000), this service will reach a higher percentage of residents. This should dramatically increase green waste pickup tonnage from 350 tons in 1996 to approximately 6,000 tons by 2000 (Namunart 1997).

On the other hand, Hawaiian Earth Products reported a significant decrease recently in the amount of incoming green waste. In 1997, the company received approximately 1,500 tons of green waste per month, mainly from private haulers, down from the 2,000 tons per month the operation received in early 1995. The company believes this may be due to both lagging interest on the part of the community, and on lax enforcement of the county's green waste ban at the Waimanalo Landfill (Hawaiian Earth Products 1995 and 1997).

11.3.2.1.5 Recommendations for Increased State and County Efforts in Recycling

While recycling efforts necessarily will vary from county to county, it appears that all of the counties can still learn from each other. Furthermore, the state has a role to play as a clearinghouse for information both between counties and from outside the state. The state can also urge the counties to make their recycling programs more consistent with each other, and to better educate the public through workshops, bill inserts, etc.

The state can help county recycling efforts in direct ways as well. For example, the state already charges an "advance recovery fee" of 1 cent for every glass container shipped into the state. This income funds glass recycling efforts in the various counties, with $100,000 going to Kauai alone in 1996 (McCabe 1997; Tanegawa 1997). Similar advance recovery fees could be charged for paper, cardboard, and other organic materials.

Another important step for the counties could take would be to increase tipping fees at landfills, which currently range from $37 on Maui to $55/ton on Oahu (plus a 6% surcharge which goes to recycling efforts) (Parke 1997; Baker 1997). A way to improve community acceptance of such a measure would be through unit pricing; in other words, "the more one throws away, the more one pays per ton" (Baker 1997). Although a tipping fee surcharge may not be as proactive or direct an approach as an advance recovery fee, the administrative costs of a surcharge would probably be much lower (State of Hawaii 1991, p. 7-9 and G-9).

As noted above, counties are moving to impose recycling mandates and further bans on landfilling (McCabe 1997). Recycling methods could be improved by increased efforts at state and county level to use locally recycled products. For example, although the state passed Act 228-96, which encourages the state government to purchase locally-produced composted products, this act is not binding (Hollyer *et al.* 1996, p. 6). None of the county governments have made commitments to buy any products from local operations that undertake either composting or other recycling (Baker 1997). Even on Maui, where the county is saving an estimated $20,000 per month in reduced hauling fees due to the activities of Maui Recycling Service, this private operation has received little support aside from the county's gift of a collection truck. This operation, which does not generate a net profit, would benefit from commitments by the county and/or state to purchase the recycled products and/or move the excess to markets off-island (Baker 1997). On Oahu, Hawaiian Earth Products has found the county to be a fairly good customer, but the state hardly ever purchases their product, using mainland compost instead (Hawaiian Earth Products 1997).

Urban curbside recycling programs were attempted in the past by more than one county, but legal or accounting hurdles tend to abort these efforts. Probably the largest county-run recycling effort to date provided curbside recycling pickup in Kailua and Kaneohe on Oahu over a period of several months in 1991. This program had strong community support, yet was discontinued due to cost. The real problem may have been inappropriate cost accounting. For example, collection vehicles and equipment costs were based upon a single year of operation rather than being amortized over a standard, useful life expectancy period for such equipment (Harrison 1997; McCabe 1997).

There now are 54 drop-off bins around Honolulu. Most are located near schools, and any income from recycling the materials collected goes for educational purposes. Maui is also attempting to initiate curbside pickups, but the program has been held up for several years due to challenges in court (McCabe 1997).

Some of the problem remains outside the jurisdiction of both state and county governments. In particular, the cost of shipping recovered material overseas for recycling remains prohibitive in many cases (McCabe 1997). Nevertheless, there are opportunities to improve recycling efforts, in particular for recycling of green waste and food waste, both of which can (and, in the latter case, must) take place within the state. Efforts to recycle green waste and food waste will be discussed further in Chapter 12.

Costs of recycling programs include capital costs for planning and equipment, plus operating costs for transportation, marketing, labor, maintenance, administration, and debt service. Benefits arise largely from the sale of recovered materials. The community benefits through savings of disposal costs and any economic stimulus the program provides. If the counties run these programs, such community benefits are largely internalized (USEPA 1989, p. 74). One small but important aspect of overall cost would be a program to inform and encourage the public to sort refuse by recyclable type. This effort is key to the overall success of the project.

Detailed costs and benefits for county-scale recycling programs in Hawaii remain largely unknown, as noted above. However, on the mainland, rising costs for virgin paper pulp and aluminum have put many recycling programs into the black in recent years, and a private firm currently finds it profitable to undertake paper recycling for the University of Hawaii system (Ah San 1997). The market for compost also appears far from saturated, since Hawaii still imports over 12,000 tons of compost and other soil amendments annually (Hollyer *et al.* 1996, p. 4).

11.3.2.1.6 Recommendation: Provide Incentives for Private Recycling, Reuse, and Remanufacturing

Recommendations to provide incentives for private recycling, reuse, and remanufacturing include:

a. **Initiate bans on green waste, food waste and cardboard from entering landfills or the H-POWER plant**. The state Department of Health (DOH) developed an administrative rule (Title 11, Chapter 58.1), which requires all counties to develop a plan to ban or require source separation of, green waste from entering a disposal facility (Hollyer *et al.* 1996, p.6). The counties are moving to meet this rule, but enforcement varies.

b. **Investigate increasing tipping fees at landfills**. Tipping fees may increase significantly (by up to 300%) due to the current trend toward de-privatization of landfills (*Honolulu Advertiser*, June 8, 1997, p. A27). On Maui, where all open and closed landfills are county-run, tipping fees and general fund allocations generate approximately $400,000 per year for recycling operations with tipping fees of $37 per ton (Baker 1997).

All landfills and the H-POWER plant charge tipping fees. A state tipping fee surcharge, in addition to the 25 cents/ton surcharge currently imposed to fund regulation, could be used to fund state-level waste management programs, (State of Hawaii 1991, p. 7-11; McCabe 1997). An additional 50-cents/ton surcharge would provide approximately $500,000 per year for recycling efforts, and added financial impetus to waste generators to make use of such alternative methods.

c. Educate businesses and residents on benefits. For the last few years, the City and County of Honolulu has sponsored the Partnership for the Environment, which brings together business leaders to share information regarding initiatives to reduce waste generation and energy use. This project has had positive results, and is expected to continue. For example, the Sheraton and McDonald's chains in Hawaii have told their suppliers to cut packaging by 25%. Supermarkets and other retailers could initiate such programs (Harder 1997).

State and county departments have also helped fund the Green House Hawaii Project, a non-profit project to display and promote building materials and designs which are resource-efficient, recycled, and locally manufactured (Green House Hawaii 1997).

The DBEDT Clean Hawaii Center promotes recycling businesses and market development through funding, workshops, a *Buy Recycled in Hawaii* guide, and a checklist of permit requirements and regulations for solid waste and recycling businesses. Continued support of the Clean Hawaii Center is recommended as many of the Center's activities such as: education, business counseling for recycling and remanufacturing businesses, remanufactured product and market development, and development of materials exchange facilities contribute to the self-sufficiency industry and public awareness of waste as resources.

d. **Educate government agencies on benefits of recycling.** State government offices also need to educate each other. Dispersed offices and agencies in particular tend to be out of the recycling loop. One notable effort currently underway is the DBEDT-coordinated program to reduce use of paper in -- and increase recycling associated with -- copy machines (McCabe 1997). Related measures include increasing the availability of electronic mail to state and county employees, and replacing paper towels with cloth towels (State of Hawaii 1991, p. G-3).

e. **Government procurement commitments to recyclers.** See discussion above. This echoes a recommendation made by the Department of Health in 1991 (ES-4).

f. **Tax breaks and low-interest loans**. Incentives could be offered to recyclers and businesses that remanufacture goods from waste resources.

Each of these options has potential in and of itself, but by combining them it is more likely that a profitability threshold will be reached, whereupon the last two options may no longer be necessary.

Some operations require funds only for startup fees. On Maui, in May 1997, the King Diesel company began converting used cooking oil from food establishments into ethanol, a nontoxic and cleaner-burning alternative to diesel fuel. This operation expects to recycle 4,000 to 5,000 gallons of cooking oil per month by the end of 1997, out of an estimated 8,000 gallons generated monthly throughout the county. Funded by the U.S. Department of Energy, this unique facility expects a 5-year payback period in spite of the $1.95 per gallon it charges, compared to about $1 per gallon for regular diesel fuel (King 1997).

Other operations, such as the Maui Recycling Service, have continually operated in the red, due mainly to low demand for their products. Not only government procurement commitments, but aid in marketing and shipping recycled products would often help such companies become self-sufficient.

All of the above operations together would have a significant effect on reducing the amount of methane emitted by MSW in Hawaii. Their contribution to CO_2 reduction would be smaller, but also noticeable. However, these efforts would be overshadowed, however, by the much larger reductions in methane emissions possible from increased flaring and burning of landfill methane for power. This is due to the fact that, on most islands, recycling efforts are well underway. Many of the easy targets have already been met, and future progress in many areas will likely be incremental, a slow but fairly steady increase over the coming decade, after which the trend will level off. Landfill methane, on the other hand, is a relatively untapped resource, and its mitigation is mandated mitigated in all of the larger landfills in the state. The following sections discuss various ways of using landfill methane or reducing its effects on global warming and climate change.

11.3.3 Recommendation: Construct and Operate Waste-to-Energy Plants (moderate to high short-term cost, moderate benefits)

11.3.3.1 Oahu Waste-to-Energy Plant

In H-POWER (Honolulu Program of Waste Energy Recovery), located in Campbell Industrial Park, Oahu is an excellent example of a successful waste-to-energy plant. It has made significant reductions in the amount of MSW going to landfills since initial operation began in 1989. The City and County of Honolulu contracted with Honolulu Resource Recovery Venture (HRRV) in July of 1985 to design, construct, and operate the waste to energy facility. The prime objective of the project was to extend the life of existing landfills and to reduce requirements for future landfills. The limited land area of Oahu offered few sites for new landfills and the desire to preserve the island's scenic beauty was an additional incentive.

Prior to the initial operation in 1989, the facility was sold to the Ford Motor Credit Company and leased back to the City and County of Honolulu. Ford obtained valuable tax credits in this transaction while the City and County received an $80 million cash profit (Greer 1997).

The capacity of the H-POWER plant is about 650,000 tons of MSW per year. Waste delivered to the facility is classified and some recyclable waste is separated out. Machinery in the facility shreds waste into refuse-derived fuel (RDF), increasing its heat value and the efficiency of steam production. H-POWER produces about 57 MW of electricity, providing 46MW to Hawaiian Electric Company under a firm power purchase agreement, and using the remainder to operate the plant.

Table 11.2 shows the amount of MSW burned by H-POWER and the amount of electricity generated for sale. While this process produces CO_2, it offsets imports of oil and prevents waste from going to landfills where methane would be produced with greater effects on global warming. Note that the methane and landfill CO_2 savings are cumulative. Had the MSW burned in H-POWER been landfilled, each year's increment would emit greenhouse gases for about thirty years. CO_2 and methane in Table 11.2 are in tons. GWP, or global warming potential, is expressed in tons of CO_2-equivalent.

Table 11.2 H-POWER Performance and Emission Reduction, 1990-1996

	1990	1991	1992	1993	1994	1995	1996
MSW (Tons)	492,984	508,000	526,447	580,375	618,976	620,286	465,388
10^6 Btu	4,929,840	5,080,000	5,264,470	5,803,750	6,189,760	6,202,860	4,653,880
MWh Generated	339,976	366,050	373,508	349,344	379,478	382,661	326,208
MWh Sold	312,479	320,038	327,600	304,344	332,505	335,576	281,517
CO_2 Produced	238,008	245,257	254,163	280,199	298,835	299,468	224,685
Utility CO_2 Avoided	295,589	293,717	302,302	303,641	331,995	345,566	288,672
Landfill CO_2 Avoided	-	2,948	6,053	9,042	12,020	15,224	18,398
Net CO_2 Emissions	(57,582)	(51,408)	(54,192)	(32,484)	(45,180)	(61,322)	(82,385)
Landfill CH_4 Avoided	-	1,072	2,201	3,288	4,371	5,536	6,690
GWP Avoided	57,582	74,992	102,614	104,820	141,342	183,114	229,565

While H-POWER contributes greatly to reducing the amount of waste landfilled, it is not clear that additional plants would be cost-effective, especially on the neighbor islands with their smaller populations and smaller waste streams. The H-POWER plant combusts approximately half of all solid waste generated in the state, and has produced a net profit only because the large majority of Hawaii's solid waste is generated on Oahu.

11.3.3.2 Potential Waste-to-Energy Plants for Maui

Maui has the second largest municipal solid waste stream at about 150,000 tons per year. This is well short of the 210,000 tons per year considered to be the minimum necessary to fuel a profitable waste-to-energy plant in Hawaii. Collecting and aggregating waste from several islands to accumulate larger tonnage on one island would be possible, but would face high transportation costs.

The best alternative at present appears to be combination of waste with biomass energy crops to produce fuels for electricity generation. An example is discussed in the following chapter. The biomass gasification facility being tested at Paia, Maui could eventually burn approximately 35,000 tons per year of biomass, green waste, and used cooking oil (Jones 1997; State of Hawaii 1995b, 7-1 to 7-5). Another possibility may be a new type of plant currently planned for Kauai, which is discussed below.

11.3.3.3 Potential Waste-to-Energy Plant for Kauai

Coxwell Energy, Inc., has announced plans to build a waste-to-energy plant, called HITECH, or Hawaiian Integrated Technology Plant, on the south coast of Kauai, to be operational by 2002. This plant would use state-of-the-art technology to convert 300 tons of MSW per day (105,000 tons per year) to 10 MW of electricity after subtracting energy used by the plant.

The HITECH process vaporizes waste using a plasma arc at 15,000 ^{o}F, leaving only synthesized gas and vitrified glassy rock. The gas would be used to power a turbine, and the rock could be crushed for use as a road aggregate or poured into molds for building material (Coxwell 1996, 1-2).

According to the developers, some 56 of these plants are already in operation or scheduled for completion worldwide in 1997, the largest producing 107 MW of energy (18-20). The operators of the HITECH plant intend eventually to mine existing landfills on Kauai for fuel as well, thus reducing and ultimately eliminating methane emissions from these sources (*The Garden Island* 1996,
1-2).

Questions have been raised regarding the capability of such a plant to produce the net 10 MW of electricity generation capacity (originally 14 MW) currently promised. More than one source has claimed that the developers based their energy production predictions on overestimates of the heat energy of solid waste and the volume of solid waste that the plant would receive. These observers are concerned that the HITECH plant may only produce enough energy to power itself, with none left over for sale (Tummons 1997; Jones 1997).

If no net energy is generated and sold, the developers estimated that tipping fees in excess of $500 per ton would be required for financial success. In addition, the developers have found that cost of acquiring permits will be higher than originally anticipated (Jones 1997). In this preparing this plan, the accuracy of Coxwell's or its critics' claims were not evaluated.

11.3.3.4 Potential Waste-to-Energy Plants for Hawaii

- No specific Big Island waste-to-energy facilities have been proposed, but the Coxwell HITECH-type plant, if successful on Kauai, may be an option.

11.3.4 Reduce Methane Emissions from Landfills by Flaring or Use as a Fuel (moderate cost, moderate to high benefit)

For the solid waste that does enter landfills -- and for the waste already at these sites -- a new set of measures is necessary. Landfills produce methane and CO_2 in approximately equal volumes. Although CO_2 is 2.75 times heavier by volume than methane, methane is a more potent greenhouse gas by both weight and volume. The global warming potential of methane is 22 times that of CO_2 by weight. Furthermore, many sources consider most of the CO_2 emitted by landfills to ultimately be taken up by plant growth, and thus they consider net CO_2 emissions to be minor. Nevertheless, in an island state like Hawaii where most landfill material has been imported, both gases are of concern.

> Anaerobic (oxygen-free) conditions begin to predominate in landfills in a few months to about two years after they are capped. Under such conditions, both methane and CO_2 are generated. methane generation rates vary both between

different landfills and within a single landfill due to differences in water infiltration, depth of landfill, composition of waste, and other considerations (EIA, 1995, 35). These variations make it difficult to estimate costs and benefits of various methods for reducing methane emissions from landfills in Hawaii.

Some generalizations can be made, however. For example, CO_2-equivalent emissions from landfills without gas collection systems are estimated to be three to five times greater on average than from landfills with collection systems (IPCC 1991, 116). Currently, Hawaii has no laws regarding methane emissions from landfills other than those mirroring federal laws (Harder 1997). In addition to increased regulation, there are three separate options for increased reduction of methane from Hawaii landfills that could be considered by the counties. These involve flaring emitted methane, burning landfill methane for energy, or burning the waste itself for energy as discussed in the previous section.

11.3.4.1 Install Equipment to Vent and Flare Methane

Any landfill containing more than a few thousand tons of MSW can continuously fuel a methane flaring system. A minimum size of 1.1 million tons WIP (with a good lining) is considered necessary to support a methane-to-energy plant, and federal laws (40 CFR 60.33c and 40 CFR 60.752b) now require all current landfills of this or greater size to collect their methane and either flare it or use it to run a generator for a minimum of 15 years after closure.

At present, only four of Hawaii's public landfills either flare their methane or burn it for power. Both processes require a network of pipes to be drilled into the landfill and routed to a central collection point where the gas is collected and either flared or fed into a power generator.

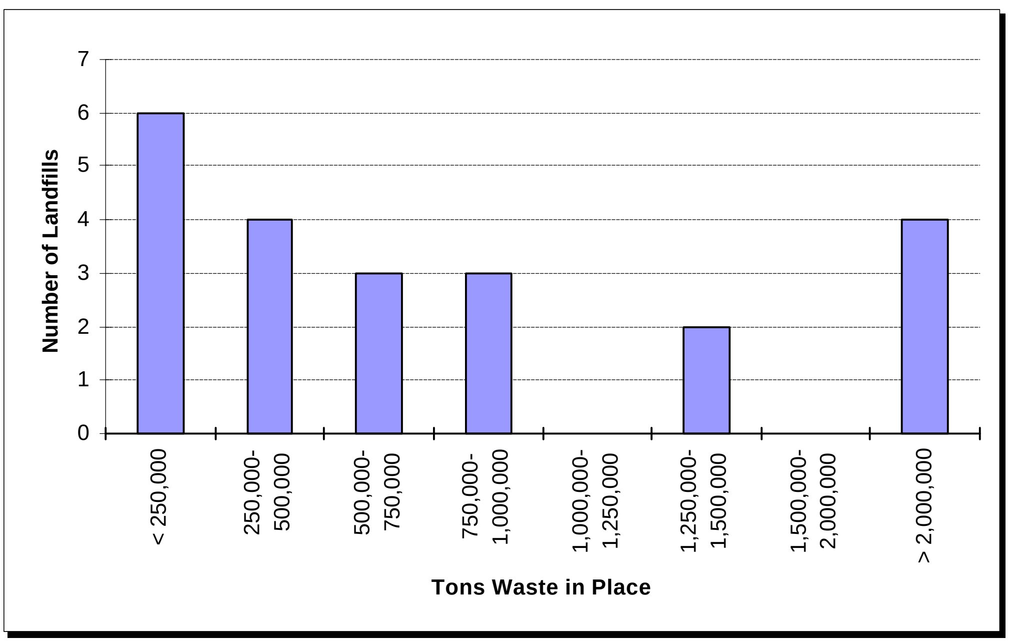
While most collection systems collect an estimated 50% to 70% of the methane and CO_2 emitted, it is estimated that collection from the Kalaheo Landfill approaches or even exceeds 90%, due to its impermeable cap and negative-pressure collection system. Collection efficiency for the other Hawaii landfills is probably about 70%, due mainly to their older, and thus more permeable, caps. At the Puu Palailai Landfill on Oahu, underground fires have burned continuously since 1988, using up some of the methane generated, but also reducing the efficiency of the flaring process since the collected gas is high in CO_2 (Harder 1997).

For large landfills and dumps closed more than 25-30 years ago, emissions may have already slowed to the point where they are too small to support a methane flare. Some other landfills never reached a size capable of supporting such a system. But for all others, the primary restraining force at present is simply the lack of a collection system. This will become increasingly the case as smaller landfills consolidate in response to the 1996 USEPA regulations. In the long run, it may be in the government's best interest to subsidize methane collection systems at medium (0.5-1.1 million tons WIP) and large (>1.1 million tons) landfills closed within the last 20 years or scheduled to close soon.

California has recommended, though not required, the installation of gas collection systems at all landfills larger than 0.5 million tons WIP, and has noted that installation at smaller landfills would produce still larger statewide emission reductions (CEC 1991, 5-85). Nationwide, a collection and flaring system for a 1 million tons WIP landfill costs an average of about $630,000, and operating costs average around $150,000 per year (Watson *et al.* 1996, Section 8.2.2). In Hawaii, the counties typically pay for methane collection and flaring (Baker 1997).

11.3.4.2 Install Equipment to Refine, Transport, or Burn Methane for Energy

It is generally agreed that it is not currently economically feasible to burn methane for energy from any landfill smaller than 500,000 tons WIP and less than 30 feet deep. Nearly all such systems operate at landfills significantly larger than 1 million tons WIP (State of Hawaii 1984, 54-55; Campbell 1989, 399). However, a 413,000 tons WIP landfill in Denmark has managed to pay for its methane-burning system within 13 years (see below). As shown in Figure 11-4, in Hawaii, the majority of both operating and closed landfills are smaller than 1 million tons WIP, and many are smaller than 500,000 tons. Thus, methane combustion for energy is a strong option at only four or five landfills in the state, and a possible option for perhaps six or seven more.



(Source: Miller 1997, Figure 12, 36.)

Figure 11.4 Number of Landfills by Size in Hawaii, 1997

Methane emissions from landfills will be reduced significantly as the counties conform to the source performance standards promulgated by the USEPA in March 1996. These standards require capturing or flaring of gas from operative landfills which (a) have greater than 2.75 million tons of design capacity, (b) accepted waste after November 1987, and (c) have non-methane organic compound emissions of greater than 50 tons per year. Such landfills must comply by the year 2000. The USEPA also recommends that any landfill with greater than one million tons WIP, which is open or recently closed, should also consider converting methane to energy (USEPA 1996a, 4-5). Hawaii has seven landfills that appear to fit these criteria; however, in 1997 only two were burning methane for power and heat generation (both at Kapaa, Oahu), and one simply flared its methane (see Table 11.3).

Table 11.3 Hawaii Landfills, Estimated Waste-in-Place, and Estimated Annual Emissions, 1996

Name	Years of Operation	MSW Landfilled per Year (Tons)	WIP (Tons)	Methane Emissions (Tons/Yr.)
Hawaii County				
Hilo Landfill	1970s-Present	**56,314**	756,860	1,734
Puu Anahulu & Kailua LFs	1970s-Present	**62,571**	643,735	1,475
Honolulu County				
Kapaa LF (6 Parts), Kailua	1960s-Present	xxx	xxx	xxx
Central Site	1970-1979		**2,500,000**	5,727
Site No. 2	1982-1997	141,333	**2,122,147**	1,090
Site No. 3	1979-1982		600,000	3,855
Two Old Landfills	1950s-1970s		348,480	798
One Old Constr. LF	1950s-1970s		145,200	333
Kalaheo LF, Kaneohe	1987-1990		**1,310,000**	4,598
Waimanalo Gulch Landfill	1989-Present	300,000	600,000	3,855
Kawailoa LF, Waialua	1960s-1986		1,057,056	2,421
Puu Palailai LF, Makakilo	1974-1988		2,800,000	6,158
Waianae Landfill	1971-1984		**1,400,000**	4,692
Nanakuli Constr. LF	1990-Present	200,000	200,000	458
Maui County				
Central Landfill	1970-Present	**152,833**	**2,312,674**	5,648
Hana Landfill	1965-Present	**1,251**	19,620	45
Olowalu & Makani LFs	Closed in late 1980s		435,600	998
Lanai Landfill	1975-Present	**2,190**	34,676	79
Kalamaula Landfill	Early '70s-1993		195,900	449
New Molokai Landfill	1993-Present	**4,693**	12,558	29
Kauai County				
Kekaha Phase I Landfill	1953-1995	62,571	458,332	1,050
Kekaha Phase II Landfill	1993-1997	65,700	298,001	683
Halehaka Landfill	1970s-1995		217,800	100
Total Statewide		**986,887**	**17,615,213**	**46,274**
Tonnage Not Landfilled and Emissions				
H-Power Plant	*1990-1996*	*600,000*	*4,120,398*	*7,541*
Recycling (Oahu)	*1980-1997*	*332,000*	*2,475,000*	*5,818*
Total Avoided		***1,119,714***	*Total Avoided*	***21,893***

Source: Miller 1997, Table 4, p 37.

Reported values for individual landfills are in bold. Other values are estimates.

If all seven had captured 75% of their methane emissions in 1996, approximately 14,700 tons of methane emissions would have been avoided. The avoided tonnage would increase further if all seven burned methane for power and/or heat.

The economic feasibility of landfill methane use depends on (a) volume and depth of the landfill, (b) composition of refuse, and (c) rate of water infiltration. If the gas is to be sold, other considerations include (d) potential buyers in the local area, (e) cost of upgrading methane to acceptable purity, (f) the going price of such natural gas, (g) regulatory restrictions, (h) the availability of tax incentives and subsidies, and (i) the anticipated social, political and technical obstacles (EMCON 1980, 111). The useful life of methane gas generation is generally about 20 years in dry climates, and often less in moist climates (Ham and Barlaz, 1989, 164). Over this period, the volume of methane and CO_2 emitted was generally in the range of 120-300 tons per cubic yard of dry waste (165).

There are three broad uses for landfill methane. In order of increasing cost, these are: (1) sale of unrefined, low-Btu gas to nearby industrial customers; (2) onsite use of this low-Btu gas for electrical generation or heating; (3) refinement into methanol (methyl alcohol) or pipeline standard gas (essentially pure methane) for injection into nearby utility company pipelines; or (4) generation of electricity onsite and sale to utility grid (EMCON 1980, 111-112).

11.3.4.2.1 Option 1 Sale of Unrefined Landfill Methane to Nearby Industrial Customers

Options 1, sale of unrefined, low-Btu gas to nearby industrial customers requires minimal processing. Processing may involve only being passed through a condensate collector and then compressed, as long as the resulting gas is not so corrosive that it would damage pipelines, boilers, and furnaces (112; State of Hawaii 1984, 65).

11.3.4.2.2 Option 2, Onsite Use of Unrefined Landfill Methane for Electricity Generation

Option 2, onsite use of low-Btu gas for electrical generation usually only requires minimal processing as outlined in Option 1, above. However, in Hawaii, utility use would require additional processing the utilities lack equipment capable of making use of landfill gas unless it has been fully refined into standard pipeline gas (Harder 1997).

11.3.4.2.3 Option 3, Refinement of Landfill Methane into Methanol or Pipeline Standard Gas for Gas Utility Use

Option 3, refinement into methanol (methyl alcohol) or pipeline standard gas (essentially pure methane) for injection into nearby utility company pipelines would require additional processing. It is doubtful that any landfills other than Kapaa/Kalaheo and Waimanalo Landfills on Oahu and the Central Maui Landfill generate sufficient methane to justify Option 3, especially since 30% to 40% of the heating value of the gas would be used or lost in the upgrading process (State of Hawaii 1984, 66).

Options for refining gas into natural gas or methanol and bottling or piping it offsite are also quite limited. The state considers these options to be economically infeasible anywhere (Harder 1997).

11.3.4.2.4 Option 4, Use of Refined Landfill Gas to Fuel an Electric Generator

More processing would also be required to permit use of Option 4. Option 4 was been implemented on Oahu. Since 1989, Kapaa Energy Partners has operated a landfill gas-fueled combustion turbine which uses burn methane from Kapaa and Kalaheo Landfills to generate electricity that is sold to the Hawaiian Electric Company, Oahu's electric utility. This plant also pipes exhaust heat to the nearby Ameron Quarry where it is used to dry aggregate (Greer 1997, 16; *Honolulu Advertiser* May 26, 1997, A22). More detail on this plant was presented in Section 7.5.2.2.

It may be possible to set up a similar facility at the Central Maui Landfill, since it also sits beside a quarry that could use the electricity and process heat produced (Harder 1997). However, the implementation of this option at the Central Maui Landfill would likely be less efficient and require additional processing due to the low percentage of methane in the landfill's gas and the high percentage of hydrogen sulfide generated by the sewage sludge biosolids deposited there over the years (Baker 1997).

Various authors provide a variety of views as the profitability of landfill methane use. According to one source (Watson *et al.* 1996, Section 8.2.2), methane-to-energy plants at landfills tend to cost about $1,000 to $1,300 per net kW, with electric generation costs ranging between four and seven cents per kWh if no collection infrastructure was previously in place. Since this is the same range of income per kWh the facility could expect, the payback period is likely to be long if not infinite. The USEPA, however, notes that a small change in energy prices can put a plant well into the black. Table 11.4 shows payback periods varying considerably by simply changing the price of energy from $0.05/kWh to $0.06/kWh. This is due to economics of methane recovery – at $0.06/kWh, it is potentially profitable to collect 65% to 75% of landfill emissions; at $0.05/kWh, this drops to 50% to 60% of emissions, and at $0.04/kWh a mere 10% to 15% can be economically collected (USEPA 1993b, 4-2).

Table 11.4 Estimated Costs, Benefits, and Paybick Periods for Landfill Methane Generation for Representative Landfills in the United States

Landfill Size (tons)	Methane Recovered (tons/yr)	Methane Emitted (tons/yr)	Generator Capacity (MW)	Cost (dollars) Capital	Cost (dollars) Annual O&M	Annual Revenue (dollars)	Payback Period (years)
Assuming $0.06/kWh and 70% recovery							
137,817	529	199	0.3	597,000	96,000	124,830	20.7
275,634	1,015	397	0.6	1,060,000	137,000	239,760	10.3
551,268	3,704	1,446	1.1	1,927,000	219,000	874,800	2.9
2,756,340	9,465	3,711	5.2	8,055,000	806,000	2,235,600	5.6
5,512,679	16,708	6,533	9.1	14,109,000	1,379,000	3,946,320	5.5
Assuming $0.05/kWh and 55% recovery							
137,817	415	298	0.3	597,000	96,000	81,734	Never
275,634	798	596	0.6	1,060,000	137,000	156,986	53.0
551,268	2,910	2,170	1.1	1,927,000	219,000	572,786	5.5
2,756,340	7,437	5,567	5.2	8,055,000	806,000	1,463,786	12.3
5,512,679	13,128	9,799	9.1	14,109,000	1,379,000	2,583,900	11.7

Source: USEPA, 1993b, pp. 4-2, 4-27 and 4-28. Note: Does not include permitting costs or revenue from process heat sold. Cost includes collection, flaring (for excess gas) and generator systems. Assumes 1,000 BTU/ft3, and 12,000 BTU/kWh.

The USEPA study cited above suggests that landfills on the order of 0.5 million tons WIP may actually have the shortest payback period. While this does not include the costs of acquiring permits and land (and does not account for the higher costs of labor and materials in Hawaii), it also ignores the revenue from heat generated. Furthermore, the USEPA has placed a dollar figure on the value of each ton of carbon emissions avoided by alternative energy sources. These added benefits are estimated to amount to between $5 and $20 per ton of carbon avoided, or $0.007 to $0.028 per kWh (USEPA 1993b, 4-5). Thus, the results of this study should be considered carefully by state and county governments.

Of course, any evaluation of the economics of flaring vs. burning methane for energy should consider the relative reductions in global warming potential (GWP). Flaring of one cubic foot of typical landfill gas results in an approximate 53% reduction in the GWP of that gas, while burning landfill gas in a combustion device results in an approximate 65% reduction in GWP. Refining the gas to pipeline quality results in an approximate 77% reduction in GWP (CEC 1991, 5-86). This equipment involved in these processes also emit greenhouse gases such as NO_x and CO, as well as hydrocarbons that react with air to form ozone (5-87).

11.3.4.2.5 Benefits of Landfill Gas Collection and Use

In addition to reduction of greenhouse gas emissions, the benefits of landfill gas collection required for flaring or use include:

- Reduction of odor and explosive hazard in the vicinity of the landfill, and thus increased land use potential;
- Reduction in emissions of other air pollutants such as hydrocarbons (Schumacher 1983, 303);

- Reduction in generation of leachate, since entrained water vapor condenses in collection pipes and is removed periodically (USEPA 1993b, 4-15);
- Since methane is poisonous to plants growing on the landfill cap, gas collection can improve the quality of grasses used to reduce erosion of the soil cap; and
- If the methane is sold or burned for energy, the landfill or its customer may reduce energy costs, and the state as a whole will see a marginal reduction in its dependency on imported fossil fuels as well as the creation of a certain number of jobs. Selling methane as natural gas is often cheaper than burning it onsite for energy.

There are tradeoffs to this approach, however:

- Collection pipes must be carefully placed and angled so as to minimize damage from settling of landfill material, as well as ponding of liquid which can clog pipes (Stegmann 1989, 171);
- Collection for power generation can only be cost-effective at large landfills;
- Enhancing methane production can require infiltration of rainwater, which in turn can increase leachate percolation into groundwater. Waste in place should have at least 50% moisture content for optimal methane generation (State of Hawaii 1984, p. 64). On the other hand, if the landfill is designed to contain its leachate, controlled addition of water can actually speed the attenuation of toxic substances within the landfill (Schumacher 1983, 269-273);
- Generation rates are also reduced when green waste, food waste, and biosolids are redirected to composting or other operations, since these wastes produce the most methane per ton of dry waste. These are the first wastes to break down in a landfill, and thus can provide extra power during the first few years of plant operation when emissions from more refractory wastes such as paper are still low (132-137). However, as noted above, biosolids also emit corrosive hydrogen sulfide gas (Baker 1997), so diversion of biosolids is a mixed blessing;
- It may be necessary to have one collection system for gas recovery and another to prevent migration of gas beyond the landfill boundary (CEC 1991, 5-84);
- Condensate can itself contain harmful substances, and if it is not feasible to return it to the landfill, disposal problems can result (Schumacher 1983, 304);
- Recovery equipment itself can emit greenhouse gases such as CO_2 and NO_x (but the global warming potential of the amounts of these gases emitted is typically less than if the methane burned was emitted);

- If the landfill is near a populated area, noise from plant operations or light from flares can cause public relations problems (304); and
- Zoning or permitting requirements may complicate matters.

11.3.4.2.6 Additional Considerations Concerning Landfill Gas Collection and Use

As of 1996, the USEPA required many landfill owners and operators to collect and, at the very least, flare their landfill gas. Many states also require collection and flaring of this gas (USEPA, 1995a, 5-39). Energy recovery projects for landfill gases in the U.S. are also aided by an "unconventional gas" tax credit of approximately one-cent per kWh (Watson *et al.* 1996, Section 8.3.3).

In Germany, laws require public utility companies to accept landfill gas for energy production (Stegmann 1989, 179). However, other regulations can get in the way of such transfers. For example, one landfill operator in southern California was required to install catalytic converters on its gas compressors in order to comply with NO_x standards (Schumacher 1983, 55). Fortunately, emissions of both NO_x and CO from burning of unrefined landfill gas are generally significantly lower than for natural gas under the same conditions (56), something which should be taken into account during the permitting process.

California's Integrated Waste Management Act of 1989 prioritized that state's options as follows: (1) source reduction, (2) recycling and composting, and (3) waste-to-energy plants. The Act's main purpose is to divert 50% of the state's waste stream from landfills by the year 2000 (CEC 1991, 5-89). Recommended measures to help accomplish this goal included: (a) a municipal solid waste sorting program, (b) education of consumers and industrial producers of recycling and composting options, (c) increasing solid waste tipping fees at landfills, and (d) research to determine the optimal mix of recycling and composting (5-101).

For gas emanating from existing landfills, the California Energy Commission recommended three separate options: (a) making collection of methane at landfills larger than 0.5 million tons WIP mandatory; (b) tightening the state's air quality regulations to further encourage such collection; and (c) encouraging upgrading landfill gas to pipeline quality through loans, tax breaks, and subsidies (5-100).

In Hawaii, state and county governments could aid landfill methane recovery and use in several ways. Monetary incentives could be offered in addition to the federal government's one cent per kWh "unconventional gas" tax credit. Other methods may be more cost-effective in the long run, however. For example, educational seminars and reports can serve to inform landfill operators of new technology for gas collection, which may tip the balance of recovery ventures into the black.

11.3.4.2.7 Recommendation: Enforce Federal Rules and Recommendations and Set Higher Standards at the State or County Level

The following actions should be considered:

- The State and Counties could implement the source performance standards recommended by the USEPA in March 1996 (USEPA 1996a), and enforce the new USEPA rules regarding methane recovery (noted above);
- Public utility companies could be required to accept landfill gas-produced electricity and streamline the permitting process for landfills which choose to sell their methane offsite; and
- The State could tighten air quality regulations to further encourage such collection, yet allow some leeway for such alternative power generator systems which otherwise reduce greenhouse gas emissions.

11.3.5 Evaluation of Municipal Solid Waste Reduction Options

- The following is a preliminary benefit/cost analysis of the various options for handling solid waste in Hawaii to reduce greenhouse gas emissions. The options range from source reduction to burning MSW for power. Average costs, benefits and payback periods of various options for treating solid waste in Hawaii and the mainland are listed in Table 11.5, along with some non-monetized drawbacks for each option.

Table 11.5 Estimated Costs and Benefits of MSW Handling Options

Type of Facility	Green Waste Composting Facility		Solid Waste Composting Facility		H-POWER	HITECH
Capacity Net Energy	2,000 Tons/Yr	60,000 Tons/Yr	100,000 Tons/Yr	200,000 Tons/Yr (w/ Sewage Sludge)	650,000 Tons/Yr 70 MW	100,000 Tons/Yr 8 MW
Capital Costs	$75,000	$2 Million	$1.5 Million	$45 Million	$181 Million	$52 Million
Operating Costs	$40,000/Yr	$120,000/Yr	$3 Million/Yr	$3 Million/Yr	$54 Million/Yr	$8.5 Million/Yr
Tipping Revenue*	$60,000/Yr	$1.8 Million/Yr	$3 Million/Yr	$6 Million/Yr	$36 Million/Yr	$3 Million/Yr
Product Revenue**	$37,500/Yr	$1.13 Million/Yr	$1.5 Million/Yr	$3 Million/Yr	$27 Million/Yr	$7.7 Million/Yr
Other Benefits	Compost, reduced landfill input.		Compost, reduced landfill input.		Power, reduced landfill input.	Power, materials, reduced landfills.
Drawbacks	Reduces methane-generating capacity of landfills for other use.		Can be fairly high concentrations of heavy metals, etc.		Dioxins; must landfill ash.	Dioxins
Payback Period	2 Years	1 Year	1 Year	5.5 Years	20 Years	24 Years
W/ Free Compost	4 Years	2 Years	Never	13 Years	N/A	N/A

Sources: Watson 1996, 8.2.1; Jones 1997; Coxwell 1996, p. 11; Hawaiian Earth Products 1995; Lounsbury & Miller 1984, p.61; Tummons 1997, p.6.

* Based on $30/Ton. ** From sales of compost or energy. Compost Revenue $25/ton for manure and green waste compost, and $20/ton for solid waste compost. Based also on 0.75 tons of compost per ton of original material.

Table 11.6 qualitatively compares the MSW emissions reduction strategies and their components. Note that the increased forest carbon storage resulting from source reduction and recycling is due to reduced requirements for timber for lumber and paper production resulting from these two methods of MSW management.

Table 11.6 Components of Net Emissions Reduction for MSW Management Strategies

MSW Management Strategy	Manufacturing and Transporting Raw Materials	Changes in Forest Carbon Sequestration	Changes in Soil Carbon Sequestration	Management of Waste
Source Reduction	Decreased emissions due to reduced energy requirements and avoided processing	Increased forest carbon storage	No change	No emissions or sinks
Recycling	Decreased emissions due to reduced energy requirements and avoided processing	Increased forest carbon storage	No change	Transportation and machinery emissions
Composting	No emissions or sinks	No change	Increased soil carbon storage	Transportation and machinery emissions
Waste-to-Energy	Processing and transportation emissions	No change	No change	CO_2, N_2O and transportation emissions; avoided utility emissions
Landfilling	Processing and transportation emissions	No change	No change	CH_4, machinery and transporta-tion emissions; avoided utility emissions

Source: ICF 1997, 20

Table 11.7 is based upon an analysis prepared for the USEPA Office of Solid Waste by ICF, Incorporated, outlined in the draft working paper, *Greenhouse Gas Emissions from Municipal Waste Management* (ICF 1997). Tables 11.7 compares the full life cycle greenhouse gas emissions for each waste management option and each major category of material. It assumes initial production using the current mix of virgin and recycled inputs and provides values on a nationwide basis. When the full life cycle, including manufacturing, is considered, source reduction dominates with lower greenhouse gas emissions on a ton-per-ton basis. The exception is in aluminum cans where recycling offers lower emissions than source reduction only because it is assumed that increased recycling would replace virgin inputs. Source reduction assumes that it results in displacement of the current mix of virgin and recycled inputs. (ICF 110)

Recycling, as shown on Table 11.7, has the next lowest emissions and has lower emissions than combustion or landfilling for all eight of the manufactured materials analyzed in the ICF study. Combustion has lower emissions than landfilling for office paper, corrugated cardboard, and steel cans. Paper and cardboard produce substantial amounts of methane when landfilled, and steel is recovered at H-POWER and most other MSW combustors. Landfilling has lower greenhouse gas emissions for plastics and newspaper, because combustion of plastic results in substantial nonbiogenic CO_2

emissions, and landfilling of newspaper results in carbon sequestration. Net emissions between combustion and landfilling are similar for aluminum cans. Composting is a management option for food scraps and yard trimmings, but the net emissions are similar to combusting or landfilling, given the uncertainty of the ICF analysis (116).

Table 11.7 Net Estimated Greenhouse Gas Emissions from MSW Management Options (Tons Carbon Equivalent per Ton of Solid Waste)

Material	Source Reduction	Recycling	Composting	Incineration	Landfilling
Newspaper	(480,000)	(370,000)	NA	400,000	280,000
Office Paper	(530,000)	(290,000)	NA	460,000	1,090,000
Cardboard	(440,000)	(300,000)	NA	320,000	440,000
Aluminum Cans	-	(1,010,000)	NA	2,970,000	2,970,000
Steel Cans	-	300,000	NA	470,000	880,000
Plastic	-	1,050,000	NA	3,980,000	2,600,000
Food Scraps	-	NA	-	(10,000)	90,000
Yard Trimmings	-	NA	-	(20,000)	(70,000)
Mixed MSW	-	NA	NA	40,000	-
Total	(1,450,000)	(620,000)	-	8,610,000	8,280,000

In summary, pre-consumer source reduction is generally the cheapest of the methods discussed above, and also produces much lower greenhouse gas emissions than do the other waste management strategies. This is generally followed by recycling, both in terms of costs and reduced greenhouse gas emissions. An action plan for this sector should concentrate on source reduction first and foremost, both pre-consumer and post-consumer. The results for the other options are more mixed. Composting appears to produce net greenhouse gas emissions, which are similar to those of combustion and landfilling, given the uncertainty in the analyses, but tends to have a much shorter rate of return.

It thus appears that, before constructing or promoting any new MSW incineration facilities, the counties should carefully consider the costs and benefits of incinerators compared to other methods of disposal. However, the primary objective, as on Oahu, may be to reduce landfill volume, which may make MSW incineration and energy production desirable even if not necessarily profitable.

Figure 11.5, below, shows the estimated effects of various burning and flaring options in reducing methane emissions. Source reduction and recycling would contribute to additional reductions by reducing landfill inputs in the first place.

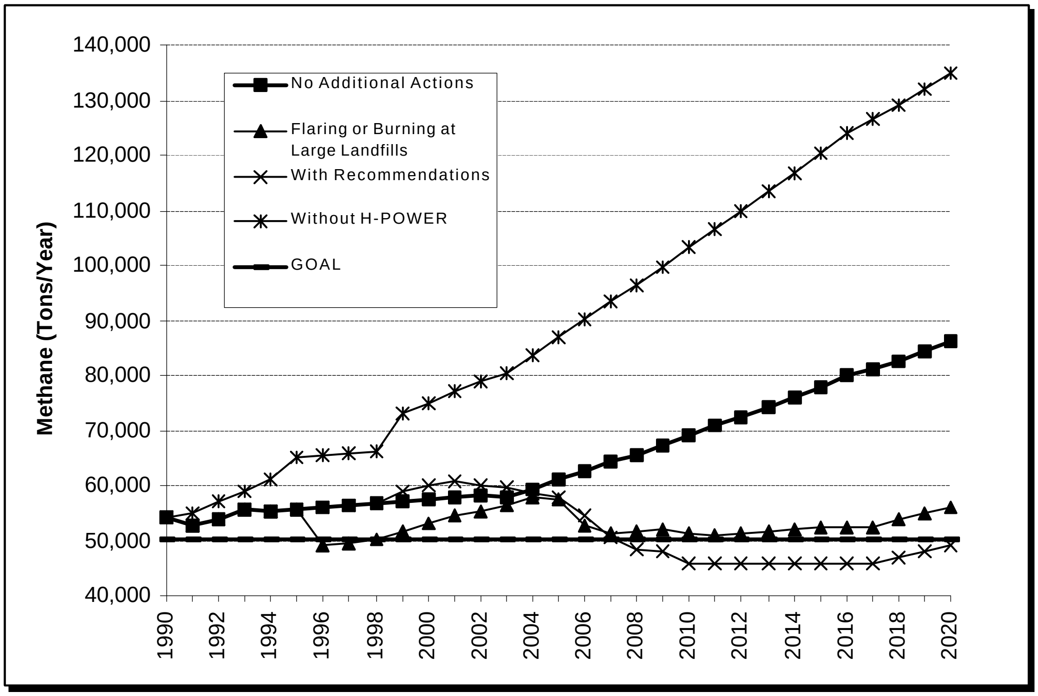


Figure 11.5 Estimated Methane Emissions from Solid Waste Management Comparing Alternative Mitigation Measures (Tons/Year), 1990-2020

As Figure 11.5 shows, H-POWER has significantly reduced methane emissions in comparison to what they would have been had the MSW burned in H-POWER gone to land fills. Despite H-POWER, methane emissions are forecast to increase, especially after 2003 should there be no additional action. If there is burning or flaring of methane produced by larger landfills (thos emitting over 1,000 tons of methane per year, the forecast emissions are generally slightly above the goal of a 7% reduction from 1990 levels. If the recommendations for MSW mitigation suggested above are followed, it is estimated that emissions can be brought below the goal by about 2007. It should be noted that there are many uncertainties involved in these estimates.

11.4 Municipal Wastewater Treatment

Municipal wastewater treatment produces both effluent and sludge (biosolids), which in turn produce methane and CO_2. Emission of CO_2 is largely unavoidable, but methane emissions can be reduced significantly at some cost. Methods to reduce emissions from effluent and sludge, or to use these products in ways that displace fossil fuel use are addressed in this section. By displacing fossil fuel use, other greenhouse gas emissions from heat or energy production may be avoided.

11.4.1 Use Recovered Methane at Sewage Treatment Plants (moderate cost, moderate benefit)

11.4.1.1 Wastewater Treatment Plants

Four types of municipal wastewater treatment are addressed in this report: anaerobic lagoon, anaerobic digestion, activated sludge, and trickling filter. Their characteristics are summarized in Table 11.8.

Table 11.8 Characteristics of Wastewater Treatment Processes

	Anaerobic Lagoon	Anaerobic Digestion	Activated Sludge	Trickling Filter
Area Required	Large	Medium	Small	Small
Volumetric Loading Range (lb BOD/ft^3/day)	0.7-1.3	1685	32-80	16-130
Efficiency (% BOD Reduction)	50-85%	65-95%	40-85%	85-95%
Shock Load Sensitivity	Low	High	Low	Low
Nutrient Requirement	Low	High	Medium	Low
Energy Costs	Low-High	High	Medium	Very Low
Biogas Production	Yes	Yes	No	Yes
Sludge Production	Low	High	Medium	Low

Source: State of Hawaii 1984, 31.

BOD is biochemical oxygen demand, the amount of oxygen taken up by the organic matter in the wastewater during decomposition.

Aerobic treatment requires less energy to operate and lower nutrient additions, and produces less sludge; however, anaerobic treatment generally is more efficient, adapts to a wider volumetric load range, and -- most importantly for this report -- converts 40% to 60% of the emitted carbon into methane rather than CO_2. Although this methane is reconverted to CO_2 when it is combusted, when used as a fuel, it can be used to power a significant percentage of the sewage treatment system, and -- if refined into a liquid -- can be used to fuel vehicles (State of Hawaii 1984, 43; USEPA 1995c, 54).

Furthermore, while solids must be retained longer in anaerobic reactors due to slower biodegradation rates, the necessary volume of the reactor vessel is smaller due lower volumes of solids (due in turn to anaerobic bacteria devoting most of their energy to producing methane). Perhaps the main negative factors regarding anaerobic systems are (1) the fact that anaerobic reactors cost about 10% more than do aerobic reactors, and (2) in situations where secondary treatment is required, anaerobically digested effluent generally requires further treatment before it can be discharged into receiving waters. This process usually involves either activated sludge or trickling filter methods, both of which are aerobic
(State of Hawaii 1984, 28-29, 33, 45 and 49).

As noted above, while activated sludge treatment is more efficient, its high-energy costs make it more expensive than trickling filter treatment. This higher cost can be offset somewhat by reusing methane generated by the anaerobic phase(s) of treatment. This has a large impact on overall operating costs, since most of the energy used in a conventional wastewater plant goes to anaerobic treatment (28).

11.4.1.2 Wastewater Treatment Methane Recovery and Use

Gas produced by anaerobic digestion of wastewater, or of the removed sludge, is about 2/3 methane and 1/3 CO_2, with small amounts of other gases. The average heat value of this gas is about 600 Btu/ft^3, somewhat higher than the 500 Btu/ft^3 recoverable from typical landfill gas. Although 1991 costs of biogas energy recovery from sewage in the U.S. averaged about $1.10 per ton of wet waste and between $11 and $27.50 per ton of methane, the payback period has been generally short, typically less than six years (IPCC 1991, 116; USEPA 1995c, 63).

Use of recovered methane to power wastewater treatment is already being carried out at a profit in Hawaii Kai (Kennedy/Jenks /Chilton, Inc. 1990, 2.5).

At the Kailua Wastewater Treatment Plant, sludge gas has been used to run two gas engine generators, and also to furnish heat to the primary sludge digester tank. A 1990 cost/benefit analysis of methane use at this secondary treatment plant concluded that methane production at the plant could only supply 25% of the plant's total power needs -- a percentage which would only rise to 41% even as late as 2007. In spite of this, the study found that any methane-powered generator supplying 70 kW or more to the plant would pay for itself in less than nine years, even when environmental externalities and costs of hydrogen sulfide scrubbing were figured in. A generator would avoid emission of significant amounts of methane by converting it to CO_2, which would have less effect on the atmosphere.

- Unfortunately, the exact tonnage of avoided methane remains uncertain, since the authors of the study concluded that avoided emissions from this one plant alone would equal more than the 1994 emissions of all wastewater treatment plants (WWTP) in the entire state (2.1). Although further analysis is necessary to assess the overall avoided methane emissions of various waste treatment options in Hawaii, it appears that, by converting each WWTP to anaerobic treatment and/or reusing its biogas, it could be possible to avoid between 25% and 75% of each facility's energy-related greenhouse gas emissions.

As with landfill gas, the City and County of Honolulu feels that sale of sewage biogas off-site cannot be done cost-effectively in Hawaii (Woo 1997). Thus, methane reclamation efforts are concentrated on on-site use of methane.

In 1984, when fuel prices were very high, the state estimated that refitting of existing sewage treatment plants to make use of the methane they generate could pay for itself via energy savings in as little as five years (State of Hawaii 1984, 32). At the Kailua plant, the City and County of Honolulu is taking a hard look at constructing a facility to recycle sludge, methane, and effluent. Effluent would be used for golf course irrigation (Woo 1997). The community and the state government should support such programs.

A benefit/cost analysis by the Department of Planning and Economic Development (now DBEDT) in 1984 concluded that the methane produced by the anaerobic digestion process could cover 75% to 100% of the overall power costs for all of Hawaii's municipal wastewater treatment plants through generation of power, steam, and/or profits from offsite sales of methane (State of Hawaii 1984, 29, 37 and 50). Although perhaps overoptimistic in light of the 1990 study cited above and the decline in energy prices since the mid-1980s, this power is equivalent to the percentage range of energy generated onsite by the Hyperion Sewage Treatment Plant, which services the greater Los Angeles area. Hyperion dries and burns its digested solids (USEPA 1995c, 24 and 61).

In summary, it appears that overall operating costs are lower for plants that primarily use anaerobic treatment and use the methane produced to power equipment or generate heat onsite. Of the processes analyzed by the 1984
DPED report, the lowest overall costs resulted from anaerobic treatment using a technology known as a biofilter, with sludge being treated first in an aerobic trickling filter and then in a separate flow-through anaerobic reactor (Table 11.9).

Table 11.9 Characteristics of Wastewater Treatment Processes

	Anaerobic Lagoon	Anaerobic Digestion	Activated Sludge	Trickling Filter
Area Required	Large	Medium	Small	Small
Volumetric Loading Range (lb BOD/ft^3/day)	0.7-1.3	1685	32-80	16-130
Efficiency (% BOD Reduction)	50-85%	65-95%	40-85%	85-95%
Shock Load Sensitivity	Low	High	Low	Low
Nutrient Requirement	Low	High	Medium	Low
Energy Costs	Low-High	High	Medium	Very Low
Biogas Production	Yes	Yes	No	Yes
Sludge Production	Low	High	Medium	Low

Source: State of Hawaii 1984, 31.

BOD is biochemical oxygen demand, the amount of oxygen taken up by the organic matter in the wastewater during decomposition.

As noted in the section on animal manure in Chapter 12 on Agriculture, which follows, anaerobic digestion plants can also be used on large farms. A cost/benefit analysis of 61 such plants on French farms concluded that they paid for themselves in an average of 17 years, not including maintenance costs. This period is too long for most investors to consider, especially since it approaches the expected lifespan of some plants. Yet the French study also made the interesting discovery that the more money invested in the plant at the outset, the quicker the payoff (Heduit *et al.* 1986, 91). Unfortunately, as noted earlier, the benefits of such economies of scale probably exclude all but the largest livestock operations in the Hawaiian Islands.

Large centralized plants which would accept biowaste from several farms and from sewage treatment plants, such as the currently-operating Unisyn plant (see Animal Waste Management section in Chapter 12) would probably be the best option for Hawaii. Such a system, when fully integrated to make use of all outputs (energy, heat, fertilizer, and irrigation) and fed by pipe from several nearby farms, has been calculated for Europe to require a total average investment of about $7.4 million, and be capable of paying for itself within five years (Naveau 1986, 100). A similar study in Belgium required assessment of "fringe benefits" arising from pollution reduction to arrive at a payback period of four years (Nyns and Ferrero 1986, 146-147). A comprehensive cost/benefit analysis of a 2.5 million sewage treatment plant in Germany which upgraded its methane to pipeline quality found that the plant was turning a profit of about $393,000 per year, even calculating in both maintenance and 10-year amortization costs (Haydt and Schanz 1986, 171-173).

Thus, it seems possible that an economic analysis of anaerobic sewage treatment systems in Hawaii which accounted for overall energy efficiency, avoided greenhouse gas emissions, avoided fumes (if any), and other externalities might cast these systems in a fresh light. Currently, there is insufficient Hawaii-specific data to accomplish a comprehensive cost/benefit analysis. As a result, the

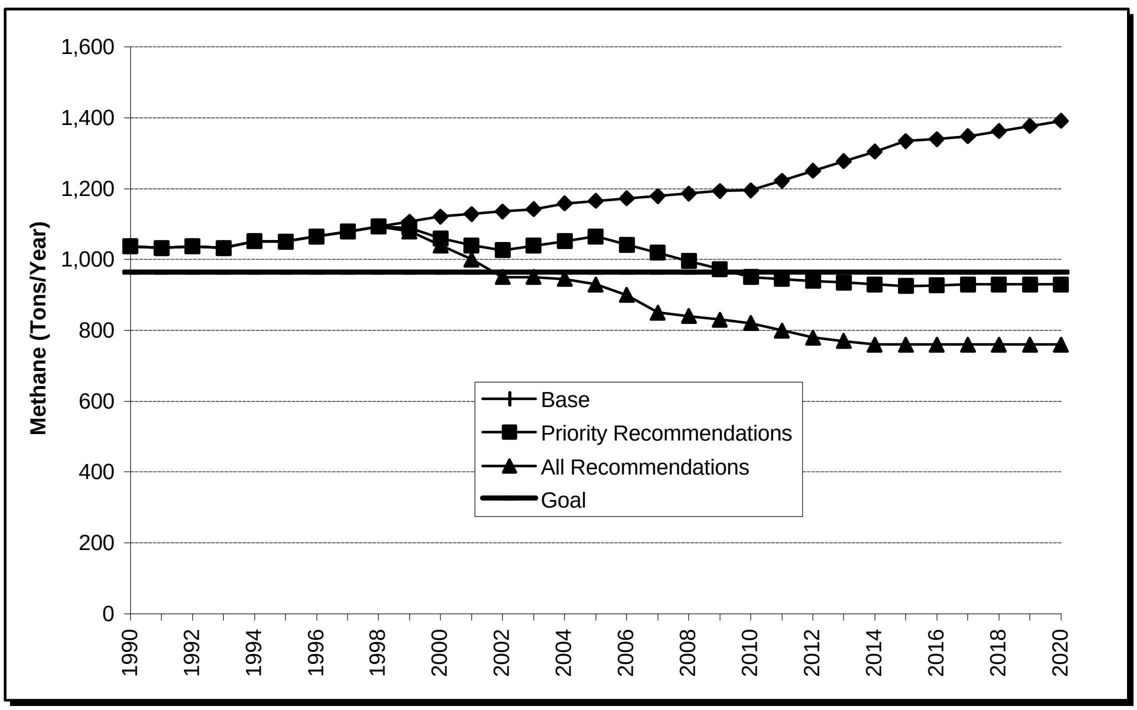


Figure 11.6 Estimated Methane Emissions from Wastewater Treatment in Hawaii Under Various Reduction Scenarios (Tons/Year), 1990-2000

"Priority Recommendations" projection in Figure 11.6 simply assume a conservative 35% reduction in statewide methane emissions if each county establishes one anaerobic WWTP serving its largest urban area in the next 20 years. Further reductions -- to about half the projected methane emissions if no mitigation was attempted -- are considered possible if the state and counties enact the other sewage management options described below. The counties should not give up their attempts to initiate properly designed anaerobic WWTPs, and should work with the public to increase acceptance of these somewhat maligned systems. In the areas of wastewater treatment, it appears possible to exceed emission reduction goals.

11.4.2 Use Directly Apply Dried Sewage Sludge as Fertilizer and Use Sewage Effluent for Nutrient-Rich Irrigation (moderate cost, moderate benefit)

Sewage sludge can be a cheap and effective fertilizer or soil conditioner when applied to pasture or farm land. Once pathogens and heavy metals have been reduced to background levels, it is legal to apply sewage sludge to edible crops in the U.S. (Statute 40 CFR 503). This is not currently being done in Hawaii, however, due to a lack of cost-effectiveness and public support. The Enviro company attempted to market sewage sludge on Oahu a few years ago, using alkali to raise the pH and kill pathogens, but the project failed due the combination of an inability to acquire permits and the opposition of neighboring businesses (Takazaki 1997). As noted elsewhere in this report, however, composting of sewage sludge is an established practice on Maui, and is being considered on Oahu (Harder 1997).

Even without composting, digested sludge becomes easily transportable and marketable when dried, typically on a bed of sand. By the mid-1980s, Oahu floral companies were already using up to 150 cubic yards of dried sludge annually as a potting mix (State of Hawaii 1984, 47). The National Research Council has recently declared that,

> While no disposal or reuse option can guarantee complete safety, the use of these materials [biosolids and reclaimed water] in the production of crops for human consumption, when practiced in accordance with existing federal guidelines and regulations, presents negligible risk to the consumer, to crop production, and to the environment (quoted in WEF 1996, 33(3), 1).

Such application is not a panacea,. It is estimated that all the sewage sludge produced in the U.S. could supply only 1-2% of the nation’s annual fertilizer nitrogen needs (Laws 1993, 144). Yet reduced fertilizer use remains a key benefit that needs to be figured into the overall cost/benefit calculation for direct application of sewage sludge.

As an example to emulate, the City of Seattle has had a program in place since 1983 which applies all of its sewage sludge (about 18,150 tons of dry solids per year of anaerobically digested, primary and secondary-treated sludge) to land operations. Of this sludge, 65% is applied to forestlands, 25% is targeted for overall soil improvement, and 10% is composted for the horticultural market.

Researchers associated with this project claim that commercially acceptable trees can be harvested in 15% to 20% less time than with commercial urea fertilizers.

Dewatered sludge cake with 18% to 25% dry solids is trucked as far as 60 miles to forest plantations, then rewatered to 10% to 13% dry solids to allow pump spraying. The cost of operation was $31.31 per wet ton in 1988 (Nichols 1991, 158-162). At present, such application of sewage sludge would probably meet public opposition in Hawaii. However, application in the proper place with the proper safeguards, and with a comprehensive public education and community relations program (as was done in Seattle), could provide a positive use of sewage sludge in Hawaii that would significantly reduce methane emissions.

The primary drawback to land application of sewage sludge appears to be the accumulation of heavy metals in typical agricultural soils, and their uptake by crop roots (Laws 1993, 145). However, the limited amount of industrial activity in Hawaii should minimize this hazard. A second drawback is more serious from the greenhouse gas emissions standpoint. It is now well-established that forest and grassland soils can act as sinks for atmospheric methane, and that these sinks can effectively be turned off by nitrogen addition in the form of fertilizers and sewage sludge. Reduction in methane uptake capacity by soils tends to average about 87% (Paustian *et al.* 1995, 76-77). However, since the methane uptake capacity of Hawaiian soils is unknown, it is difficult to quantify this problem.

Economically, the primary negative factor is the cost of sludge transport and application, which would likely have to be borne by the state in order for the sludge to be cost-competitive with commercial fertilizer (Laws 1993, 144). In spite of these drawbacks, nationwide between 15% and 20% of municipal sewage sludge is currently being applied to the land (146).

Table 11.10 Growth Response of Various Tree Species to Sludge Fertilization in the Southeast United States

	Loblolly Pine	Virginia Pine	Sweet Gum	Green Ash	Yellow Poplar
	Percent Increase Over Commercial Fertilizer				
Height Growth	56%	67%	489%	xxx	xxx
Diameter Growth	66%	101%	453%	xxx	xxx
Biomass Growth	42%	xxx	123%	278%	661%

Source: Nichols 1991, 158.

Sewage sludge application to tree plantations has been studied on the mainland for some time. In Hawaii, the two tree types, which have received the most attention for plantation cultivation, are varieties of eucalyptus (gum) and pine (see Chapter 13). The results of a mainland study on sludge application to stands of these and other tree types are shown in Table 11.10.

From this table, it appears that sewage sludge may in some cases perform significantly better than commercial fertilizer when applied to eucalyptus (gum) trees, but not when applied to pine varieties. Thus, any sewage sludge application to tree plantations in Hawaii should concentrate on the former.

In addition to sludge, sewage effluent can also be used for land application, and virtually all of the studies conducted to date have concluded that this is a safe and practical way to dispose of sewage wastewater if reasonable precautions are exercised. The principal limiting factors appear to be the amount of land required and the accumulation of nitrate in groundwater supplies.

Nitrate accumulation is of particular concern in Hawaii for two reasons. First, experiments on the mainland have experienced sewage effluent percolating through the soil so quickly that crop roots were unable to filter out much nitrogen, to the point where additional fertilizer had to be added to make up the deficit (Laws 1993, 138 and 141). Second, soils beneath former sugar and pineapple plantations in Hawaii tend to have high nitrate concentrations already. However, if land application is practiced in areas seaward of the limit of potable groundwater, such as is currently being planned near Barbers Point, Oahu, the nitrate problem should be essentially eliminated. Other possible drawbacks, such as accumulation of pathogens, heavy metals, and salts, have been found to be insignificant over the short-to-medium term in most cases, but over a period of decades the effects tend to become apparent in the form of declining crop yields (139-140).

The USEPA recommends land application of primary treated sewage if the crops are not intended for human consumption (e.g., for cattle fodder). Secondary treated sewage should be applied to crops destined for human consumption only if the crops are canned or similarly processed before sale (State of Hawaii Administrative Rule Title 11, Chapter 62). These recommendations are not binding (142), but Hawaii law does require that even secondary treated sewage effluent cannot be applied to any vegetable crop. Treated effluent can, however, be used on sugarcane, pineapple, and on crops not destined for human consumption, such as forage crops (Yee 1997). Effluent has also found increasing acceptance for nutrient-rich irrigation of golf courses and flower plantations (State of Hawaii 1984, 47). Currently, only about 5% (8 million gallons per day) of Hawaii's wastewater is reused, mainly on golf courses. Yet it has been estimated that nearly 50% (75 million gallons per day) is emitted sufficiently near to irrigation areas to merit its reuse. This irrigation could provide water to some 15,000 acres, or around 100 golf courses (Ferguson *et al.* 1996, 3). However, distribution costs are not insignificant: on Maui, these costs range between $0.42 and $1.04 per 1,000 gallons (4).

Side benefits of sludge and effluent reuse include:

- Eliminates cost of incineration and (for irrigation) of dewatering;
- Reduces the need for energy to manufacture chemical fertilizers; and
- Lower cost than commercial fertilizers (State of Hawaii 1984, 47).

As with composting, diversion of sludge from landfills avoids costs for hydrogen sulfide scrubbing at landfills which collect and burn their methane;

In Washington state, application on forest land has actually led to an increase in floral and faunal health and fertility, with no buildup of contaminants in body tissues (Nichols 1991, 201).

11.4.3 Compost Sewage Sludge for Use on Vegetables and Other Crops and Pastures (moderate cost, moderate benefit)

For a discussion of the possibilities of sewage sludge compost, see the section on fertilizers in Chapter 12.

11.4.4 Inject CO_2 and Possibly Methane into Sewage Effluent Being Sent into Offshore Outfall Pipes (moderate to high cost, moderate to high benefit)

Sewage effluent contains some dissolved CO_2, but it has a capacity for significantly more. Injection of CO_2 into this effluent as it passes out into the outfall pipes of WWTPs would thus provide a way to sequester carbon below the sea surface for a certain period of time. Hawaii's deepwater sewage outfalls tend to empty out near the thermocline (Miller 1997), and any CO_2, which mixes underneath the thermocline, can be sequestered for significantly longer than that which remains in shallower water. Costs for such a process would be only moderate to high, consisting mainly of energy costs for aeration of the effluent with CO_2.

Both the costs and the benefits should be studied in detail, since this process could sequester a fairly large volume of CO_2 on a constant basis. In particular, some method needs to be developed to determine the average residence time of CO_2 in the water column at various outfalls under various conditions. This process could also form a sink for methane, but this should be approached cautiously since methane is an explosive gas that also could be toxic to aquatic life in sufficient concentrations. This process could not form a sink for N_2O, since one of the main goals of sewage treatment is to remove nitrogen from wastewater in the first place. See the discussion of deep ocean CO_2 sequestration in Chapter 13.

11.4.5 Use Sewage Effluent as Reinjection Fluid for Geothermal Wells in the Puna District of the Big Island (high cost, low benefit)

Geothermal energy currently provides about 30 MW of energy on the Big Island. This project reinjects water (cooled from geothermal steam) back into the underground formations to allow the water to reheat. The system has had some problems, however, due to corrosive acids and other materials retained in the reinjected water. In California, the Geysers geothermal site, which generates over 1,000 MW of energy, has been losing about 6% of its power production annually since the mid-1980s due to declining steam concentrations in the subsurface. A project to pipe sewage effluent 26 miles to the site was scheduled to go on-line in late 1996 or early 1997 (USEPA 1995c, 55-57).

Sewage may have benefits over geothermal wastewater for reinjection. Such a project would have high costs, however, in particular the cost of pipeline construction and maintenance. In addition, the geothermal plant on the Big Island are neither large nor experiencing significant power decreases due to diminishing steam resources. The plants are also not located near significant population sources for sewage effluent. Thus, this solution does not appear viable in the near term.

CHAPTER 12 AGRICULTURE

12.1 Overview

This chapter suggests measures for consideration to reduce Hawaii's greenhouse gas emissions from agricultural activities. It is an edited version of the recommendations and supporting analysis reported in *Greenhouse Gas Strategy for Hawaii, Phase II: Forecasts and Mitigation Options for Non-Energy Emissions Sources* (Miller 1997) as part of this project. The report was prepared by the University of Hawaii Environmental Center. The activities covered in this chapter include livestock and manure management, fertilizer and compost, crop burning and bioenergy crops, and land use management.

For the U.S. as a whole, methane emissions from agricultural sources totaled nearly one third of all anthropogenic methane emissions in the early 1990s, and livestock emissions have been increasing by about 1% per year. Some 94% of these emissions are from livestock management, resulting from enteric fermentation in digestive tracts (63%) and the decomposition of animal waste (31%). Burning of crop residues comprises much of the remainder
(EIA 1995 37).

12.2 Emissions from Agricultural Activities

12.2.1 1990 Baseline Emissions

The estimated anthropogenic emissions of greenhouse gases from agricultural activities in Hawaii in 1990 are summarized in Table 12.1.

Table 12.1 Estimated Greenhouse Gas Emissions from Hawaii Agriculture, 1990

Land Use	CH_4 Emitted (Tons CH_4)	N_2O Emitted (Tons N_2O)	CO Emitted (Tons CO)	NO_X Emitted (Tons NO_X)
Domestic Animals	13,368			
Manure Management	6,056			
Sugarcane Burning	543	8	10,857	140
Fertilizer		196		
Total	**19,967**	**204**	**10,857**	**140**

Agriculture contributed only 3% to Hawaii's global warming potential as measured in tons CO_2 equivalent. However, agricultural activities generated 36% of CH_4 emissions in Hawaii in 1990, second place to municipal waste management at 72%. While transportation energy use caused 65% of Hawaii's N_2O emissions, agricultural activities, and fertilizer use accounted for 30%.

12.3 Emissions from Livestock and Manure Management

12.3.1 Sources of Emissions from Livestock and Manure Management

> Methane emissions from enteric fermentation sources in the United States are increasing by about 2% per year, due mainly to increases in beef cattle populations but also to increased animal sizes and productivity (EIA 1995, 37-38). Methane production from enteric fermentation is greatest among ruminant animals, including cattle, sheep and goats. These animals possess a rumen, or forestomach, that allows them to digest large quantities of cellulose found in plant material via microorganisms present in the rumen. This digestive process emits methane. Other animals, such as swine and horses, also emit methane, but at much smaller rates than do ruminants.

Methane production from livestock digestion is a function of several variables, including quality and quantity of feed intake, the growth rate of the animal, its productivity (reproduction and/or lactation), and its mobility (38-39). As with methane emissions from enteric fermentation, over half (57%) of all emissions from manure management in Hawaii were from cattle, with chickens and pigs making up much of the rest (see Table 12.1). As an extreme example of the volume of manure potentially involved, Hawaii's principal feedlot (now closed), a 14,000-head lot at Campbell Industrial Park on Oahu, accumulated a 150,000 ton mountain of manure over a 10-year period in the 1970s and early 1980s (Dugan and Takahashi 1985, 5).

Although some information about livestock operations in Hawaii is proprietary, it is known that the largest cattle operation in Hawaii today is the 21,000 head calf-breeding (or cow/calf) Parker Ranch on the Big Island. Approximately 800 more cow/calf farms are operating, most of which have less than 200 head and many have less than five head. Nearly all calves about (40,000 per year) are sent to the mainland to fatten on pasture (Rauson 1997). Only one feedlot, for a few hundred head, continues to operate on Maui. This feedlot slaughters cattle on-island. The largest hog farm has about 300 head, while most of the 350 or so others have less than 60 head (Zaleski 1997; Moniz 1997).

Manure emissions vary as a function of the amount of decomposable organic matter in the manure, and by the way the manure is managed. The amount of decomposable organic matter in the manure varies according to diet: The greater the digestibility of the feed, the greater the methane-producing potential of the manure (USEPA 1995c, 61).

Manure management varies according to animal type, with all but beef cattle being mainly kept in pens or cages. As a result, most agriculture operations, in Hawaii and elsewhere, use liquid-based waste management systems that operate predominantly under anaerobic conditions (EIA 1995, 40-41).

12.3.2 Estimated Future Emissions from Livestock and Manure Management

Future emissions of greenhouse gas emissions from livestock and manure management are extremely difficult to estimate. There are no long-term estimates of activity in these areas and recent history, particularly in the dairy and beef cattle industry, has seen a decline in livestock herds. Activity in this industry depends upon a wide range of market and economic conditions. Given the lack of industry projections, activity was forecast to continue its general decline over the period of the estimates. The resulting estimates are depicted in Figures 12.1 and 12.2.

Figure 12.1 shows estimated methane emissions from livestock and manure management. The livestock estimate is based upon calculated cattle, sheep, and swine eructation emissions. Of these, cattle were estimated to produce 98% of current and future emissions. Manure management emissions include cattle, swine, sheep, and poultry. The estimates presented in Figure 12.1 reflect the expected continuation of the current trend of gradual, ongoing decline in Hawaii's livestock industry.

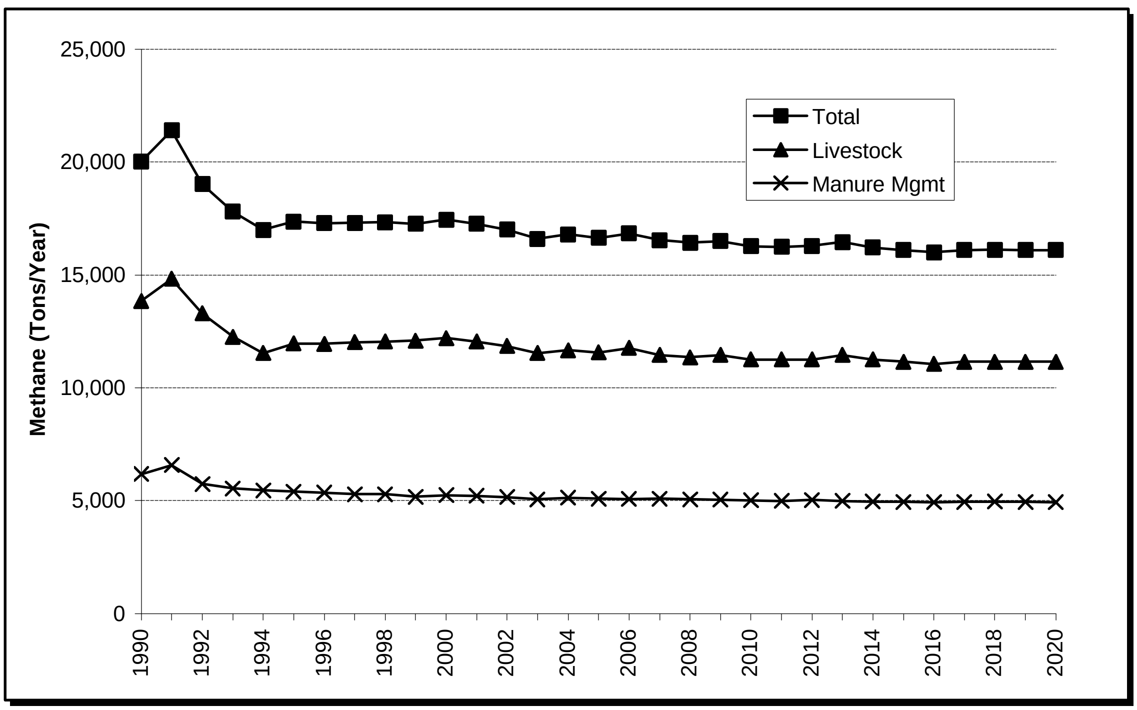


Figure 12.1 Estimated Methane Emissions from Livestock and Manure Management in Hawaii, 1990-2020

12.4 Recommendations for Livestock and Manure Management Emission Reduction

The sections below will examine ways of reducing emissions from Hawaii's livestock and from manure management.

12.4.1 RECOMMENDATION: Recover Methane from Stored Manure (moderate to high cost, moderate benefit)

The United States Office of Technology Assessment estimated that about 50% to 90% of the methane currently generated from animal waste worldwide can be recovered and used for energy instead of being vented to the atmosphere (OTA 1991, 255). A technique called anaerobic digestion (also known as anaerobic fermentation) can be used to maximize methane generation from livestock waste within a controlled, oxygen-free environment. The gas produced is called biogas (generally about 60-70% methane and 30-40% carbon dioxide) and can be used as a substitute for natural gas or combusted for electricity generation (CEC 1991, 5-104; Hobson and Wheatley 1993, 240).

While combustion converts methane into CO_2, creating approximately the same amounts of CO_2 that aerobic process would have produced, burning replaces the fossil fuels which would have been used instead. The gas emitted by anaerobic digestion is compared to the products of simple anaerobic ponds and aerobic lagoons in Table 12.2.

Table 12.2 Composition of Gas Produced by Animal Waste Treatment Technologies

Gas Type	Technologies		
	Aerobic Spreading	Anaerobic Lagoon	Anaerobic Digester
CH_4	<1%	60%	>60%
CO_2	>85%	<5%	30%
H_2	<5%	5-10%	5%
N_2	<10%	20-30%	<5%

Source: Dugan and Takahashi 1985, 22; Joblin 1996, 439

In China and India, millions of anaerobic digesters, averaging about 30 cubic feet in size, have been in use for many years for production of biogas and fertilizer on small farms. Even as few as seven or eight cattle can be sufficient to produce enough gas for one family's cooking and lighting needs in these countries, while supplying fertilizer to fields and fishponds. Unfortunately, these digesters, while cheap to construct and maintain, tend to be labor-intensive (Hobson and Wheatley, 1993, 186-188 and 240). Another concern in the U.S. is the common addition of antibiotics to livestock feed as these antibiotics can also kill anaerobic bacteria (Heduit 1986, 92).

Anaerobic digester methane recovery potential from manure depends on many factors, including equipment design and livestock type (Table 12.3). So far, anaerobic digesters have only proven cost-effective in the U.S. for livestock operations larger than those in Hawaii.

Table 12.3 Typical Methane Yields from Sewage Sludges and Farm Slurries in the EEC

Type of Waste	Methane Yield (m3) per Ton
Sewage Sludge	400-450
Pig Slurry	450
Cattle Slurry	200-400

Source: Bruce 1988, 188.

In spite of these drawbacks, in 1992 at least 23 projects were recovering methane from dairy, swine, poultry and goat manure nationwide. The average U.S. manure digesters for cattle, swine and chickens were served by around 600, 3,300 and 200,000 head, respectively (USEPA 1993a, 6-16, Table 9). These populations are significantly larger than the typical livestock operation in Hawaii, but a cluster of operations could muster the necessary populations. While benefit-cost data for mainland operations have not been found, one would expect that at least some of these operations (especially the larger ones) must be cost-effective in order to drive the market for their construction.

Table 12.4 Average Sizes of U.S. Feedlots Fueling Anaerobic Manure Digesters in 1990 as Compared to Hawaii Livestock Populations in 1994

Animal Type	Digesters in Use Nationally, 1990	Average Number of Head Serving Each Digester	Number of Head in Hawaii, 1994	Number of Farms in Hawaii, 1994	Estimated Number of Digesters Hawaii Could Support	Methane Production in Hawaii, 1990	Estimated Methane Production in Hawaii Using Digesters at Moderate-size Farms
Cattle	15	600	16,112	900	2	3,244	650
Swine	5	6,600	35,000	350	2	1,101	400
Chickens (Layers)	2	200,000	823,000	55	2	1,400	400
Total	22			1,305	6	5,745	1,450

Sources: USEPA , 1993, 6-16; Hawai'i Agricultural Statistics Service, 1995.

As shown in Table 12.4, six digesters may be possible in Hawaii. The six digesters could be further consolidated if they not only fed neighboring farms with the same type of livestock, but neighboring farms with different livestock types; e.g., cattle farms and hog farms.

For the largest farms, evaluate a system that would combine anaerobic digestion, burning of the methane for power, and photosynthetic reclamation of the remainder.

One interesting option, which has been considered for Hawaii, involves supplementing a methane-to-energy animal waste treatment plant with cultivation of some crop, such as algae, which uses the remaining nutrients. For example, Dugan and Takahashi estimated the cost of a 60-acre plant to treat the waste slurry from a 10,000-head beef feedlot operation, which combined anaerobic digestion, burning of the methane for power, and photosynthetic reclamation of the remainder. These authors concluded that the construction and maintenance costs would total approximately $1 million in 1985 dollars, with the biogas and algae each bringing a profit of $500,000 per year. As a result, they estimated a 5-year payback period even without including the benefits of reduced waste shipping costs (52-53).

12.4.1.1 Place covers on liquid waste lagoons at individual farms, and treat solid manure with plug flow or mixed tank digesters. Flare the methane or use it to generate electricity and heating for farming uses.

This methane recovery approach has rarely been used in Hawaii, primarily due to the relatively small size of Hawaii's farms and the lack of a thorough economic study on the potential costs and benefits (Paquin 1997). This option is widely used elsewhere, and could be valuable in terms of both sustainable energy use and the mitigation of methane emissions. A cost-benefit analysis of several mainland livestock methane-to-energy projects is summarized in Table 12.5.

Table 12.5 Costs and Benefits of Livestock Methane Recovery and Electricity Generation Systems

Recovery System	Farm Size (Head)	Cost (Dollars) Capital	Cost (Dollars) Annual O&M	Annual Benefit (Dollars)	Payback Period (Years)
Dairy Farms					
Covered Lagoon	250	69,500	2,100	10,600	7.0
Complete Mix	250	117,400	1,500	8,600	11.7
Plug Flow	250	97,800	1,100	6,200	10.3
Covered Lagoon	500	99,800	4,200	21,300	8.2
Complete Mix	500	168,200	3,100	17,100	15.2
Plug Flow	500	130,100	2,200	12,500	12.3
Covered Lagoon	1,000	163,800	8,500	42,600	11.0
Complete Mix	1,000	261,800	6,100	34,300	21.4
Plug Flow	1,000	190,300	4,400	24,900	16.1
Hog Farms					
Covered Lagoon	500	48,900	1,100	6,000	5.7
Complete Mix	500	86,000	1,000	6,400	9.1
Covered Lagoon	1,000	71,700	2,300	12,000	7.0
Complete Mix	1,000	112,000	2,000	12,700	10.6

Recovery system costs for covered lagoons do not include the cost of the lagoon itself.
For dairy farms, average gas recovery rates and electricity rates for Erath County, Texas are applie
For hog farms, average gas recovery rates and electricity rates for Sampson County, NC are applie
Plug flow systems do not include slurry from pens. Average weight of cows is 1,400 lbs.,
and that of hogs is 138 lbs. Source: EPA 1993b, p. 6-38--6-40.

Table 12.5 suggests that, under the right conditions, a wide range of farm sizes may be able to profitably generate electricity, at least on the mainland. Undoubtedly, conditions are different in Hawaii, in particular the lack of any hog farms over 350 head in size. But ventures collecting manure from several nearby farms in Hawaii do appear to merit further study.

The primary drawback to methane collection from lagoons in Hawaii is the apparent lack of cost effectiveness when confined to a single farm. An important aspect of the cost is the corrosiveness of some of the gases produced, in particular hydrogen sulfide (H_2S). Mitigation measures that reduce this gas also have costs involved. For example, the necessary use of absorbents such as iron oxide adds labor and transportation costs to the cost of disposal (Hoeksma, 1986, 93). Once the methane has been collected, it may be flared, burned for heat, or burned or sold for electricity. Flaring produces no financial benefit but does reduce the global warming potential. Burning for heat may be beneficial, especially for farms at higher elevations where piglets need heated pens (Zaleski, 1997); but since most farms do not require the amount of heat that can be generated, much of the heat would be wasted (USEPA 1993b, 6-23).

Of the various options available to livestock managers in Hawaii for reduction of methane emissions from their animals, covered lagoons tend to offer the least retooling of current waste management systems and the least long-term cost (6-22 and 6-23). Dairy and swine operations in particular keep the animals in enclosed pens from which the manure is collected by flushing with large quantities of water. The substantial dilution, which results, generally prevents solid waste management techniques such as composting from being either operationally or economically feasible (6-23; Zaleski 1997).

Hawaii has some experience with this approach. From 1991 to 1995, the Happy Hula Hog Farm in Kula, Maui used hog manure to operate a 20 kW electricity generator. A 61,000-gallon biomass digester with a floating cover was used to produce biogas from the waste slurry of about 150 to 160 sows, which fueled the generator system. Due to the small amount of biogas produced, the system could produce fuel to operate the generator only 8 to 10 hours per day and was primarily used as a backup to utility power. Component failure caused its shutdown in 1995, and plans by the owners to sell the farm have prevented its repair (Greer 1997, 16). A manure digester used on a hog farm on Kauai also produced biogas used to run a generator, but the low concentration of methane in the biogas (~60%) has made it necessary to use a fuel mixture of 3/4 diesel and only 1/4 biogas (Zaleski 1997).

A biogas plant operated by Unisyn, Inc., in Waimanalo, on Oahu originally got most of its material from a 1,200-head dairy farm nearby. However, the plant now uses material from several other sources.

12.4.1.2 Provide incentives for transfer of waste slurries to centralized waste-to-energy plants

While waste-to-energy plants at individual farms are generally not cost-effective unless the farms are of moderate to large size, combining the waste from a group of neighboring farms may be significantly more economical. For example, this could involve construction of one or more small, Unisyn-type plants on each island. Unisyn Biowaste Technology has operated a unique bioconversion plant in Waimanalo, Oahu, since 1986. This plant processes about 35 tons per day (13,000 tons per year) of wet organic waste, initially including animal manure from a 1,200-head dairy, food waste, and (since 1995) green waste. Capacity is 110 tons per day of wet organic waste and 30 tons per day of green waste. While not currently being used to process animal manure, the process could again be used to that end.

The process is centered on anaerobic digestion, wherein the waste is converted into biogas, granular fertilizer, compost, and irrigation water. The biogas fuels a generator, which satisfies most of the facility's energy requirements. The fertilizer and compost produced are sold to plant nurseries, golf courses and landscapers, and the irrigation water is kept for moisture needs or donated to local farmers via a plastic pipeline. This water has been approved by the DOH for use on soybeans, corn, bananas and other crops (Lyum 1997; USEPA 1993b, 6-26).

As seen in Table 12.4, above, it may be possible to run a handful of slurry-to-energy plants in Hawaii. Using swine as an example, there may be an opportunity to build two centralized waste-to-energy plants along the west coast of Oahu using animal slurries from surrounding farms. Although the average size of the 350 or so hog farms in Hawaii is only on the order of 50 to 100 hogs, it is estimated that approximately half of the hogs in the state are raised in this area due to favorable zoning. While such restrictions may be barriers elsewhere (see below), here they may prove a boon by providing the proximity necessary to allow pipeline construction costs and hauling fees to become economical. As such, it may be possible to construct one plant serving the Waianae area and another serving Nanakuli farms. Ownership could be either by a separate entity or through joint ownership with neighboring farms. A precedent already exists in the form of the Producer's Co-Op, which runs the area's slaughterhouse.

However, even a plant using slurry biogas from several farms may be insufficient without upgrading of the gas, which is typically only about 60% methane. The best use of such gas is probably for heating rather than electricity generation (Zaleski 1997). The key is finding a customer in need of heat, such as the quarry, which receives heat from the methane emanating from Kapaa Landfill to dry its aggregate *(Honolulu Advertiser*, May 26, 1997, A22).

A centralized, Unisyn-type plant for livestock biomethanation would have both positive and negative aspects. Benefits would include (Hoeksma 1986, 94):

- Cost reduction per cubic meter of digester volume;
- Smoother input, since variations in feed from one farm are partially mitigated by feed from other farms; and
- The opportunity to site the plant for maximum use of available animal waste.

Disadvantages would include:

- Added costs for transport to the plant (possibly counterbalanced by increased proximity to fertilizer and/or energy market);
- Increased complexity of administration; and
- Possible additional odors around the plant.

Government initiatives for increasing the capture rate for methane emissions from animal manure could include both incentives and regulations. Possible incentives include tax rebates, low-interest loans and training workshops. Regulations could mirror those of several other states that currently require farms to more stringently manage their animal wastes (USEPA 1993a, 6-24). Care must be taken to ensure that such anaerobic digesters work properly. When not working optimally, they can increase methane emissions from animal waste (6-25).

One potential source of support is the federal AgSTAR Program. AgSTAR is a voluntary pollution prevention program operated in conjunction with the livestock industry. The program encourages dairy and hog farms to adopt "best management practices" which profitably manage animal manure, while reducing pollution and fertilizer costs. This program seeks to overcome a number of barriers that currently hinder the more widespread use of on-farm energy recovery technologies, including lack of information and technological support. This program is also part of the U.S. Climate Action Plan (Hedger 1996, 24 and 26).

A more intensive and localized program could follow the example of Missouri, which recently began a cooperative venture with local livestock and poultry producers, in conjunction with the USEPA. In this program, the relevant state agencies work together through the State Revolving Loan Fund, sale of water pollution control bonds, and federal capitalization grants to finance animal waste treatment systems at below conventional interest rates (USEPA 1996b, 5). Creative measures like this could help put animal waste management systems into use in Hawaii.

12.4.2 RECOMMENDATION: Improve the Diet Quality of Ruminants (low to moderate cost, moderate benefit)

Much of the food eaten by cattle, sheep, and goats (but not hogs) cannot be digested until it has been fermented. This process, involving bacteria that produce methane as a by-product of the fermentation process, takes place in the part of these animals' digestive systems called the rumen. The efficiency of methane formation in the rumen varies with animal type, type of fiber in feed, level of feed intake, and retention time of fiber in the rumen. Animals fed forage (grasses and legumes) tend to produce more methane per unit of feed dry matter than animals fed diets rich in readily-digested concentrates (especially grains) (Kirchgessner et al. 1995, 333-348). This is the opposite of the effect of readily digested feed on manure, as might be expected, since the organic matter not utilized by the rumen must pass on through (USEPA 1995c, 61). Yet , to reduce methane emissions of ruminants, the digestibility of feed should nevertheless be increased where possible, despite this contradiction, for two reasons: First, overall emissions in Hawaii from manure are less than those from rumination. Second, reduced emissions from rumination also tend to be associated with improved animal productivity (IPCC 1991, 111).

In Hawaii, the two main classes of cattle are dairy cattle and beef replacement cattle (0-12 months old). Dairy cattle generally graze on pasture, while the latter tend to be raised in feedlots. Of the beef cattle kept in feedlots on Maui, 10% to 15% finishes on grass (Moniz 1997).

To carry out the recommendation to improve the diet quality of ruminants, the following actions could be taken:

12.4.2.1 Promote and support research into economically viable diets for dairy cattle and pasture supplements for beef cattle which increase productivity without increasing methane emission rates, emphasizing maximization of nitrogen-fixing crops where possible.

Typical feedlot diets in the U.S. consist of only about 15% forage and about 85% “concentrate ration,” which consists mainly of grains (USEPA 1993b, 5-33). In the Maui feedlots, the main feed is pineapple silage, supplemented by protein sources such as soybeans or cottonseeds from time to time (Moniz 1997). Dairy farmers tend to balance reasonable price with cattle needs, buying feed in bulk from the mainland and mixing it onsite, again adding a protein source. Dairy cattle diets tend to have a higher percentage of forage, considered necessary for proper milk production. However, the USEPA has concluded that opportunity still exists for dairy farmers “to increase grain feeding in response to changes in milk pricing” (USEPA 1993b, 5-30). Such changes would of course be market-driven, but opportunities would remain for the state to help educate consumers and farmers regarding the benefits of altered diet.

For grazing animals, supplementing forage with minerals and protein sources is an important way of increasing the efficiency of pasture use. Supplements such as whole cottonseed appear to be particularly promising in terms of reduced methane emissions (IPCC 1991, 112). The potential for improving the nutritional status of grazing animals using supplements is considered to be greater in tropical regions than in temperate regions because tropical forages have a higher fiber content and are thus of lower digestibility than temperate forages (Joblin 1996, 441). It is uncertain where Hawaii’s grasses fall on the digestibility continuum, but the subject merits further study.

For developed countries, some researchers have estimated that methane emission reductions on the order of 25% are possible in some cases by using both nutritional supplements and growth hormones such as bovine somatotropin (bST) (442-443). However, public concern is growing regarding the impacts of the latter on human health (IPCC 1991, 111), and the USEPA predicts that bST alone would only be responsible for 3% to 7% of all foreseeable reductions in methane emissions from cattle in the United States. (USEPA 1993b, 5-4). It has also been recommended that feed be supplemented with ionophore antibiotics, which kill methane-generating bacteria in the rumen. However, these techniques are generally only feasible for cattle kept in pens or feedlots, and methanogenic bacteria can become resistant to antibiotics (OTA 1991, 253-255; Joblin 1996, 442-443).

Some studies have further concluded that supplementing cattle feed with urea -- a common practice on the mainland -- causes a noticeable drop in methane emissions. Very little urea is fed to cattle in Hawaii, however, both because it is used mainly for fattening and because maintaining a proper proportion is a risky operation, which done improperly, can kill the cattle (Rauson 1997).

The USEPA has concluded that improved forage and nutrient supplements alone can decrease methane emissions from dairy and beef cows by 30% to 45%, while increasing productivity by an equal amount (Tables 12.6 and 12.7). The main methods recommended for forage improvement are improved fertilization schedules and a thorough understanding of nutrient needs (USEPA 1993b, 5-4; 5-24 to 5-25). Comparisons of various diets for both metabolizable energy (ME) and methane production in USEPA tests are shown in Tables 12.6 and 12.7.

Table 12.6 Methane Emissions per Unit of Metabolized Energy for a Variety of Dairy Cattle Diets

Lactation Diet	Diet ME	Methane/ME (kg/ME)	
(Fed 305 days/year; replaced by Diet #9 the other 60 days)	(Mcal/kg)	Study A	Study B
1. High quality alfalfa hay (20% protein)	2.4	59.1	58.7
2. 75% alfalfa, 25% corn-soybean meal	2.5	53.6	41.9
3. 60% alfalfa, 40% corn-soybean meal	2.5	49.0	46.6
4. 50% alfalfa, 50% corn-soybean meal	2.6	44.4	40.2
5. 60% alfalfa, 40% corn-cottonsead meal	2.6	50.8	50.0
6. 50% alfalfa, 50% barley-soybean meal	2.6	45.5	41.2
7. 40% alfalfa, 54.5% cornmeal, 5.5% soybean meal	2.7	34.1	37.0
8. 40% alfalfa, 54.5% oatmeal, 5.5% soybean meal	2.6	41.8	46.0
9. Timothy hay (9% protein), plus some cottonseed meal	2.4	56.4	57.3
10. 40% timothy hay, 45% cornmeal, 15% soybean meal	2.7	45.7	47.6
11. 70% corn silage, 16% cornmeal, 14% soybean meal	2.7	42.6	45.3

(1 ME = 1 Mcal/kg of feed) After USEPA 1993, 5-10

Table 12.6 shows that, for dairy cattle, mixtures of approximately half alfalfa hay and half corn-soybean meal cause both high productivity and low methane emission rates. The highest emission rates for dairy cattle are produced by diets which consist essentially of hay (alfalfa or timothy) alone. Unfortunately for our recommendation made elsewhere in this report regarding planting of nitrogen-fixing crops, the best dairy cattle diets are also those lowest in such nitrogen-fixing crops as hay and soybeans.

Table 12.7 Simulated Methane Emissions per Head of Beef Replacement Cattle on Three Separate Diets

	Diet 1 Legume Pasture with Supplement	Diet 2 Very High Quality Grass (18% Protein)	Diet 3 Corn Silage with Supplement
Diet ME (Mcal/kg)	2.48	2.58	2.66
Methane/head (kg/head)	18.1	27.2	15.8
Methane/head/ME	7.3	10.5	5.9
Percent of Farms Using	50%	50%	0%

(1 ME = 1 Mcal/kg of feed) After USEPA 1993b, 5-21

Similarly, beef cattle productivity is highest -- and emissions lowest -- on a diet consisting mainly of corn silage. As can be seen in Table 12.7, this diet is rare to absent across the western U.S., although half of all farms graze on clover and other legumes. In Hawaii, most pastures are grass rather than clover. Although legume forage is less efficient in terms of its conversion into energy (and meat), any change toward a more legume-rich (or grain-rich) diet would have positive results in terms of methane emissions. Thus, the feasibility of increasing legume and grain supplements to beef cattle diets -- or seeding pasture with legume ground cover -- should be carefully studied. It must be kept in mind, however, that for livestock operations in Hawaii, any efforts to reduce greenhouse gas emissions must also be cost-effective when implemented or the industry will likely oppose these measures (Moniz 1997).

It should be noted that the values in Tables 12.6 and 12.7 were produced via model simulations, then verified through observations of animal performance. Although the resulting uncertainty is + 20%, the general conclusions of these tables appear to be valid, and have been accepted as representative by the USEPA (USEPA 1993a, 5-34).

Side benefits of improving the diet quality of ruminants include:

- Lowering methane production in the rumen will increase the amount of energy captured from forage by the animal, thus improving animal productivity; and
- Healthier, more profitable products will be produced.

Drawbacks include:

- Increased use of grain decreases market for nitrogen-fixing plants; and
- Increases the percentage of crops not intended for direct human consumption.

To achieve decreased methane emissions from ruminants will require considerable research and development. The ideal scenario is to increase the individual performance and productivity of ruminants. Intensive management is the most important factor because of the variability involved. The feed efficiency of ruminants can vary according to animal type, health (especially degree of parasitism; see below) and age. For example, yearling cattle require a diet higher in protein than do adult cattle (Zaleski 1997). Specific feed mixtures are difficult to recommend for Hawaii, because all the feed is manufactured on the mainland. Different mixtures that work well elsewhere may not achieve the same production levels in Hawaii. Therefore, trial-and-error processes and comparisons of different management techniques remain the major means of improving overall ruminant performance in Hawaii.

Although such efforts will largely be market-driven, ostensibly leaving the state and county governments with little to do, one key to the success of such efforts is careful record keeping regarding feed type and tonnage purchased, and resulting growth rate and market value, both within and between growth cohorts or litters. The state and counties can help by designing, promoting and perhaps mandating specific forms in order to normalize such record keeping (Zaleski 1997). In particular, these bodies can participate in the U.S. Ruminant Livestock Methane Program, a partnership between the USEPA, the USDA, and livestock producers which aims to increase livestock productivity while reducing costs, producing healthier products and reducing methane emissions. The program, which has been incorporated into the U.S. Climate Action Plan, seeks to implement all of the measures discussed above (Hedger 1996, 23).

Table 12.8 Summary of Cattle Emissions Options in the United States

Option	Description	% Total Reductions
	Dairy Farms (33% of Total)	
Improve Dairy Cow Productivity	Continue to improve nutrition management and genetics	10-15%
	Use bST to improve production	3-7%
Refine Milk Pricing System	Adjust rations to reduce milkfat and methane emissions	10-20%
	Beef Farms (67% of Total)	
Improve Beef Production Productivity	Continue to use nutritional management to improve cow-calf reproductive performance	20-30%
	Improve feed efficiency via ionophores	5-15%
	Provide information to help market incentives reduce trimmable fat	4-6%
Refine Beef Marketing System	Provide information to help market incentives move calves directly to feedlots, further reducing fat	20-30%

From USEPA 1993b, 5-4

There is at least one more option for which the government could provide aid, which is also addressed by the U.S. Livestock Methane Program. It is known that reducing the fat content of milk and beef also results in reduced methane emissions from these animals, reinforcing an ongoing decrease in fat intake by Americans. Indeed, the USEPA predicts that this trend could be responsible for 45% to 65% of all foreseeable reductions in methane emissions from dairy and beef cattle (Table 12.8). Such reductions occur in part due to changes in feed, but also due to changes in breeding and management of beef calves (USEPA 1993a, 5-42; USEPA 1993b, 5-4, 5-32 and 5-33). Again, this change is largely market driven. In Hawaii, cattle ranchers adjust by artificially inseminating their stock to improve its genetic makeup, in an effort to produce lean carcasses for which processors pay top dollar (Zaleski 1997).

12.4.2.2 Educate markets and consumers regarding the combined health benefits and reduced methane produced by low-fat cattle products.

Efforts by the state to further educate markets and consumers in Hawaii regarding the combined health and reduced methane benefits of low-fat cattle products would help to improve both health and the state economy while reducing greenhouse gas emissions. In particular, the state could support and augment the "Value-Based Marketing" initiative begun by the beef industry in the early 1990s (USEPA 1993b, 5-32). In 1993, the USEPA calculated that eliminating the creation in the first place of all fat subsequently trimmed from beef would save about $2 billion per year nationwide. Assuming that 4% of gross energy intake in a steer is normally converted to fat, this savings translates to a nationwide reduction in methane emissions of about 120,000 tons per year (5-32 and 5-33). Unfortunately, the costs of such a program have apparently not been quantified.

12.4.3 RECOMMENDATION: Improve Efficiency of Livestock Feed Application (low cost, low to moderate benefit)

12.4.3.1 Improve monitoring and design of feed bins

Often up to 25% of feed is directly wasted, especially on cattle and hog farms. Better monitoring of the feeding process and improved feeding bin designs would reduce this wastage, as well as emissions from decomposing feed.

12.4.3.2 Maintain a good parasite control program

Parasites reduce the efficiency of feed uptake and reduce the health of the animals by sapping fluids and nutrients from livestock.

12.4.4 RECOMMENDATION: Increase Aerobic Treatment of Manure (low cost, moderate benefit)

12.4.4.1 Expand the market for composted manure as fertilizer

Composting is the aerobic decomposition of organic material to produce a soil amendment. Onsite composting occurs on many livestock farms in Hawaii. For example, nearly all of the dairy cattle manure on Oahu is being composted onsite and then applied to pineapple fields (Lee 1997). Swine owners have attempted to market their compost fertilizer as well, but often lack the necessary funds and management capabilities (Zaleski 1997). Instead, most of Hawaii's swine waste systems are composed, at least in part, of open lagoons that are anaerobic below the top few inches of slurry. Such lagoons predominate because they provide the cheapest long-term method for dealing with animal excrement, with costs generally in the range of $100 to $200 per lagoon, with lifetimes averaging 15 years (Zaleski 1997). On the other hand, lagoon systems dilute manure considerably, making it costly to transport the treated effluent offsite (USEPA 1993b, 6-14).

Composting can be a cost-effective method for managing livestock manure. On Oahu, composted dairy cattle manure currently sells for $30 per cubic yard, compared to approximately $10 per cubic yard for unprocessed dairy solids (Zaleski 1997; Hawaiian Earth Products 1995). If the composting process costs less than this difference, then composting would be the preferred disposal method. Currently on Oahu, only one hog farm has an aerobic composting system that operates completely outside the animal pens, yet this operation appears to be turning a profit. The neighbor islands appear to be particularly suited to compost marketing, with dairy cattle compost occasionally commanding in excess of $300 per cubic yard (Zaleski 1997).

Provide expertise and financial incentives to swine and poultry owners who wish to compost and market their manure, targeting systems that mix the manure with green waste. Most of the composting operations described above, as well as essentially all of the methane-generating operations described below, were made possible by county, state or federal grants. It appears that most farms must not only be of a certain size to be economical to operate commercially (at least 20 animals for cattle and hog farms), but must be of a significantly larger size to maintain a cost-effective composting operation (at least 100 animals for cattle and hog farms). This minimum size can be reduced somewhat if these livestock operations also maintain crops on their farms. For example, one hog farm in Naalehu on the Big Island uses its compost to fertilize its stands of coffee trees and ti plants (Zaleski 1997).

In situations where several farms are clustered together, as in the Waianae district of Oahu, a central composting system may be possible. Again, funding may need to come from government sources, but the possibility exists that land will be offered for free from private landowners. Indeed, land was offered recently for just such an operation by the Lualualei Golf Course, which hoped to use the compost on its grass. Unfortunately, the area available was determined to be insufficient for the needs of the facility and the project was shelved (Zaleski 1997).

12.4.4.2 Identify and work to eliminate any significant obstacles to the integration of livestock and crop production operations.

Currently, there are two policies hindering wide-scale composting on Oahu, and similar hindrances may exist in other counties. The first is a land-use policy. On Oahu, agricultural lands are divided into Agricultural Zone 1 (AG-1) and Agricultural Zone 2 (AG-2). While the City and County of Honolulu allows livestock raising, composting, and crop production in both zones, large-scale livestock operations are restricted to AG-1 land (City and County of Honolulu Chapter 21, Article 5.20). This distinction has increased the average distance between potential compost suppliers and potential compost users, causing transport to rise to roughly $200 per 4000-gallon load (Zaleski 1997). On the other hand, by clustering of larger livestock operations, large-scale composting may be made possible in the first place. Unless the city and county alters its zoning laws, an important consideration in any project should be meeting the costs of transportation.

12.4.4.3 Reduce the length of the permitting process for farms that desire to transport composted material to offsite customers.

The second, and more important, policy hindering wide-scale composting on Oahu is the fact that on-site composting on both AG-1 and AG-2 land is a conditional use; i.e., it is allowed only with a permit from the county. This requirement applies even to minor composting operations on AG-1 land (City and County of Honolulu Chapter 21, Article 5.20). Since AG-1 land is intended to be located some distance from residential areas anyway, it appears possible that permits could be waived for both small-scale and large-scale composting operations on AG-1 land if certain guidelines were followed. However, largely as a result of concerns of some neighbors about the Unisyn plant, two bills introduced in the 1997 session of the state legislature (HB 2244 and SB 1666) failed to pass. These bills would have specified that composting be a permitted use in the agricultural district.

Composting on any land appears to be problematic at present in Hawaii. All composting operations must apply first for conditional use permits, then another round of permits for the actual composting process. Both sets of permits can require extensive time for approval. For example, it took the Hawaiian Earth Products company approximately three years to obtain an air quality permit to compost green waste and dairy manure at Campbell Industrial Park (Zaleski 1997). Reducing permitting time will require extensive consultation and public education, but it is in the best interest of everyone in Hawaii for the state and county governments to continue working to resolve this problem.

Side benefits of composting include:

- Increases water retention potential of soil more than most fertilizers, thus reducing water requirements;
- Provides an alternative to chemical fertilizers that cause more chemical contamination of water resources and require more energy to create;
- Reduces odor problems, as composting operations typically emit less odor than manure lagoons; and
- When co-composted with biosolids, the high nitrogen and phosphorus levels in the biosolids complement the high carbon levels in the green waste.

12.4.4.4 Direct land application for aerobic decomposition

Direct land application involves mechanically dumping and spreading livestock manure or slurry as a fertilizer on pasture or forage crops. The solid component of manure is deposited on the soil surface, while the liquid component can be injected under the soil surface. Specific recommendations include:

12.4.4.5 Evaluate costs and benefits of injecting animal slurry into soil as a crop amendment

To date, soil injection has only been attempted on Lanai, at a hog farm, which has since gone out of business (Zaleski 1997). It has been demonstrated that injection of waste slurry 4-6 inches below the surface with mechanical injectors can increase yields of corn more than 200% over surface spreading in certain soils, with lower emissions of nitrogen to the atmosphere (Larsen 1986, 77). However, this method is not only slower than surface spreading, it is also much more expensive. Indeed, the method which appears to best combine effectiveness and low cost is surface spreading, followed by simply turning the slurry into the soil with a shovel or plow depending on the size of the farm (Zaleski 1997).

More research needs to be done regarding the relative effectiveness of surface application and subsurface injection of liquid slurries. In Europe, some researchers have concluded that the yield increases noted above for surface application may be applicable only to crops; broadcast spreading on pastures has actually been found to decrease the quality and palatability of grass to livestock (Kemppainen 1986, 64). On the other hand, one hog farmer in Kamuela on the Big Island has set up an irrigation system to apply his lagoon-stored slurry to pasture, concluding that grass growth has increased 500% with no loss of palatability. Since this farmer is currently in the process of shipping over a larger-caliber hose system to improve application rates on his mid-size farm and reduce clogging, there appears to be potential for this method which merits further study (Zaleski 1997).

12.4.4.6 Promote storage of manure in closed tanks or pits

Much of the recommendation in Section 12.3.5.1 to expand the market for composted manure as fertilizer applies to direct land application of livestock manure. Transport costs are especially important in determining whether or not this measure would be cost-effective in reducing methane emissions. Under aerobic conditions, livestock manure produces very little methane. This is the reason that beef cattle manure is not a significant source of methane, since beef cattle excrement is deposited primarily on open farmland or pasture.

As for nitrogen emissions, studies in Europe have found that waste slurries which have simply been stored in closed tanks or pits volatilize the least amount of nitrogen after they have been applied to fields (Tables 12.9 and 12.10).

Table 12.9 Total Nitrogen Content of Various Animal Waste Slurries			
Animal Type	**After 7 Days Storage in Closed Pits**	**After Aerobic Treatment**	**After Anaerobic Digestion**
Cattle	1.86%	1.83%	1.88%
Pig	5.14%	5.12%	5.05%

Source: Suess and Wurzinger 1986, 48.

Table 12.10 Nitrogen Losses from Various Animal Waste Slurries After 7 Days Exposure			
Animal Type	**After 7 Days Storage in Closed Pits**	**After Aerobic Treatment**	**After Anaerobic Digestion**
Cattle	12.8%	11.6%	28.4%
Pig	11.4%	26.5%	25.6%

Source: Besson et. al. 1986, 43.

Nitrogen is emitted in greatest amounts from anaerobically treated slurry, mainly due to a significant portion of its organic nitrogen being converted into ammonia (NH_4). While ammonia is not considered a greenhouse gas, it can react with oxygen to form N_2O and NO_x (Besson et al. 1986, 43; Suess and Wurzinger 1986, 53). Additional benefits of direct land application have been found to:

- Improve overall soil structure as the organic material increases nutrient- and water-holding capacity;
- Reduce runoff and soil erosion (due to improved soil structure) thus making the soil easier to plow; and
- Increase the pH of acid soils (Reinhart et al. 1996, 4).

Swine and poultry manure typically contains more nitrogen than dairy manure (Zaleski 1997). Because of this, dairy manure can be composted with soil in direct land application, while swine and poultry manure compost quicker and better mixed with green waste, although direct land application is still an option. This is because effective composting requires a proper carbon/nitrogen ratio.

The benefits of composting include an essentially odor-free product that can bring a monetary return. On the other hand, the composting process also requires substantial additional labor and management, as described in Fertilizer section below. In addition, direct land application retains all the fertilizing value of livestock manure whereas the composting process consumes a portion of the nutrients which could otherwise be utilized (Zaleski 1997).

In Hawaii, the main drivers for manure management are DOH regulations and technical advice from the Department of Land and Natural Resources. Educational workshops are provided by the U.S. Department of Agriculture (USDA), but essentially no incentives for comprehensive manure management operations are offered by either the county, state or federal governments (Moniz 1997).

As Table 12.8, above, showed, only relatively small percentages of methane emissions from manure can be expected. There are few applicable studies that have calculated the net emissions reduction to be expected from various measures to reduce greenhouse gas emissions from livestock rumination and manure management.

12.5 Emissions from Fertilizer and Compost

The primary greenhouse gas emission concern regarding fertilizer application is the volatilization of nitrous oxide (N_2O). Globally, agricultural processes contribute approximately 70% of anthropogenic N_2O emissions, predominantly via fertilizer application (EIA 1995, 46). Although some studies claim that there is no correlation between fertilizer type and emissions rate, most researchers agree that emissions are actually a function of a variety of factors, including fertilizer type (especially slow-release vs. fast-release), soil moisture, soil type and whether irrigation or rainfall occurred shortly after application (46-47). Fertilization increases N_2O emissions from soil between 1.7 and 6.6 times what the soil was previously emitting (73). The following recommendations attempt to take these considerations into account.

12.5.1 RECOMMENDATION: Promote expanded use of organic fertilizers (low to moderate cost, moderate to high benefit)

12.5.1.1 Initiate and support diversion of more green waste to municipal, county and private composting and mulching factories

Concentrate on aerobic and dry anaerobic methods. As noted in the sections of Chapter 11 on landfills, although one might think that diverting green waste and food waste to composting operations would reduce the volume of methane that landfills can generate for power, this is generally not the case. Instead, overall proportions of waste types are more or less retained due to other materials being removed from the waste stream at approximately the same rates as green waste. In addition, Hawaii generates a greater volume of green waste per capita than do mainland states due to its subtropical climate; thus, it can be argued that diversion of a moderate amount of green waste would have little effect on landfills. Furthermore, composting would only affect methane generation during the first few years after the green waste's diversion. Moreover, since all but the largest landfills in the state are at the lower end of the size spectrum for economic methane production, a substantial diversion of green waste could move a marginally profitable landfill into the red, but overall the benefits of green waste composting appear to outweigh the possible negative impacts on landfills (State of Hawaii 1984, 52).

Green waste composting uses bacteria which are naturally abundant in organic matter and which facilitate the decay of cellulose and other plant matter. Oxygen, temperature, moisture, acidity, and nutrient levels must be properly managed to create a maximum amount of useable compost. A notable benefit from the standpoint of greenhouse gas emissions is that grass clippings, when incinerated, can be a significant source of nitrogen oxides (NOx) -- a source which is eliminated when such clippings are composted (USEPA 1989, 91).

In 1988, the Noyes Data Corporation published a rigorous benefit/cost analysis of composting methods on the mainland. The three methods studied in the analysis were the aerated static pile, conventional windrow, and aerated windrow methods. Unfortunately, this analysis was unable to produce a definitive comparison of composting methods in terms of overall costs and benefits. Yet the study was able to conclude that all three methods were capable of sustained production of 0.4 to 1.0 cubic yard of compost per wet ton of sewage sludge, weighing 900 to 1,500 pounds per cubic yard.

The aerated static pile method -- the only method for which costs were available -- cost $36 to $51 per wet ton of sludge, not including transport or dewatering. The static pile method required a minimum of 21 days per composting load, while windrow methods required a minimum of 30 days. No data were collected on greenhouse gas emissions during composting or profit from compost sales (Benedict et al. 1988, 12-15).

The USEPA calculated relative costs for various aerobic composting methods. The USEPA ranked the methods as follows: (1) large windrow, (2) conventional windrow, and (3) aerated windrow methods. Large windrows tend to be cheaper (due to more infrequent turning), but require more time (1-3 years) and area (due to greater odor problems and the resulting need for a wider buffer zone) than other methods. Aeration reduces time (to about a year) and area (due to reduced odor), but is significantly more expensive due to added infrastructure and labor needs. An additional problem is that composting facilities tend to violate the economies of scale (USEPA 1989, 83-85).

Taking facilities using large windrows in the late 1980s as an example, medium-sized facilities (20,000 to 30,000 cubic yards) cost an average of $4 per cubic yard to operate, while larger facilities (80,000 cubic yards or more) tended to cost about $6 per cubic yard (86).

Dry anaerobic composting is another method that has proven cost-effective, since the resulting methane can be captured and utilized for energy production in the composting facilities. Dry anaerobic composting also reuses the water necessary for compost production, thus allowing reuse of the composting bacteria that it contains. Dry anaerobic composting is particularly applicable to the conditions in Hawaii since it does not require as much land or water as does wet composting.

Each representative from the four county solid waste programs has stated that the amount of composting has increased over the last decade and will continue to expand in the coming years. For example, on Oahu the 25,000 tons of green waste and 12,000 tons of food waste composted in 1996 is expected continue to grow in the coming years, although at a decreasing rate. One program that shows particular promise on Oahu is a series of workshops explaining the techniques and benefits of backyard composting. The amount of food waste composted in particular is likely to remain stable over at least the next couple of years due to a lack of price incentives. The City and County of Honolulu is also considering the composting of sewage sludge in the future (Harder 1997; McCabe 1997).

In 1996, Maui composted approximately 14,000 tons of green waste and 19,000 tons of wet waste (sewage sludge and food waste). This tonnage has grown rapidly since 1993, but projections are for this growth to begin to level out in the near future.

For Kauai and the Big Island, the tonnage composted are estimates only. For 1996, the best estimates are 4,000 tons on Kauai and 1,200 tons on the Big Island. Since Kauai does most of its composting through private corporations, it is difficult to know the exact tonnage being composted, both in total and according to waste type. It appears that few companies are attempting to compost on the Big Island, with small groups of people taking it upon themselves to compost instead. Some products of commercial activities that could be composted, such as macadamia nut husks, are burned instead to power on-site equipment or to produce process heat. The Big Island first initiated, then suspended, a composting contract with private operators (Harder 1997; McCabe 1997).

The state government has a potential role to play as well. For example, it could make a larger commitment to use local compost for landscaping, since most of the compost used in state-funded landscaping still comes from the mainland. This will require changing regulated specifications in compost material, but the state has moved partway to this goal through its recent guarantee to developers, architects, and landscapers that local compost will be of comparable quality to mainland compost (McCabe 1997).

Further research needs to be done on the benefits and economics of aerobic composting for Hawaii. In particular, studies should investigate developing aerobic composting so as to produce a natural slow-release fertilizer for commercial or personal use. The state has also found that composting for use on-site is most successful when farmers reuse effluent as well (Yee 1997).

12.5.1.2 Advertise and educate the public regarding existing programs, especially for home pickup of separated green waste

Curbside pickup and centralized drop-off points for green waste are currently in place in parts of Honolulu and elsewhere (McCabe 1997); however, these programs remain poorly advertised and most people capable of taking advantage of them are unaware of these programs' existence. The public needs to be made aware of the benefits of composting, even though many of these benefits may be more for the long term. Encouraging the public to separate their green waste, combined with some sort of incentive program is always helpful in getting the cooperation needed for further success. The idea of private composting for use in home gardens and greenhouses should also be encouraged. With private composting, use of nitrogen-rich fertilizer is reduced, saving money as well as reducing greenhouse emissions.

Educating the public on the potential of composting facilities is very important for future success. This factor is especially important as community boards have assumed an increasing influence concerning the development of industrial facilities. There have been examples of community boards blocking the construction of waste management and composting operations. In one recent case, an attempt by the state to create a large-scale dairy operation with a sophisticated wastewater facility was canceled due to opposition by the community and their legislators (Yamamoto, 1997). Numerous complaints have also been voiced regarding the Unisyn operation in Waimanalo (*Honolulu Star-Bulletin*, January 14, 1997, A3).

The public must begin to realize that a well-managed composting facility can have many benefits (as described in previous sections) and should not be considered a blemish to the local community. County governments can provide financial incentives to companies and individuals to increase composting rates, as well as provide relevant information.

12.5.1.3 Promote mulching

Mulch consists of an organic and/or inorganic material that is spread over soil to reduce erosion, weeds, and evaporation. As such, mulch can reduce the need for fertilizers, herbicides, and water. Indeed, mulch generally retains more moisture near the soil surface than does traditional compost. This reduces volatilization from both soil and fertilizers (Barden et al. 1987, 198-199).

One negative aspect of mulching is its relatively high cost, including both labor and the mulch itself, relegating its application to high-valued garden plants and crops. In Hawaii, these high-valued crops include snap beans, Maui onions, green onions, and red bell peppers, the prices of which currently range from $1.69 to $4.99 per pound in the supermarket (Hawaii Agricultural Statistics Service 1991, 24, 47 and 57-59; Manoa Safeway Produce Department, 1997).

In addition, one study found that the absence or presence of thatch (mulch consisting only of grass) dramatically affects volatilization of ammonia and N_2O. Eight days after application of urea to a plot of Kentucky bluegrass containing a 2-inch layer of thatch, nitrogen volatilization was measured to be 39%, compared to only 5% in a plot with no thatch (Spectrum Research 1990, 131). Thus, mulch and fertilizer applications should be staggered carefully in order to minimize nitrogen emissions.

One type of mulch in Hawaii is simply a polyethylene plastic sheet spread over the soil, in particular over pineapple fields. Seeds or pineapple tops are planted in perforations in the plastic. The perforations also allow rainfall and irrigation water to reach the ground in amounts necessary for the crops' survival. In the end, there is almost complete elimination of evaporative loss of water, and applications of fertilizer and irrigation water can be reduced. The primary drawbacks are the cost of the plastic and the litter it produces. Plastic also emits hydrocarbon pollutants as it degrades.

In contrast, organic mulch is generally cheaper and lends itself more to net carbon uptake than to net emissions. Additional benefits of mulching include:

- Reduced weed growth;
- Cooled ground surface, which helps seeds germinate;
- Increased water infiltration and retention; and
- Reduced erosion.

Educating farmers on the positive environmental effects from the use of mulch can be aided by demonstrations of its application to various crops.

12.5.1.4 Help expand the market for composted manure as fertilizer

This recommendation was made in the Livestock and Manure Management section above. Composted manure can be an excellent substitute and/or supplement for chemical fertilizers, as previously described -- in part since compost tends to involve fewer greenhouse gas emissions during its preparation. In addition, the nutrients in compost are released slowly to the roots of plants through microbial activity over an extended period of time, thereby reducing the potential for nutrients to leach from the soil. Unfortunately, an important drawback is the tendency for N_2O emissions generally to be higher per pound from organic fertilizers produced from farm animal or human excreta than from mineral fertilizers (EIA 1995, 89).

As a result, a combination of organic soil amendments and petroleum-based fertilizers may offer the best means for producing high-quality crops. The organic component provides good overall soil structure and the fertilizer supplies the nutrients necessary for desired growth (USEPA 1994a, 88). However, the proper proportions of this mixture depend on the concentration at which the positive aspects of the compost are maximized, a proportion which varies from place-to-place and season-to-season, complicating attempts to support or legislate the use of compost as a soil amendment. As a result, the various government agencies involved could simply provide as much support as possible to the market mechanisms seeking to find this balance. On the other hand, one active approach, which the state can take, is the taxing of all imported fertilizer to encourage use of locally produced compost and mulch (Zaleski 1997).

12.5.1.5 Help expand production and marketing of anaerobically digested biosolids (sewage sludge) as fertilizer

Biosolids from animal and human waste streams that have been treated anaerobically can also be applied as fertilizer to crops and pastures. Indeed, the most common use of anaerobically digested biosolids in the world has been, and remains, as fertilizer for farm crops (Hobson and Wheatley 1993, 238). Digesters not only leave a sludge residue that retains high levels of nutrients, but they provide energy-generating methane as well as discussed in (See Chapter 11). Digested cattle biosolids, when used in mushroom compost, have even been found to cause better and quicker mushroom growth than conventional compost (238). Furthermore, as noted earlier, diversion of biosolids from landfills preserves those landfills' methane collection systems from hydrogen sulfide fumes emitted by biosolids (Baker, 1997).

The economics of composting operations vary widely, however, according to their location, size, price of their compost, and the number of factors figured into the analysis. The City of Los Angeles uses the windrow method of composting. Los Angeles and reported costs of only $5 per wet ton in the summer months in the early 1980s; at the time, Los Angeles was composting up to 23% of its total sewage solids (Goldstein 1984, 19). Similarly, on the mainland, composting of feedlot manure was estimated in the early 1980s to cost an average of $10 to $13 per ton of compost if the compost company worked independently, and only $7.50 to $10.50 per ton if it became partners with one or more feedlots. A net profit was generated in either case, since at the time compost was selling for $22.50 to $30 per ton, spread (40). The price of compost remains in this range in Hawaii today, while the cost of composting would be undoubtedly higher than it was in the Los Angeles analysis. This has the effect of decreasing the benefit/cost ratio in Hawaii and increasing the payback period. Fortunately, the payback periods for composting facilities measured in other studies have been quite rapid, suggesting that such operations are likely to be profitable in Hawaii as well.

On the other hand, composting operations in some areas have shown significantly higher costs than those in the Los Angeles study, where the market for the compost is limited. In general, composting operations tend to have high rates of return, especially the windrow method, which generally costs only about 2/3 as much per ton as does the aerated pile method.

Collateral benefits of land application (and composting) of anaerobically digested sludge include:

- Compost is essentially free of pathogens and weed seeds;

- Odor of manure is reduced via the composting process;
- Compost is often cheaper than chemical fertilizers;
- Compost avoids emissions caused by the manufacturing of chemical fertilizers;
- Methane collection systems at landfills are spared the corrosive effects of hydrogen sulfide gas which landfilled sludge emits;
- Liquid effluent from digesters can also provide nutrient-rich irrigation for non-vegetable crops;
- Such fertilizers can be relatively slow-release, since digester bacteria leave behind the poorly degradable constituents in the waste. This release can be delayed further by (1) tertiary treatment of sludge, or (2) via a process wherein it is combined with urea, lime and formaldehyde at pH 4, then mixed with peat moss;
- Reduces input to landfills. (Can also be a negative aspect; see below); and
- Allows feedlot owners to clean pens more routinely, thus improving cattle performance. (Goldstein 1984, 40; Hobson and Wheatley 1993, 228-234; Baker 1997)

One possible drawback is the common practice of adding copper sulfate to pig feeds to improve animal performance. This copper, usually added to pig feed in concentrations of about 0.17 tons per cubic yard, becomes concentrated to as much as 0.72 tons per cubic yard in the dry digested solids. Fortunately, the copper tends to remain as insoluble copper sulfate and is generally not taken up by plants or livestock if they are not turned out on fields immediately after sludge is spread. Millions of tons of sludge containing copper sulfate have been applied to crops and pastures in Great Britain without ill effect (Hobson and Wheatley 1993, 233).

12.5.2 RECOMMENDATION: Improve Efficiency of Fertilizer Use (low to moderate cost, moderate benefit)

Recommendations for ways to improve the efficiency of fertilizer use include the following:

12.5.2.1 Improved Fertilizer Management Approaches (Based on USEPA 1995a, 5-54)

Promote improved fertilizer application rates and timing. Matching fertilizer application with specific crop requirements would reduce excess fertilization. Typical fertilizer application rates vary depending upon crop type, soil conditions, fertilizer pricing, and environmental policies (Spectrum Research 1990, 65). Precipitation and irrigation are also very important determining factors in the amount of volatilization that occurs after application. For example, one study has determined that irrigating shortly after fertilizer application can reduce volatilization from 36% to less than 8% (118).

Promote improved frequency of soil testing. Regular soil testing could decrease fertilizer use.

Promote improved placement of fertilizer. Spreading fertilizer onto the surface of bare soil is actually the worst possible application method. Application either onto the plants themselves or a few inches below the soil surface can both curb nitrogen volatilization and improve plant uptake.

Promote reduced crop rotations. Rotating crops increases CO_2 and N_2O fluxes to the atmosphere through physical disturbance to soils (Li and Cialella 1992, 3).

12.5.2.2 Improved Fertilizer Technology Approaches (Based on USEPA 1995a, 5-54)

Encourage reduced use of fertilizers containing anhydrous ammonia. N_2O is produced when fertilizer nitrogen is volatilized to the atmosphere. Studies suggest that fertilizers containing nitrogen in the form of anhydrous ammonia tend to have higher N_2O emissions than other nitrogenous fertilizers. In the U.S., anhydrous ammonia accounts for about 38% of nitrogenous fertilizer use, compared to 21% for ammonium nitrate and 11% for urea (OTA 1991, 257). Use of anhydrous ammonia in Hawaii may be less, but no specific figures are available at this time.

Encourage increased use of fertilizers with slow-release coatings. The determinants of nitrogen volatilization are considered to be fertilizer type, application rate, and application method. For example, granular fertilizers tend to volatilize less than do liquid fertilizers. Release rates of granular fertilizers can then be further reduced via coatings such as sulfur or plastic, which degrade over time. These improve efficiency by releasing nitrogen at rates that approximate crop uptake. This reduces the amount of excess nitrogen that can be volatilized at any given time. Under certain conditions, application of slow-release fertilizer in the U.S. can double fertilizer efficiency, although whether overall N_2O emissions are simultaneously reduced is unclear (257).

One plastic coating, isobutylene, is actually a side product of the film industry which would otherwise be added to the waste stream (Spectrum Research 1990, 118). Another advantage of isobutylene is that it is released by contact with water, which causes it to release its fertilizers only during irrigation or rainfall. The tradeoff is that isobutylene-coated fertilizers tend to be more expensive then other slow-release fertilizers, and slow-release fertilizers in turn tend to be more expensive than regular fertilizers. As a result, their use in Hawaii is mainly relegated to golf courses, ornamental plants and high-income crops. Plastic and sulfur may also be considered pollutants under certain conditions (Klawitter 1997).

Another type of slow-release fertilizer is sulfur-coated urea (KNO_3), which is often preferred in wetter areas (Spectrum Research 1990, 118). KNO_3 is a key ingredient of yet another class of slow-release fertilizers that tend to work better in drier areas (117). All of these fertilizers have properties that recommend them for further study regarding their applicability to agricultural and recreational uses in Hawaii.

Promote increased application of nitrification inhibitors to fertilizer. A wide range of additives curtail nitrification processes in the soil around applied fertilizers, in some cases increasing the efficiency of nitrogen uptake by plants by some 30% (OTA, 1991, 257).

Promote increased application of hormones to grasses of recreational areas such as golf courses and sports fields. Certain hormones can also be added to fertilizers to stimulate growth, mainly of turf grass. As a result, the grass becomes more resistant to the stress placed on it by recreational activities. The savings in fertilizer use have made these biostimulant fertilizers economically viable in many areas of the developed world, even for short-term consumers. Grasses also become more resistant to diseases (Schmidt 1990, 1-4).

Promote planting of grasses and crops that require less fertilization. On golf courses, turf grass is the predominant grass due to its aesthetics, reliability and resilience. Alternatives do exist, however. One alternative to turf grass could be the use of zoysia grass. Compared to typical turf grass, zoysia grass is drought-resistant, salt-tolerant and requires significantly less fertilizer. It lacks some of the aesthetics of turf grass due largely to its coarser texture, but when planted in the roughs alongside fairways, zoysia grass would help the industry to further reduce its greenhouse gas emissions (1-3.). Rye grass and fescue also tend to have fewer fertilizer and pesticide needs than do the bluegrasses (Klein 1990, 28).

Various options discussed in this section can be combined into a system of “cultural practices” which maximize the efficiency of applied fertilizer. The Hapuna Golf course on the Big Island is one example of a golf course that incorporates such cultural practices. First of all, the superintendent fertilizes only about once every three months, at which time approximately half a pound of slow-release fertilizer is applied every 1,000 square feet. Quick-release fertilizers are used only for greens. The course superintendent plans to further reduce this application amount to about 1/3 of a pound in the future, by adding a variety of bacteria to the fertilizer (Nakagawa 1997).

As can be seen, most, if not all, golf courses incorporate a mixture of slow-release and quick-release fertilizers. Pending further study, it may be possible to recommend that a minimum of 50% of the fertilizers used on golf courses in

Hawaii should be slow-release varieties (Klawitter 1997). Superintendents can also be educated on the effects of excess nitrogen-rich fertilizers and volatilization. In some states, the superintendents are required to get training and certification acknowledging that they understand the effects of overfertilization and methods to mitigate this practice. Such a requirement would likely provide much of the incentive necessary for improved maintenance practices at Hawaii's golf courses.

The fertilizers and additives discussed here do not exhaust the range of existing varieties, but should be sufficient to demonstrate the merits of further study and experimentation with these in Hawaii. Golf courses are an important component of the state's economic health, and can serve as attractive showcases for careful management of resources and minimized emissions. Incorporating any of the fertilizers or amendments suggested above could thus have positive repercussions beyond the reduction of nitrogen volatilization alone.

12.5.3 RECOMMENDATION: Promote Planting of Cover Crops Which Capture Nitrogen (low to moderate cost, low to moderate benefit)

Nitrogen-fixing crops can substantially augment nitrogen inputs into agricultural systems via absorption into soil. Nitrogen fixation can decrease emissions not only of N_2O, but CO_2 and CH_4 as well (Johnson and Henderson 1995, 138), and can also benefit overall crop production.

12.5.4 RECOMMENDATION: Promote Improved Soil Management (low to moderate cost, low benefit)

It should be noted that the following discussion is also applicable to parts of the land use management and manure management sections. Soils are significant reservoirs of carbon, and various conservation practices can be employed to reduce their greenhouse gas emissions. Nitrogen is particularly critical because it is both required by plants in relatively large amounts and subject to loss via leaching, volatilization, and denitrification. A sustainable farm relies principally upon organic nitrogen sources, especially legumes and animal manure. Synthetic, soluble nitrogen sources should be discouraged, where possible, since they require non-renewable petrochemicals in their manufacture and may have negative effects on soil physical and biological properties (Andrews 1990, 283-284).

Central Oahu has a potential problem regarding legumes, however. Soybeans and most other legumes are not very acid-tolerant, and farmers in this area are currently increasing their applications of lime and other alkali sources to raise the pH of Hawaii's naturally acidic soils. Unfortunately, it was recently discovered that a large lens of nitrate currently resides in the upper 35-40 feet below the surface in this area, a lens which would be liberated to enter the island's main aquifer if the soil's pH rises above a certain level. Although some deep-rooted legume crops such as the calliandra tree can extract nitrate from this depth, most legumes are shallow-rooted and their cultivation could actually worsen Oahu's nitrogen problems rather than improve them. Crops extracting nitrogen from the soil also forego the more difficult process of fixing nitrogen from the air, so their net benefit in terms of greenhouse gas emissions is negated (Uehara 1997). This dilemma deserves much greater scrutiny than it has received to date.

The following management practices promote soil carbon retention as suggested by Dixon 1993, 563:

- Promote and undertake afforestation and removal of marginal lands from agricultural production (see section on Land Use Management below).
- Promote reduction of crop tillage intensity.
- Reducing the amount of tilling in fields can result in increased retention of soil and organic carbon, and thus reduced CO_2 and possibly N_2O emissions.

The degree to which the change in tillage intensity affects carbon sequestration depends on crop type; but according to modeling results, the effect of such changes on CO_2 emissions is much greater than on N_2O emissions (Li and Cialella 1992, 1-3). The tradeoff is that these tillage practices tend to improve the habitat for crop pests, increasing the need to apply pesticides (OTA 1991, 253). Such practices may also reduce the uptake of nitrogen by crops, increasing the need for fertilizers, and thus negating any reduced N_2O emissions (Li 1995, 105-106). Currently, about 27% of cultivated land in the U.S. employs reduced tillage methods, and 10% to 14% of the total acreage of corn, soybeans and wheat in the country were managed with no tillage at all in 1992 (Hedger 1996, 28).

12.5.5 RECOMMENDATION: Consider Indirect Approaches (low cost, indeterminate benefit)

In addition to the actions outlined above, the following measures would provide more indirect encouragement to reduced emissions from agriculture in general and fertilizer use in particular:

12.5.5.1 Keep and compile better records of agriculture practices

The types of crops, area under cultivation and yields of each, amounts of fertilizer and burning employed, and related data are necessary for better planning and modeling. The Department of Agriculture is not yet empowered to collect such information (State of Hawaii 1992b, 102).

Modify land tenure to allow longer-term leases, thus giving better encouragement to farmers to spend money on long-term conservation and emissions reduction practices (IPCC 1991, 191; Zaleski 1997).

12.5.5.2 Develop a policy to manage and possibly regulate fertilizer use statewide

At least as recently as 1992, the state has not managed or regulated the use of fertilizers in any way. The DOH has, however, included mitigation of potential fertilizer impacts on drinking water resources among its twelve conditions for golf course development. Developers and owners must monitor runoff and groundwater for fertilizer contamination, waterproof buildings where fertilizers are stored and surround them with protective berms, implement “best management practices” for application and monitoring of fertilizers, and irrigate using reclaimed water where possible (State of Hawaii 1992b, 22 and D-1 to D-3).

Few states have authored legislation addressing fertilizer use in recent years. One exception is Minnesota, which established a Nitrogen Fertilizer Task Force to study the effects of nitrogen fertilizer use on water resources in order to help the state develop best management practices, a fertilizer management plan, and nitrogen fertilizer use regulations (OTA 1991, 330). There is clearly room for improvement in this regard in Hawaii, not for golf courses alone but for all large-scale fertilizer users in the state.

12.5.6 RECOMMENDATION: Consider Measures Involving Crop Burning and Bioenergy Crops

Emissions from burning of crop residues have been decreasing both nationwide and in Hawaii over the last decade (EIA, 1995, 42). Since the carbon content of crop residue varies from 40 to 50% of dry matter, burning of these residues emits carbon into the air. Most of this carbon is in the form of carbon dioxide, but varying levels of CO and methane are also produced. A certain amount of N_2O is produced as well. In some states today, such burning is now banned by law (EIA 1995, 43).

In Hawaii, about 35% of sugarcane residue (“crop waste”) has traditionally been burned directly in the fields, with the remainder (“bagasse”) going to generate power for sugar mills and to sell power to the county utilities. This should be encouraged since it avoids burning imported oil and emitting associated greenhouse gases. Both sugarcane and pineapple production have dropped precipitously from their levels of just five years ago. What bagasse is not collected and burned in the mills is often mulched to serve as fertilizer for the next crop (Whalen 1997). Since some crop waste is still burned on the fields, however, the decline of this industry has reduced greenhouse gas emissions from agricultural fields, since other crop residues are generally not burned to the same extent as sugarcane and pineapple residues. However, this also has negative impacts on the sugar and pineapple workers and the mills that were designed to burn bagasse. Since 1992, almost half of the state’s biomass energy conversion facilities have closed down. Some of these mills could perhaps be revived by using different biomass sources or a different cultivar of sugarcane (local agronomists are currently experimenting with a variety of cane which can be harvested in 14-16 months rather than every two years), but at present the selection is rather limited (Whalen 1997).

A 1995 study concluded that the biomass alternatives to sugarcane which offer the most potential to Hawaii were *Eucalyptus* and *Leucaena* trees and napiergrass (*Pennisetum purpureum*). Eucalyptus is particularly promising since eucalyptus plantations covered 85,000 acres in Hawaii in 1993. On the other hand, sugarcane can also be fermented to produce such liquid fuels as ethanol, a benefit not offered by most other biomass sources (PBQD 1995, 7-5).

The Waialua Sugar Mill on Oahu, which began burning wood chips and waste car oil to produce 8 net MW of power in 1997(*Honolulu Advertiser*, March 11, 1997, B3), has considered using napiergrass grown nearby as a fuel source, but even this is considered feasible only with a government subsidy. The Mill operators announced the shutdown of the Waialua Mill as of July 31, 1998, due to lack of profitability.

The cost of producing biomass for fuel varies considerably from place to place, with most estimates for Hawaii ranging from $30 to nearly $100 per dry ton. An estimate of benefits and costs associated with cultivation of various bioenergy crops in Hawaii is shown in Table 12.11.

Table 12.11 Estimated Cost and Benefits for Commercial Biomass Crops

Crop (Rotation)	Commercial Yield (Tons/net acre/yr)	Production Cost ($/net acre/yr)	Value of Replacing #2 Oil at $32/bbl ($)
Unirrigated			
Sugarcane (2 year)	12	1,075	768
Napiergrass (4 year)	9 to 15	800	576 to 960
Eucalyptus urrophyla (5 year)	6 to 10	633 to 679	384 to 640
Irrigated			
Sugarcane (2 year)	16	1,190	1,024
Leucaena K636 (5 year)	10	1,028	640
Napiergrass (4 year)	20	1,059 to 1305	1,280
Sweet sorghum (2-4 year)	17 to 21	1,333	1,088 to 1,333
Eucalyptus (5-7 year)	10 to 12	1,400	640 to 768

Note: One ton of biomass is considered equivalent to two barrels (bbl) of oil.

Sources: Osgood and Dudley 1993, 38; PBQD 1995, 7-18; Egged, 1995

As can be seen in this table, on a per-acre basis, none of these crops appear to be cost-effective at this time. The crops most closely approaching profitability in Hawaii are probably napier grass, sweet sorghum, unirrigated eucalyptus and irrigated sugarcane, and research into more productive cultivars is ongoing (Osgood and Dudley 1993, 5; PBQD 1995, 7-19).

With the preceding in mind, the following measures can be recommended for reducing emissions from crop burning:

12.5.6.1 Encourage Planting of Crops which do not Require Burning as do Sugarcane and Pineapple (low cost, moderate to high benefit)

12.5.6.2 Promote Biomass-to-Energy Plants, Especially Those Using Crops Grown Expressly for that Purpose (high cost, high benefit)

If experimental plantations are initiated, they should be located as close as possible to bioconversion plants in order to reduce both costs and emissions resulting from transportation.

12.5.6.3 Study and Promote Bioenergy Plantations (low to moderate cost, moderate benefit)

Encourage planting of sugarcane cultivars, napiergrass, and other fast-growing biomass crops.

Encourage agronomic practices which maximize biomass available for energy production.

12.5.6.4 Study and Promote Plowing Under Crop Waste Instead of Burning (low cost, low to moderate benefit)

CHAPTER 13 FORESTRY

13.1 Overview

This chapter will examine the contribution of forestry in Hawaii in taking up greenhouse gas emissions from the atmosphere, reducing effects on climate change. Michael Buck, Administrator, Division of Forestry and Wildlife, State of Hawaii Department of Land and Natural Resources prepared this chapter.

13.2 Forests and Greenhouse Gas Reduction

13.2.1 U.S. Forests and Global Climate Change

A low-cost way to reduce levels of CO_2 in the atmosphere is by planting or preserving trees, which absorb the gas through their normal growth process. Major studies conducted by scientific, technical and conservation organizations support forestry activities as an important strategy for greenhouse gas reduction and climate change mitigation. Trees are an important route for CO_2 to move from atmospheric gas to solid form (usually expressed as carbon (C) equivalent). This carbon is sequestered, primarily in the new wood and increased soil organic matter that accompany forest growth. Wood is about 50% carbon, and a net increase of one cubic foot of merchantable wood (a common measure of forest growth) in a forest represents a total increase (all wood, soil carbon, etc.) of about 35 pounds of carbon storage. (See Table 13.1)

Table 13.1 Expected Net Annual Change in Growing Stock Volume and Forest Carbon Storage for Selected U.S. Forest Types Planted on Converted Cropland

Region/Forest Type	Cutting Period (Years)	Growing Stock Volume (Ft^3/acre year)	Carbon (lb. acre year)
Southeast			
Planted pine	30	93.5	3757
Oak-hickory	40	53.5	3247
Northeast			
White/red pine	65	34.8	2854
Spruce-fir	80	27.4	2460
North Central			
White/red pine	80	85	4344
Spruce-fir	80	20.6	1979
Pacific Coast			
Douglas-fir	80	215.2	6657
Ponderosa pine	100	46.1	2074

Source: Birdsey (Undated)

Table 13.1 depicts the expected net annual change in growing stock volume and forest carbon storage of selected U.S. forest types for forests planted on converted cropland. The table is provided as an indication of the potential for forestry in the continental United States.

At the recent Kyoto Climate Change Conference, New Zealand said that its growing forest industry is expected to absorb 87% of its country's carbon emissions. Carbon offsets are not a substitute for direct emission reductions, but they offer comparable environmental benefits, usually at less cost. In this manner, the protection of existing and creation of new forests can create CO_2 offsets, which could be offered to buyers that want to buy carbon credits to offset their CO_2 emissions.

Forests can be used to affect global CO_2 balances in at least five ways. These include:

1. Expanding forest area or the rate of net forest growth by planting marginal crop and pastureland to trees, improving growth rates of existing forests, or reducing wildfire size and intensity.
2. Growing short-rotation woody crops for energy supply.
3. Increasing tree cover in urban areas (this also contributes to energy conservation).
4. Planting trees in shelterbelts, etc.
5. Increasing wood substitution and recycling.

13.2.2 Hawaii and Carbon Offset Forestry Projects

The State of Hawaii has a unique combination of attributes that make it an ideal place to establish carbon offset forestry (COF) projects. These attributes include:

1. Thousands of acres of vacant sugar land and underutilized pasture lands;
2. Tropical growth rates which can result in large amounts of carbon sequestered in a short time period;
3. A developing forest industry supported by private sector investors; and
4. The political stability of being a state of the United States to assure long-term project success.

Carbon offsets through forestry have the potential to play a significant role in ameliorating global environmental problems as well as helping Hawaii's economy. Sustainable forestry has social and economic side effects that are mostly beneficial, ranging from maintenance of biodiversity and endangered habitats to providing sources of sustainable harvested forest products and quality employment for forest communities.

13.3 What Happens to Carbon in a Forest?

There are two principal phases to the plant energy production/consumption cycle. During the photosynthesis phase, plants use sunlight to convert water and CO_2 into energy containing organic compounds. During the second or dark phase, plants consume the energy stored in these compounds and respire CO_2. The balance favors the net accumulation of carbon in trees, shrubs, herbs, and roots. The rate of carbon storage in an ecosystem is known as net productivity. Young, vigorous forest stands tend to exhibit the greatest growth rates. However, total carbon stored at any time is greatest in older, mature forests, even though they have a net growth rate near zero. Much of the carbon in older forests is hidden -- as much as 60 percent of the carbon in forests is stored below ground in organic matter (including roots) and organisms in the soil.

The effect of cutting forests on atmospheric CO_2 depends on how much carbon was stored in the forest, what happens to the cut wood, and how the lands are managed. Cut wood left on site decomposes. Microorganisms (e.g., fungi, and bacteria) consume it, along with leaf and branch litter. Through their metabolic activities, microorganisms convert carbon in the wood to CO_2. Decomposition rates depend on factors such as oxygen availability, temperature, and moisture. Burning wood directly emits CO_2. In some cases, though, wood fuel can replace traditional fossil fuels; over one-half of the wood removed from U.S. forests in the early 1980's was burned for energy. The net effect on CO_2 depends on combustion efficiency, the relative CO_2 emissions of fossil fuel replaced, and carbon storage rates of vegetation that replaces the trees.

Finished wood products store carbon until they decompose. Durable products such as construction lumber retain carbon for decades or even centuries; about one-fourth of stem wood harvested during the last 35 years has been converted to such products. Short-lived products such as paper may decompose and release CO_2 or methane quickly after being discarded. Carbon release rates depend on the conditions at the discarded site. Methods for reduction of emissions from paper and other municipal solid waste constituents were discussed in Chapter 11.

After harvesting, CO_2 is again taken in by new vegetation growing on the site, assuming the land is not converted to a non-vegetative state. The net offset in CO_2 emissions from the harvesting depends on the type of vegetation (e.g., crops, pasture, or trees), the rate at which it and the soil stores carbon, the availability of nutrients, and how long the vegetation grows before being harvested again. If the time scale is long enough, the land is used for a series of harvests, and the harvested wood is converted into durable products or displaces fossil fuels, then forests can be a net sink for carbon.

13.4 Hawaii's Forests

The State of Hawaii encompasses just over 4,109,000 land acres. Before the arrival of the first Polynesian travelers, forests probably covered approximately 80% of the islands. By the time of Captain James Cook's arrival in the Hawaiian islands in 1778, the original forests, especially in the lowlands, had been greatly altered by over 1,000 years of intensive agriculture and certain introduced plants and animals brought by the Hawaiians. With European contact, these impacts and changes accelerated dramatically and spread into the mountain forests with new agricultural and forest uses, increased population pressures, and the introduction of more damaging plants and animals that multiplied unchecked throughout the forests.

Water has long been recognized as the most important resource of Hawaii's forest lands, as mountain watersheds are the primary source of water for the islands' urban, industrial, and agricultural areas. In 1892, a Bureau of Agriculture and Forestry was established. The Legislature of Hawaii, with the support of the Hawaiian Sugar Planters' Association, passed a bill in 1903 calling for a Division of Forestry, which had the authority to establish forest reserves for the protection of springs, streams, and other water supply sources.

The first decade (1904-13) saw the establishment of thirty-seven forest reserves totaling nearly 800,000 acres of state and private land. A primary management goal was the exclusion of livestock from the native forests. The program was expanded in 1907 by a hunting license program to enlist the help of the general public. Along with the fencing and programs aimed at the elimination of feral livestock came tree planting and fire control programs. Reforestation began before 1900 in the valleys behind Honolulu and reached a peak during 1935-41, when an average of nearly two million introduced trees were planted annually in the forest reserves.

By the advent of World War II, the forest reserve system included 25 percent (1.2 million acres) of the land area of Hawaii. Most severely eroding areas had been reforested, and feral livestock numbers were at manageable levels. Water was still the most important product of the forest reserves, but their potential to provide other benefits became recognized. Mechanization of agriculture had led to labor surpluses on the neighbor islands, the need for a more diversified industrial base, and increased rural employment opportunities. The rapidly growing local demand for lumber led to the possibilities of a small forest products industry.

The 1960s saw a renewed tree-planting program, with over seven million seedlings planted during the decade. In 1961, a greenbelt law established two new land use categories; "urban" and "agricultural", and included the forest reserves, along with other lands, in "conservation districts". This act reflected a growing awareness that the limited resources of Hawaii must be used in environmentally sound ways. The laws did not change prior legislation but extended the powers of the state to influence the manner in which both public and private lands within the conservation districts are used.

Today, Hawaii has the eleventh largest state-owned forest and natural area reserve system (700,000 acres) in the United States. A similar acreage of forestland in private ownership and an additional 200,000 acres within federal jurisdiction (national parks, national wildlife refuges, and military training areas) augment the state holdings. The forest reserves and much of the watershed within the conservation districts are in good hydrologic condition. Hawaii's long-standing policy of watershed protection has resulted in dramatic improvements from the degraded conditions that prevailed at the turn of the century. Management activities, such as protective zoning, fencing, removal or control of feral animals, reforestation, and fire protection have reduced excessive erosion and loss of vegetative cover.

In spite of these achievements, much work is still needed. The challenge of saving Hawaii's unique native resources, endangered by the invasion of alien species, is enormous. The increased demand for forest recreation, conflicting user groups, local community and native Hawaiian cultural concerns have resulted in emotional, and at times divisive, debates over forest land use practices. Wild cattle still roam portions of Forest Reserves on the island of Hawaii. Goats and deer are devastating portions of remote forests on the islands of Maui and Molokai. The costs of managing watersheds are not considered in the sale or use of the water resource. Population growth resulting in increased residential development and improved access to wild lands has increased the potential for wildfire, placing public safety and resources at risk.

13.5 Hawaii's Developing Forestry Sector

13.5.1 The Goal of Hawaii's Forestry Programs

Commercial forests that are environmentally sustainable and economically profitable for the potential investor, small and large landowners, the people of Hawaii, and fit within a landscape of healthy watersheds and native ecosystems.

13.5.2 The Opportunity

Ironically, it is out of unprecedented rapid decline of the sugar industry in Hawaii, that a unique opportunity in the form of available high quality agricultural lands, provides the opportunity to develop a sustainable forest industry, one that is largely financed by private investment, and strategically augmented by public assets. Hawaii's major advantages for forest investment are its political stability, ideal growing conditions, skilled workers with relatively easy transition of skills and machinery from the sugar industry, infrastructure (roads, ports, excellent telecommunications), research and development institutions, and attractive living conditions.

The state currently imports almost all of its wood, so there is ready demand for local wood products. Hawaii's location will also allow a forest product industry to market throughout the Pacific Rim area. The supply of hardwood timber in this region has decreased sharply over the last five years and is predicted to drop even further. Wood products are already being shipped to these countries from South America and Canada. Hawaii could gain a position of some importance in the international forest product trade. Some countries in the Pacific region have already created such a position from relatively small land bases, e.g. New Zealand and Fiji. There are also countries that have liquidated major forest resources and are now importing wood products; e.g., Malaysia and the Philippines.

13.5.3 Land for Forestry in Hawaii

The Islands of Hawaii and Kauai offer the greatest opportunities for an expanded forest industry at this time as there are an estimated 120,000 acres of available land, formerly in sugar cane, that is ideally suited for forest planting. There are an additional 200,000 acres of pasture and brush land on prime forest sites on the Island of Hawaii. Approximately three-quarters of this acreage are privately owned.

Forestry is an extensive land use that is ideal for the large acreage coming out of sugar and pasture production. It should not compete with other forms of higher value agriculture. Quality agricultural accessible to existing irrigation systems should be reserved for other diversified agricultural crops (e.g., taro, ginger, nurseries, and aquaculture).

There are four potential commercial forest management scenarios to consider in Hawaii:

1. Short rotation (6-12 years) forest plantations;
2. Longer rotation (15-40 years) forest plantations;
3. Afforestation of mountain pasture lands and enhancement of degraded native forests; and
4. Agroforestry.

The majority of forestry land use under scenarios 1 and 2 would occur on former sugar lands or existing forest plantations in lower elevations. Under scenario 3, the majority of the forestry land use would be in higher elevation pasture lands on former forest sites and should emphasize native koa (Acacia koa), which is both commercially and ecologically valuable. Existing legislation prohibits the clearing of native forests for introduced plantations. In scenario 4, agroforestry could occur on all elevations in conjunction with farming and pasture use.

13.5.4 Hawaii's Forest Industry

In 1991, the forest industry in Hawaii contributed 26 million dollars and 736 jobs to Hawaii's economy. Its payroll exceeded 21 million dollars and the average salary was over $14/hour. Over 90% of the forest industry is dependent on the sale and value-added processing of Hawaii's premier tree species, koa.

The economics of plantation forestry gained credibility in Hawaii as a result of the state's first major forest development project, a multi-million-dollar Eucalyptus plantation by the Prudential Timber company. This announcement accelerated interest from other companies who are currently negotiating for the next phase of forest development. Large blocks of public timber are being offered to the private sector with a focus on attracting high quality processing investments. Small landowner interest has also dramatically increased, assisted by cost sharing programs for reforestation.

Hawaii's future in the forest products industry will depend on maximizing local processing, not simply growing the trees. The State supports the development of an integrated forest industry linked to multiple processing options to provide suitable outlets for the range of species and grades of wood available from existing and future forests. Early commitment to the establishment of veneer and/or sawmill plants will provide immediate employment opportunities in construction. It will also encourage investors to become involved in plantation forestry at the onset, providing additional employment opportunities.

There has been increasing interest in sustainable forest management issues in Hawaii. The State of Hawaii, Hawaii Forest Industry Association, and the Nature Conservancy have received a grant from the MacArthur Foundation to explore how the use of forest certification can contribute to that goal over a range of existing and potential forested landscapes. State and Federal government agencies have formed the Hawaii Forestry and Communities Initiative, leveraging their limited budgets to build up needed forestry capacity through extension, training, and inventory projects.

In addition, growing concern about climate change and global warming due to anthropogenic greenhouse gas emissions has led to increased interest in ways to reduce or offset those emissions. Forestry in Hawaii offers some new opportunities for such offsets.

13.6 Forestry and Emissions Trading Under the Kyoto Protocol

As discussed in Chapter 5, in December 11, 1997, in Kyoto, Japan, over 150 nations adopted the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The Protocol committed nations, for the first time ever, to place legally binding limits on their emissions of greenhouse gases ("GHG"). A central feature of the Kyoto Protocol is a set of binding emissions targets for developed nations. The specific limits vary from country to country, though those for the key industrial powers of the European Union, Japan, and the United States are similar -- 8% below 1990 emissions levels for the EU, 7% for the U.S., 6% for Japan.

13.6.1 Emissions Trading Opportunities

The Kyoto Protocol establishes two innovative mechanisms for implementing emissions caps:

1. Trading of portions of nations' "assigned emissions amounts" (i.e., total GHG emissions limits) among nations that have adopted legally binding targets; and
2. Project-based emissions reduction credit trading, among nations that have adopted legally binding targets and also between such nations and those that have yet to adopt targets.

Both forms of trading -- trading of assigned emissions amounts, and project-based emissions reduction credit trading -- have the potential to tap the power inherent in a market system for spurring industrialized and developing nations to shift to greenhouse-friendly development. Importantly, the Protocol also opens the door to apply these incentive systems to the conservation, management, and regeneration of forests that sequester CO_2, the principal greenhouse gas. Whether nations will use these legal tools effectively to reduce greenhouse gas emissions and curb global warming, however, depends on the extent to which the tools gain international political acceptance and whether nations adopt implementation rules that enhance, rather than diminish, the usefulness of these instruments.

Additional steps will need to be completed before a global emissions trading system becomes fully effective. The Parties to the Framework Convention will meet in Buenos Aires, Argentina, in November 1998 to elaborate rules and guidelines for these several types of trading under the Protocol. The Buenos Aires rules may facilitate or hamper the operation of emissions trading, and consequently enhance or diminish the environmental and economic effectiveness of the Protocol. In addition, emissions trading is not well understood, and not well accepted, in a number of regions of the world, in particular in Europe. With increased international understanding of the principles and mechanisms by which trading can improve environmental performance, reduce costs and expand economic opportunity, however, these features of the Protocol will be welcomed more broadly in the international community.

The U.S. National Association of State Foresters supported many of the positions that the U.S. delegation took in regard to the potential of sustainable forest management to make meaningful contributions to the reduction of greenhouse gases. The Kyoto Protocol allows activities that absorb carbon, such as planting trees, to be counted as offsets against emissions targets. This treatment of these so-called "sinks" was a controversial issue at Kyoto and many countries wanted sinks to be excluded. The United States insisted that they be included in the interest of encouraging activities like afforestation and reforestation. Accounting for the role of forests is critical to a comprehensive and environmentally responsible approach to climate change. It also provides the private sector with low-cost opportunities to reduce emissions.

The United States prevailed in securing acceptance of emissions trading among nations with emissions targets. This free market approach, pioneered in the U.S., will allow countries to seek out the cheapest emissions reductions, substantially lowering costs for the U.S. and others. Under an ideal emissions trading regime, countries or companies can purchase less expensive emissions permits from countries that have more permits than they need (because they have met their targets with room to spare). If structured effectively, emissions trading can provide a powerful economic incentive to cut emissions while also allowing important flexibility for taking cost-effective actions. The United States reached a conceptual agreement with a number of countries, including Australia, Canada, Japan, New Zealand, Russia, and Ukraine, to pursue an umbrella group to trade emissions permits. Such a trading group could further contribute to cost-effective solutions to this problem.

13.6.2 Carbon Offset Forestry Projects

Carbon offset forestry (COF) projects have already been established and many more are being considered at this time. Although the protocol for carbon credits for such projects has not been finalized, many companies are already investing in projects. Many projects undertaken have had public relations as well as carbon sequestration benefits, but all have offered valuable experiences that will affect the future of other larger scale COF projects. There has already been a wide diversity of approaches, especially in regard to funding and monitoring.

Many COF projects have been designed for tropical forests in developing countries as a means to address global deforestation and biodiversity issues. While offering reduced cost in labor and land coupled with tropical growth rates, many of these countries present challenging institutional, socioeconomic, and monitoring challenges that must be considered and overcome.

Criteria to consider in designing a successful COF project include:

1. **Credibility.** Credibility of a project's ability to modify otherwise prevailing carbon flows over a given period (e.g., links between forestry projects and their impact on carbon flows is not always direct).

2. **Reliability.** Reliability should be based of global experience with similar projects and the expertise and capability of the project proponents, as well as the prevailing social, economic, and political context in the country where the project is implemented.

3. **Measurability.** Ability to measure and verify the claimed carbon sequestration credit as a result of the project's activities is crucial.

4. **Cost-effectiveness.** Cost-effectiveness compared to alternative mechanisms for controlling net CO_2 emissions is a major consideration of project investors.

5. **Opportunity.** Availability of window of opportunity situations (e.g., downsizing of the sugar industry in Hawaii) can play a role in early project design.

6. **Public benefits.** Additional benefits of the project (e.g., biodiversity, and economic development) are important to encourage innovative partnerships and attract a wider range of investors.

A sampling of COF projects around the world demonstrates the diversity of approaches that have already been considered:

AES Thames Guatemala Project. AES Thames, a subsidiary of AES Corporation, is investing to establish agroforest and woodlot systems in Guatemala to help offset CO_2 emissions from its coal-fired plants. In consultation with the World Resource Institute (WRI), AES developed a program linking greenhouse gas mitigation with the goal of sustainable economic development. Through a grant to CARE, an international relief and development organization, the AES Thames project is intended to assist 40,000 farmers in Guatemala to plant trees over a 10 year period.

AES Hawaii Paraguay Project. As discussed in Chapter 7, AES Hawaii, another subsidiary of AES Corporation, has committed monies to The Nature Conservancy (TNC) for land purchase and forest conservation. A TNC partner, the Mosies Bertoni Foundation, will invest the AES Hawaii contribution plus additional funds for 56,8000 hectares of endangered tropical forest in Paraguay formerly owned by the World Bank. A Paraguayan forest products company who defaulted on their lands and forfeited the land to the World Bank as payment formerly owned the land.

Dutch Electricity Generation Board FACE Project. The Dutch Electricity Generation Board established the FACE (Forest Absorbing CO_2 Emissions) Foundation in 1991, with the aim of offsetting CO_2 emissions equivalent to those from a large coal fired power station with a life span of 25 years. The FACE

Foundations has established a contract to conduct a pilot tree planting project on 2,000 hectares of degraded forest lands in Danum Valley, Sabah, Malaysia.

New England Electric System Malaysian Project. The New England Electric System (NEES) has agreed to assist a state-run forest products enterprise in Sabah, Malaysia (Innoprise) improve rain forest logging techniques to preserve terrestrial C, and, in turn, help offset CO_2 emissions from NEES power production facilities in the U.S.

Pacificorp Projects. Pacificorp has begun two pilot projects: (1) rural reforestation in Southern Oregon, USA, where Pacificorp is working with the Oregon Department of Forestry to assist nonindustrial landowners in planting trees on private lands currently covered with non-forest vegetation. Pacificorp provides 75 to 100% of site preparation and tree planting costs and landowners retain ownership of the forest; and (2) an urban forestry project in cooperation with TreeUtah around houses and multi-family dwellings to achieve maximum windbreak/shade effect. Windbreaks tend to reduce winter heating energy requirements, while shade reduces summer cooling requirements.

U.S. Initiative on Joint Implementation (USIJI). The USIJI recently approved a project to consolidate and legally protect national parks and biological reserves in Costa Rica. The project breaks significant new ground with its innovative financing approach, size of more than 500,000 hectares and national scale, and incorporating monitoring, verification, and guarantee provisions. Using an innovative market mechanism, the project intends to purchase threatened park lands from private owners and non-government organizations and transfer them to the Costa Rican Ministry of Environment and Energy (MINAE) for permanent protection. Tropical deforestation will be avoided and carbon sequestration from natural growth will increase in secondary forests and pasture lands converted to protected areas.

The project will generate funds to purchase these lands from the sale of "Certifiable Tradable Offsets" (CTOs) or 'carbon bonds.' Each CTO will represent third party certification of 1,000 tons of carbon sequestered by the project in the previous year. An experienced commodity trade-monitoring firm will conduct detailed monitoring and verification of the project's increased carbon sequestration, as well as the original baseline. The Costa Rican government will guarantee the CTOs for 20 years. World Bank funding will help support the monitoring and the insurance for the CTOs.

The project participants estimate that more than 15.6 million metric tons of carbon will be sequestered on 530,498 hectares over the 25-year project life. A surplus of 15% of the carbon sequestered would be maintained to guarantee the CTOs sold. Project Partners include the Florida based Earth Council Foundation-U.S., Costa Rican Ministry of Environment and Energy, Costa Rican National Parks Foundation, and Earth Council Foundation-Costa Rica.

CTOs will be issued annually based on carbon benefits accrued during the past year, in those areas for which all actions necessary to transfer ownership to MINAE or provide clear title have been completed and certified by the third party. The sale of CTOs will fund most of the titling and surveying work, and establishment of a trust fund to support protection activities. CTOs will also fund construction of a $20 million Earth Center, as a visionary ecotourism education and entertainment locus for visitors to the park system.

13.7 Carbon Sequestration Potentials of the Forest Sector in Hawaii

Hawaii has great potential for carbon sequestration in its forest sector. This can be achieved through protection of existing forest resources, active reforestation, restoration of koa forests, and reforesting idle cropland.

13.7.1 Protection of Existing Forests

The total potential of Hawaii's forested landscapes and wood-based products to sequester carbon (C) is closely related to the management of the forest resources, the production processes in forest industry, and the use of its products. One obvious CO_2 sequestration practice is to protect existing forests or "carbon sinks". A preliminary estimate, using a conservative value of 90 tons per acre in mature tropical/subtropical Lower Montane moist and wet forests, indicate that the 1.2 million acres of native and naturalized forests in Hawaii are storing approximately 108 million tons of carbon. Table 13.2 summarizes carbon sequestration in Hawaii's plantation forests.

Table 13.2 Carbon Sequestration in Hawaii's Plantation Forests

Species	Location	Age	Tons C per Acre	Tons C per Acre per Year
Eucalyptus spp.	Hamakua, Hawaii	5	27.2	5.4
Eucalyptus spp.	Hamakua, Hawaii	6	32.1	5.4
Eucalyptus spp.	Hamakua, Hawaii	7	38.3	5.5
Eucalyptus Saligna	Kamahina, Hawaii	7	135.9	19.4
Eucalyptus Saligna	Lupi, Maui	8	114.9	14.4
Eucalyptus Robusta	Waiakea, Hawaii	10	79.1	7.9
Eucalyptus Saligna	Wailua, Kauai	12	127.3	10.6
Eucalyptus Saligna	Kamahina, Hawaii	12	242.2	20.2
Eucalyptus Saligna	Lupi, Maui	13	159.4	12.3
Eucalyptus Saligna	Kamahina, Hawaii	18	362	20.1
Eucalyptus Saligna	Lupi, Maui	19	270.6	14.2
Eucalyptus Saligna	Kainehe, Hawaii	32	790.7	24.7
Eucalyptus Microcorys	Kalopa, Hawaii	33	411.4	12.5
Norfolk Isle Pine	Hamakua, Hawaii	38	583.2	15.3
Eucalyptus Microcorys	Kalopa, Hawaii	39	543.6	13.9
Grevilla Robusta and Tropical Ash	Kalopa, Hawaii	43	502.8	11.7
Eucalyptus Pilularis	Kalopa, Hawaii	45	887.1	19.7
Eucalyptus Microcorys	Kalopa, Hawaii	45	679.5	15.1

Threats such as wildfires, noxious weeds that threaten forest regeneration processes, feral animals that threaten forest integrity, insects and diseases, and unsustainable forest harvesting can reduce existing carbon sinks. Fortunately, management activities can be applied to retain carbon sinks or mitigate potential losses in all of these cases.

13.7.2 Reforestation

Another set of actions can be initiated to increase carbon sinks through active reforestation efforts. Increasing tree cover in urban areas can help reduce fossil fuel used for cooling while increasing carbon storage in the urban landscape. Hawaii's tropical climate is ideally suited for longer lived street tree plantings that could qualify for carbon sequestration projects.

13.7.3 Restoration of Hawaiian Koa Forests

Another window of opportunity for large-scale carbon sequestration is the restoration of Hawaiian koa forests. Koa is the premier Hawaiian timber for furniture, cabinetry, interior work, and woodcrafts. Equally important, native koa forest ecosystems provide significant wildlife habitat, watershed recharge areas, and recreational opportunities. Land clearing, poor harvesting practices, destruction by animals, insects, and fire have all taken a toll on Hawaii's koa forests. Koa forests have been reduced to approximately 25% of their original extent.

On the islands of Oahu, Kauai, and Molokai a little over 40,000 acres of koa dominated forests remain, much of it found on steep slopes in protected native forests. Non-native weeds and insects have degraded much of these forests. The larger koa forests on the Big Island of Hawaii have also suffered from unsustainable harvesting, land conversions to pasture, and insects and disease. Unfortunately, koa trees and forests are disappearing much faster than natural regeneration and current planting programs can replace them, resulting in continuing erosion of this valuable resource. Fragmented koa patches, degraded koa woodlands, and deforested pasturelands litter the landscape. There is a unified desire to have koa reestablished in portions of its historic range from all sectors of the community.

Studies indicate that there are over 600,000 acres of prime forestland on the Island of Hawaii. Of that acreage, over 80,000 acres is currently in pasture use, the majority on sites that formerly were koa forests. Assuming that these sites could sequester 100 tons/acre, there is the potential to sequester 8 million tons of carbon through an active koa restoration program. The benefits to the local forest industry and direct employment on the Big Island would be enormous. COF projects could provide the long-term forest investment partnerships needed to restore and enhance Hawaiian koa rainforests, providing habitat for some of the world's most threatened and unique biodiversity as well as helping create high value forest resources for Hawaii's developing forest industry.

13.7.4 Reforest Idle Cropland

Another obvious CO_2 sequestration practice is to plant idle cropland with trees. This is especially relevant for Hawaii as there are thousand of acres of vacant former sugar lands where managed plantation growth rates can exceed 500 tons per acre (See Table 13.2 for carbon sequestration rates for Hawaii's forest plantations). Many of these acres are already being planted for shorter rotation Eucalyptus which may not qualify for carbon offset projects, especially if the end product is wood chip export for paper. The economic challenge for forest plantations is that they often do not have positive cash flows for 5-10 years. The high cost of capital and delayed returns lead to favoring monocultures of high-yield species, short rotations, and minimal cost management policies, all of which can be environmentally problematic. By COF investment sharing the cost of the capital, longer rotations of high value mixed species plantations for Hawaii's forest industry could be established on former sugar lands.

For example, if 60,000 acres of shorter rotation forest plantations (6-12 years) could be extended to forty-year cycles, there is a potential net carbon gain of 300 tons per acre resulting in an overall 18 million tons of carbon sequestration.

13.8 Recommendations for Hawaii

Hawaii has a unique combination of attributes and a window of opportunity to establish carbon offset forestry (COF) projects. Successful COF projects can be designed in Hawaii that meet all identified international criteria. Hawaii's existing native and naturalized forests, which have been under active management since the turn of the century, already provide a large carbon sink. Thousands of acres of agricultural lands are now vacant after over 100 years of sugar production. Under-utilized pasturelands are also opening up and being considered for other uses. The private sector has recognized Hawaii's advantages for forest investment (political stability; ideal growing conditions; skilled workers with relatively easy transition of skills; machinery from the sugar industry; excellent roads, ports, telecommunications; research and development institutions; and attractive living conditions), and has begun to make major investments in forest plantations.

The State should develop and aggressively promote COF strategies that are cost-effective for reasons other than just for their greenhouse gas reduction benefits. Sustainable forestry has social and economic side effects that are mostly beneficial, ranging from maintenance of biodiversity and endangered habitats to providing sources of sustainable harvested forest products and quality employment for forest communities. Hawaii's existing forests are already acting as a carbon sink for 108 million tons. The two scenarios presented in this chapter (koa reforestation and longer rotation high value forest plantations) have the potential to sequester an additional 26 million tons of carbon. At $2 to 10 per ton of carbon, this represents a potential $52 to 260 million for forest investment that offer a range of public benefits for the people of Hawaii. If utilities partner with the State and high quality forest investors in joint venture projects to create a value added forest industry, the trees planted today will be fully grown by the year 2012, just about the time when electric utilities around the country will be looking to meet their emission reduction goals. How can Hawaii take advantage of this window of opportunity? The following recommendations should be considered:

13.8.1 Recommendation: The State should expand its forest inventory to all forestlands to determine existing timber resources and reforestation opportunities.

13.8.2 Recommendation: The State should assure that disposition of wood from its lands and future leasing of its forest lands are done strategically for value-added purposes that optimize carbon sequestration.

13.8.3 Recommendation: The State should review its pasture leases to identify what lands have the potential for reforestation and determine which of these lands could make the best contribution to a value-added forest industry and COF projects.

13.8.4 Recommendation: The State should sponsor a COF conference with select utilities, large landowners, forest investors, financial institutions, and relevant public officials to determine how COF projects can help contribute to Hawaii's forestry sector. Specific COF project scenarios should be explored in depth. They include:

a. Urban forestry;
b. Wildland fire protection;
c. Native forest protection;
d. Koa reforestation;
e. High value, longer rotation forest plantations;
f. Agroforestry; and
g. Private Landowner Partnerships.

13.8.5 Recommendation: The State's major financial institutions should design the appropriate investment platform such as "Certifiable Tradable Offsets" (CTOs) or "carbon bonds" now being used in the Costa Rican CFO project, or other forms of "carbon banking" that could help encourage COF projects in Hawaii.

CHAPTER 14 RESEARCH AND DEVELOPMENT, FUTURE TECHNOLOGY, AND TECHNOLOGY EXPORT

14.1 Overview

This report has focused on ways to reduce greenhouse gas emissions. In the model runs and analysis, existing technologies were considered in developing and addressing options. In the energy sector in particular, the estimates indicate that it will be very difficult to reach the Kyoto Protocol goal of 7% below 1990 levels of greenhouse gas emissions using existing technology.

This chapter discusses several research and development efforts currently underway in Hawaii that may contribute to greenhouse gas emissions reductions. It also examines a number of technologies under development internationally that are expected to provide energy and transportation with reduced greenhouse gas emissions. Finally, the chapter discusses the potential contribution of the State of Hawaii's Strategic Technology Marketing and Development Program to reducing greenhouse emissions in developing nations of Asia.

14.2 Hawaii Research and Development Projects

There are a number of current and recent research and development projects in Hawaii that offer potential contributions to greenhouse gas reduction and climate change mitigation.

14.2.1 International CO_2 Ocean Sequestration Field Experiment

During the Third Conference of the Parties of the Framework Convention on Climate Change at Kyoto in December 1997, agencies of the governments of the United States, Japan, and Norway signed a major international research agreement to develop technologies to sequester CO_2 removed from fossil fuel combustion from the atmosphere. Under the agreement, researchers from the three nations will test the feasibility of deep ocean sequestration of CO_2 via discharge from submerged pipelines.

The objective of the experiment is to identify safe and practical means of reducing CO_2 emissions while ensuring a stable and inexpensive energy supply. The first phase of the experiment will release a modest amount of CO_2 at depths of more than 3,000 feet during the course of a month. Data on the dissolution and dilution of the CO_2 will be obtained to assess any impacts on the deep ocean environment and to develop models of the discharge that can be used to predict and quantify changes in seawater chemistry. The first phase of the project will run through

March 2002, with the experiments taking place in the summer of 2000 (Masutani 1998).

The Pacific International Center for High Technology Research (PICHTR) of Honolulu is the general contractor. The experiment will take place in the ocean research corridor offshore of the Natural Energy Laboratory of Hawaii Authority at Kailua-Kona, Hawaii.

It should be noted that ocean sequestration is potentially well suited for fossil-fueled power stations in Hawaii. As noted in Chapter 7, Hawaii's power producers do not enjoy the option of switching to lower cost and lower carbon content fuels such as natural gas as is occurring with Mainland utilities. CO_2 removal from stack gases and sequestration in the deep ocean could be added to their other CO_2 reduction options of improved heat rate, energy efficiency programs, and use of renewable energy resources.

Hawaii's power stations probably have the best access to the deep ocean in the U.S. (Masutani 1998). The U.S. Department of Energy, however, estimates that about 30% of U.S. power plants would have access to deep-water sequestration (USDOE 1997b). A pilot facility, which is being planned by the three nation consortium for development in the 2005-2010 time frame, could well be sited in Hawaii, possibly next to the Hawaiian Electric Company's Kahe station on Oahu (Masutani 1998).

Hawaii researchers have previously proposed and published papers on a process to reduce CO_2 emissions from power plants by precombustion reforming of the fuel and deep ocean discharge of the CO_2 separated from the fossil fuel. The process involves reforming a hydrocarbon fuel into a mixture of hydrogen and CO_2 before combustion takes place. The gases are separated and the hydrogen is used for power generation while the liquefied CO_2 is discharged into the deep ocean. Based upon their analysis of a 500 MW methane-fueled power plant, it appeared that the system would incur moderate power and cost penalties. In the future, such measures may be among those necessary to reduce CO_2 emissions and their impact on global climate (Nihous et al. 1994).

14.2.2 Open-Cycle Ocean Thermal Energy Conversion (OTEC)

The technology for generating electricity from different ocean temperatures is known as ocean thermal energy conversion, or OTEC. OTEC makes use of the difference in temperature between the warm surface water of the ocean and the cold water in depths below 2,000 feet to generate electricity. As long as a sufficient temperature difference (about 40 degrees Fahrenheit) exists between the warm upper layer of water and the cold deep water, net power can be generated.

Almost all of major U.S. OTEC experiments in recent years have taken place in Hawaii. The Natural Energy Laboratory of Hawaii Authority (NELHA) on the

Big Island is recognized as the world's foremost laboratory and test facility for OTEC and OTEC-related research. The State of Hawaii with significant USDOE participation has funded the facility. Some of the research conducted there is described in the following sections.

14.2.2.1 Mini-OTEC, 1979

In 1979, the first successful at-sea, closed-cycle OTEC operation in the world was conducted aboard the Mini-OTEC, a converted Navy barge operating in waters off Keahole Point. The plant operated for three months, generating approximately 50 kilowatts of gross power with net power ranging from 10-17 kilowatts. This was a joint effort by the State of Hawaii and a private industrial partner.

14.2.2.2 OTEC-1, 1980

In 1980, OTEC-1, a converted Navy tanker moored in waters off Kawaihae on the Kona Coast, tested heat exchangers and other components of a closed-cycle OTEC plant and investigated the environmental effects of an ocean-stationed OTEC plant. It was not designed to generate electricity.

14.2.2.3 Design of a Utility-Scale OTEC Plant, 1983-4

Ocean Thermal Corporation, under a contract from the USDOE, in 1983 designed a 40-megawatt OTEC pilot plant to be located on an artificial island at Kahe Point off the coast of Oahu. The State of Hawaii contributed about $2 million towards this project. The design plans were completed by the end of 1984, but the construction of the plant was not funded. Oil prices soon fell to a relatively low levels, making OTEC noncompetitive with fossil -fueled electric generating plants.

14.2.2.4 210-kW Open-Cycle OTEC Plant, 1995

The Pacific International Center for High Technology Research (PICHTR) in Honolulu continued work with the State of Hawaii and the USDOE on the final design, construction, and operation of a 210-kilowatt open-cycle OTEC plant. The plant set the world record for OTEC power production at 255 kilowatts gross. Testing ended in 1997.

OTEC continues to offer a way to generate greenhouse gas emission-free electricity. Additional research, component cost reduction, and funding of a utility-scale plant are needed to create a viable commercial technology.

14.2.3 Hydrogen: Fuel of the Future

Hydrogen has been called the fuel of the future. It may be the ultimate energy carrier -- a versatile, transportable fuel that can be converted easily and efficiently to other forms of energy without producing harmful emissions. Hydrogen can be used as a fuel for transportation, electricity generation, cooking, and heating. It can be produced from renewable resources, such as electrolysis of water into hydrogen and oxygen using solar energy or wind energy, or direct conversion of biomass into hydrogen and other gases (Hydrogen 1998).

In the past, the cost of production, difficulties in storage, and lack of infrastructure have been obstacles to everyday use of hydrogen. The U.S. Department of Energy Center for Excellence for Hydrogen Research and Education at the University of Hawaii's Hawaii Natural Energy Institute (HNEI) is conducting research to address the cost and storage issues. Work is underway in the area of photoelectrochemistry, biomass gasification of hydrogen, and hydrogen storage technologies (Hydrogen 1998).

14.2.3.1 Photoelectrochemistry

Research is being conducted at HNEI on ways to electrolyze water into hydrogen and oxygen using only sunlight for energy. Analyses indicate that photoelectrochemical reactors based on multijunction amorphous silicon solar cell technologies can potentially achieve high hydrogen production efficiencies at reasonable cost. Using high-efficiency triple junction amorphous silicon solar cells provided by Solarex Thin Film Division and HNEI's own thin-film catalytic coatings, researchers have demonstrated conversion efficiencies greater than 7.5%. The technology has operating lifetimes in excess of 7,000 hours. HNEI research is now focused on improving protective coatings. Work is also being done in collaboration with the National Renewable Energy Laboratory to optimize the engineering design of these photoelectrochemistry reactors (Hydrogen 1998).

14.2.3.2 Biomass Gasification to Create Hydrogen

Researchers at HNEI's Renewable Resources Research Laboratory are optimizing a new catalytic process which causes biomass to react with water at high temperatures and pressures (called "supercritical water") to produce hydrogen, CO_2, and some CH_4. The process is similar to current commercial hydrogen production using reaction of natural gas (CH_4) with water. The advantage of HNEI's process is that it can use renewable biomass (such as wood sawdust, water hyacinth, banana stems, or sewage sludge) and supercritical water as reactants. Unlike all other biomass gasification processes, the HNEI process produces no tars or char, only a hydrogen-rich gas. A patent is pending on the process and researchers recently issued a second patent disclosure. With support from the U.S. Department of Energy, General Atomics Corporation is now preparing a business plan to commercialize the HNEI work (Hydrogen 1998).

14.2.3.3 Hydrogen Storage Technology

Hydrogen storage has long been a problem. Hydrogen is normally stored as a gas in high-pressure tanks, or as a liquid at cryogenic temperatures. Hydrogen can also be stored as a solid by reacting it with a variety of metals. These materials, known as metal hydrides, provide safe, low-pressure storage; however, the amounts of hydrogen have been too small to be practical or the hydrogen formed too strong a bond with the metal hydride, requiring large energy inputs for its release (Hydrogen 1998).

Over the ten years from 1986 to 1996, HNEI's research focused toward developing "non-classical" polyhydrides -- transition metal complexes -- as a storage media. Experiments showed that this new class of material could store and discharge hydrogen with lower energy inputs than conventional hydrides (Hydrogen 1998).

Recently, HNEI researchers discovered that these same metal complexes can catalyze the dehydrogenation of cyclic aromatic hydrocarbons at low temperatures, a step that had long been a barrier to using such hydrocarbons as a storage medium. Research has been redirected to concentrate on the development of metal complex catalytic systems for reversible hydrogenation of unsaturated hydrocarbons. Within the past year, new and significantly improved catalysts have been developed. Studies were also initiated to characterize the kinetics and thermodynamics of the reaction system. Future work will include improvement of the fundamental catalyst properties and construction of a membrane reactor to demonstrate reversible operation of the hydrocarbon storage system (Hydrogen 1998).

14.2.4 Charcoal Production

Charcoal has been made in virtually the same way for 6,000 years. The process is long, causes severe air pollution, and has low yields. An innovation by HNEI researcher Dr. Michael J. Antal, Jr., at the University of Hawaii offers the potential to greatly reduce production time to an hour or less, while reducing smoke and other pollution, and doubling or tripling yields. This technique could help slow deforestation and reduce pollution in the many developing nations that use large amounts of charcoal, reducing greenhouse gas emissions. The process, which recently received a U.S. patent, can use a variety of feedstocks, including moist wood logs, wood chips, coconut shells, corn cobs, macadamia nut shells, and other commonly available biomass and agricultural byproducts. The greater efficiency of this method could save thousands of acres of forests from harvesting and reduce air pollution by shortening production times and improving yields.

14.3 Future Technology

14.3.1 The Need for New Technologies to Reduce Greenhouse Gas Emissions

In examining Hawaii's options to reduce its future greenhouse gas emissions, it is clear that, while reductions below the "business as usual" levels are possible, the measures identified do not bring Hawaii's emissions below the Kyoto target (See Chapter 4). It is encouraging that major reductions in emissions in municipal solid waste management, wastewater management, livestock, animal manure management, and fertilizer use are possible. However, using available technologies to meet Hawaii's energy needs, it does not appear that the target can be reached. Hawaii, and the rest of the world, will need new technologies to effect significant reductions in greenhouse gas emissions and to reduce the consequences of global warming on climate change.

The U.S. Secretary of Energy recently asked the Directors of the Department of Energy's national laboratories to identify technologies that could be used to meet this challenge nationally. The study was summarized in *Technology Opportunities to Reduce U.S. Greenhouse Gas Emissions* (NLD 1997), published in October 1997.

In addition, President Clinton set a challenge for the United States: to reduce greenhouse gas emissions and grow the economy. The National Laboratories identified 47 technology pathways that have the potential to reduce greenhouse gas emissions. They conclude that success in meeting the President's challenge will require simultaneous pursuit of multiple pathways. As the National Laboratory Directors stated, "Advances in science and technology are necessary to reduce greenhouse gas emissions from the United States while sustaining economic growth and providing collateral benefits to the nation" (NLD 1997, xiii).

14.3.2 The Outlook for Technological Solutions

The National Laboratories pointed out that solutions available early are more effective in reducing emissions. They believe that, by 2030, a vigorous research, development, and demonstration program could result in a "wide array of cost-effective technologies that together could reduce the nation's carbon emissions by 400-800 million metric tons of carbon per year. This decrease represents a significant portion of the carbon emission reductions that may be targeted by the U.S. for 2030" (xiv).

Looking ahead over the next thirty years, each decade was seen as distinct in the range of potential greenhouse gas reduction technologies. The technological pathways identified were energy efficiency, clean energy, and carbon sequestration.

In the first decade (2000-2010), advances in energy efficiency would reduce the energy intensity of the U.S. economy. Clean energy technologies would continue to grow, and carbon sequestration technologies could begin to emerge.

In the second decade (2011-2020), continued improvements in energy efficiency, and research-based advances in clean energy technologies would significantly reduce U.S. carbon intensity (the amount of carbon emitted per unit of energy used). A wide variety of improved renewable, nuclear, and fossil energy technologies could be introduced and widely deployed.

During the third decade (2021-2030), clean energy technology reductions could begin to exceed the impact of increased energy efficiency by 2025. In addition, carbon sequestration technologies could begin to add an important dimension to reducing emissions at the end of this period. Success in the area of carbon sequestration is seen to be essential for the U.S. to continue its extensive use of fossil fuels without harming the global environment (xiv).

The following table is based upon Figures 5.1 and 5.2 in the National Laboratory Director's study. Table 14.1 is an illustrative time-line of anticipated technology products for the energy sector, 2000 - 2030 (5-10 -- 5-11).

Table 14.1 Illustrative Time-Line of Anticipated Technology Products, 2000-2030

2000	2005	2010
Energy Efficiency	Energy Efficiency	Energy Efficiency
1 kWh/day refrigerator	**Fuel cells providing combined heat and light for commercial buildings**	**Widespread use of hybrid lighting, combining light concentrators, efficient artificial sources, and fiber-optic distribution systems**
80% efficient advanced turbine system for industrial cogeneration	**R-10+ windows and electrochromic windows**	**Real-time monitoring of water and nutrients in agricultural systems**
Advanced industrial process sensors and controls	**Energy efficient catalysts for chemical synthesis**	**Three times greater fuel economy vehicle**
Direct injection stratified charge gasoline engine	Clean Energy	Clean Energy
Advanced heavy duty diesel	**Gasoline electric hybrid vehicle**	**Hybrid fuel cell advanced turbine system for power generation with efficiencies of 70%**
	Clean diesel for light trucks and sport utility vehicles	**Biofuels competing with petroleum-based transportation fuels**
	Cofiring with biomass and coal	**Clean coal technologies increase efficiencies to 55%**
	Wind-generated electricity at 2.5 cents per kWh	**Superconducting transformers an 200 HP+ industrial motors**
	Superconducting cables for	Carbon Sequestration

	underground transmission	
		Injection of carbon into aquifers

Continued on the Next Page

Table 14.1 Illustrative Time-Line of Anticipated Technology Products, 2000-2030 (Continued)

2015	2020	2025	2030
Clean Energy	Energy Efficiency	Energy Efficiency	Clean Energy
Widespread production of chemicals from biomass feedstocks	**Phase-change building materials with storage capacity and adaptive release rates**	**NEW SYSTEM: Mass produced customized buildings and integrated envelope and equipment systems designed and sized for specific sites and climates**	**NEW SYSTEM: Broad-based biomass industry with new crops and feedstocks producing food, transportation fuels, chemicals, materials, and electricity**
Hydrogen fuel cell vehicle	**NEW SYSTEM: Widespread use of industrial ecology principles with linked industries and energy cascading**	**Travel demand reductions through real-time information systems**	**Utility scale photovoltaic systems**
Superconducting generators for utility systems	Clean Energy	Clean Energy	**NEW SYSTEM: Fission reactors with proliferation resistance, high efficiency, and lower costs**
Diesel fuels from natural gas	**Production of hydrogen from solar conversion of water**	**Advanced geothermal hot dry rock and magma energy systems**	
Photovoltaics for distributed and peak shaving utility systems	**NEW SYSTEM: Mature hydrogen supply infrastructure enabling multiple modes of hydrogen based transportation**		**NEW SYSTEM: Energyplexes that integrate fossil fuel-based production of power, fuels, and chemicals from coal, biomass, and municipal wastes with nearly zero emissions**
	Simultaneous gas hydrate production and CO_2 Sequestration		Carbon Sequestration
	Feasibility of oceanic sequestration established		**Enhanced natural CO_2 absorption**

14.3.3 National Goals for Research, Development, and Demonstration (RD&D)

The National Laboratory Directors suggested the following goals for a RD&D program:

14.3.3.1 National Energy Efficiency RD&D Goals

- Use energy efficiency more efficiently through the development of advanced technologies (e.g., intelligent building control systems, cost-effective refrigerators that use half as much electricity as today's models, and fuel cells for heat and power in commercial buildings).

- Reduce use of gas and oil for space and water heating through building efficiency measures (e.g., super insulation, gas-fired heat pumps that provide highly efficient space heating and cooling, and building envelopes that capture and store solar energy for later use). (Note: While Hawaii has minimal space heating requirements, some of these measures can reduce the need for air conditioning or be used to provide for cooling in large buildings. Solar water heating remains an important technology for Hawaii's residential and smaller commercial buildings.)

- Improve industrial resource recovery and use (e.g., develop and integrated gasification combined cycle power technology, which can convert coal, biomass, and municipal wastes into power and products) and industrial processes to save energy (e.g., advanced catalysts and separations technologies).

- Increase transportation efficiency through new technologies (e.g., a hybrid electric vehicle that is three times more fuel-efficient than today's standard model) (xv).

14.3.3.2 National Clean Energy RD&D Goals

- Change the energy mix to increase use of sources with higher generating efficiencies and lower emissions -- increased use of natural gas, safer and more efficient nuclear power plants, renewable energy (e.g., solar and wind power; electricity and fuels from agricultural biomass), and hydrogen (to produce electricity through fuel cells.

- Develop "energyplexes" that would use carbon efficiently without emitting greenhouse gases for the integrated production of power, heat, fuels, and chemicals from coal, biomass, and municipal wastes.

- Distribute electricity more efficiently to reduce emissions (e.g., distributed generation using superconducting transformers, cables, and wires).

- Switch transportation to energy sources with lower emissions (e.g., trucks that run on biodiesel fuel, ethanol from cellulosic feedstocks, etc.).

- Remove carbon from fuels before combustion. (xv).

14.3.3.3 National Carbon Sequestration RD&D Goals

- Efficiently remove carbon dioxide from combustion emissions before they reach the atmosphere.
- Increase the rate at which oceans, forests, and soils naturally absorb atmospheric carbon dioxide.
- Develop technologies for long-term carbon storage in geological deposits, aquifers, and other reservoirs.

14.3.4 Hawaii and Future Technology

As noted in section 14.2, above, Hawaii is participating or has participated in RD&D efforts that could contribute to greenhouse gas reduction or to the achievement of national technology goals. Hawaii has advantages in a number of areas that should be considered in siting RD&D efforts.

14.3.4.1 RECOMMENDATION: Support Deep-Ocean Carbon Sequestration Research and Possible Future Installation of a Pilot Facility in Hawaii

This technology, if proven, could provide an excellent way of reducing Hawaii's near-term CO_2 emissions. If the CO_2 sequestration effort is successful, installation of a pilot facility at a power plant in Hawaii should be encouraged. Many of Hawaii's power plants could inject CO_2 from their locations relatively near the coast.

14.3.4.2 RECOMMENDATION: Conduct RD&D on Carbon Sequestration and OTEC at NELHA, Using Hawaii's Deep Ocean Access

Hawaii's geography provides ready access to deep ocean areas from coastal areas. The Natural Energy Laboratory of Hawaii Authority at Kailua-Kona on the Big Island operates facilities that provide land-based access to deep, cold ocean waters offshore. This is highly useful for RD&D on deep ocean carbon sequestration and ocean thermal energy conversion, as noted above.

14.3.4.3 RECOMMENDATION: Conduct RD&D on Renewable Energy Technology Using Hawaii's Abundant Renewable Energy Resources

As noted in Chapter 7, Hawaii has significant wind and solar resources, which were identified during work on the Hawaii Energy Strategy project. Hawaii has the highest per capita use of solar water heating. In addition, volcanoes on the Big Island provide a major geothermal resource. As also noted in Chapter 7 and in the following section, Hawaii's sugar industry leads the world in efficient of its electricity production from sugar bagasse. Hawaii's lack of space for landfills led to construction of a municipal solid waste to energy plant on Oahu.

Land available due to sugar plantation closure could be used for further RD&D into biomass-to-energy systems. Although the Maui Biomass Gasifier project was cancelled, Hawaii remains an excellent location for similar efforts to produce liquid fuels from biomass and municipal waste.

14.3.4.4 RECOMMENDATION: Conduct Building Efficiency RD&D in Hawaii which Yield Rapid Payback

Hawaii's average statewide electricity costs are the highest in the nation. This factor enhances the attractiveness of conducting building efficiency RD&D in Hawaii. Efficiency measures will yeild rapid payback of their costs, helping finance the RD&D. Due to the need for 12-month air conditioning use in commercial buildings, Hawaii also offers an excellent location for air conditioning efficiency improvement RD&D.

14.3.4.5 RECOMMENDATION: Conduct RD&D on Clean Energy and Transportation Energy Efficiency to Reduce Hawaii's Overdependence on Oil

Hawaii's short driving distances make the islands an ideal location for RD&D involving widespread deployment of electric vehicles and hybrid vehicles. Hawaii's virtually total dependence on jet aircraft for its overseas, interstate, and interisland passenger transportation place a premium on the use of efficient aircraft. Hawaii should support RD&D efforts to improve aircraft efficiency and the development of alternative fuels for jet aircraft.

14.3.4.6 RECOMMENDATION: Conduct RD&D on Electricity System Efficiency and Clean Energy for Electricity Generation in Hawaii

Hawaii has six relatively small, isolated electric systems. The short transmission and distribution distances offer excellent test locations for superconductive cables, transformers, and wires. The high cost of electricity places a premium on efficiency and cogeneration. The isolated nature of the systems may provide opportunities to test distributed systems. Hawaii also offers the opportunity to test a variety of fossil fuel and renewable technologies in an integrated system designed to overcome the challenges posed by the intermittent nature of some renewable technologies. Technologies developed for Hawaii's separate island systems may also have application in developing nations that lack a national or regional power grid. Such nations effectively have "island" systems.

14.4 Hawaii's Strategic Technology Marketing and Development Program

Hawaii's Strategic Technology Market Assessment and Development (STMAD) Program was designed to facilitate increased exports of U.S. energy, environmental, and other sustainable technologies and related services into Asia/Pacific markets. The Energy, Resources, and Technology Division of the State of Hawaii Department of Business, Economic Development, and Tourism (DBEDT) manages the program. STMAD focuses on Asia-Pacific markets due to their high growth history prior to the current downturn and expected future potential. A key objective is to facilitate sustainable, technology-related economic development for Hawaii, create higher valued jobs, and diversify the State's economy. Sustainable technology, especially in the areas of energy and environmental technologies and related services will also help to mitigate and reduce greenhouse gas emissions.

Private/public sector partnerships are a central component of STMAD. STMAD seeks to match commercial applications of sustainable technologies and related services to targeted demand in the Asia-Pacific region. U.S. Federal agencies and non-governmental organizations (NGO), such as the National Association of State Energy Officials, Export Council for Energy Efficiency, National Association of Energy Service Companies, etc., are active partners and participants in program activities. This type of governmental facilitation of U.S. technology exports is a key component of the U.S. Department of Energy's draft Comprehensive National Energy Strategy.

14.4.1 STMAD Goal, Priorities, and Activities

STMAD has the following major goals, priorities, and activities in these areas:

- **Supply** -- First priority is on expanding and diversifying the export activities of Hawaii's existing sustainable technology and related service companies; next priority goes to attracting Mainland technology firms to locate in Hawaii;

- **Demand** -- The emphasis is on identifying and developing strategic technology niche markets that comport with State economic development goals, which Hawaii companies can serve now or gain the capacity to serve, or markets that will attract Mainland technology enterprises to Hawaii;

- **Technology Industry Development & Promotional Activities** -- These include the STMAD Workshop Series -- a series of workshops on program activities, infrastructure project technology and service export opportunities, trade missions, demand assessment results, and key energy, environmental, and other relevant technology trade issues and policy developments -- for targeted industry and public sector audiences;

- **Specific Projects** -- These focus on identification, facilitation, and development of specific sustainable infrastructure projects to increase exports of U.S. technologies and services from Hawaii;

- **Finance** -- DBEDT plans to continue providing tailored sustainable infrastructure project finance training for potential client country decision-makers and to facilitate financing arrangements for specific projects;

- **Continued Market Analyses and Evaluation** -- These activities are designed to contribute to continued economic expansion and diversification through measurement, analysis and reporting of technology-related economic development in Hawaii. This information will also be used to tailor future STMAD Program activities for greater efficiency and effectiveness; and

- **Energy/Environmental Needs Assessments** -- Energy and environmental infrastructure assessments will be conducted in partnership with industry and the host Asia/Pacific countries to identify specific project development opportunities for Hawaii and other U.S. companies.

Some examples of STMAD-related activities conducted in 1997-1998 include:

- Thailand Business Opportunities Mission;

- Philippines Sustainable Energy Technology and Policy Transfer Project;

- Hainan Province, China, Preliminary Energy Infrastructure Assessment and Sustainable Development Project; and

- State of Hawaii & People's Republic of China Infrastructure Project Finance Seminar.

The remaining discussion will focus on the Philippines Sustainable Energy Technology and Policy Transfer Project and the Hainan Province, China, Preliminary Energy Infrastructure Assessment and Sustainable Development Project as they are expected to contribute significantly to greenhouse gas emission reduction and climate change mitigation.

14.4.2 Philippines Sustainable Energy Technology and Policy Transfer Project

14.4.2.1 Project Description

The main purposes of the project are to promote environmentally sound energy practices in the Philippines and to assist the Philippines in taking advantage of their biomass-to-energy potential. There are two components of the project: (1) the Project for Energy Efficiency Policy and Technology Transfer for Improving Environmental Protection and Economic Efficiency, and (2) the Comprehensive Assessment of Biomass-to-Energy Potential for the Philippines. Both components will contribute to Philippine efforts to reduce greenhouse gas emissions and to improve energy efficiency.

These projects were initiated during a mission to Manila led by Hawaii Governor Benjamin J. Cayetano, May 18-23, 1997, to build upon Hawaii's long-standing, excellent relationship with that country and to facilitate increased trade with the Philippines, especially the exports of U.S. energy and environmental expertise, technology, and services from Hawaii. A highlight of the mission was the May 19, 1997, signing by Governor Cayetano and Philippine Secretary of Energy Viray of a Memorandum of Understanding agreeing to technical cooperation on a comprehensive biomass-to-energy program and projects in the Philippines. Further discussions also led to a Philippine request for collaboration on energy efficiency policy and technology transfer, and ways to develop the Philippine energy service company (ESCO) industry (State of Hawaii, 1998c).

14.4.2.2 Project for Energy Efficiency Policy and Technology Transfer for Improving Environmental Protection and Economic Efficiency

This component project is providing technology transfer and assistance in the following areas:

Energy Efficiency. Energy efficiency areas include model energy codes and standards, utility demand-side management, performance contracting, clean air standards, policy guidance on cost calculation for project planning, and reduction of greenhouse gas emissions. Hawaii is one of a few U.S. states that has an advanced model energy code capable of achieving significant energy savings through a set of comprehensive requirements for the design of new buildings. Hawaii's code is also tailored for application in a subtropical climate. Hawaii's Energy, Resources, and Technology Division has led implementation of performance contracting for state government facilities. This model can assist the government of The Philippines and other entities in updating the efficiency of their buildings.

Energy Efficiency Technologies. Energy efficiency technologies involved in the project through Hawaii ESCOs include high efficiency electro-technologies such as lighting, cooling, and building energy management systems, and other demand-side management technologies and processes, such as solar water heating. Hawaii is a leader in the use of efficient electro-technologies and other demand-side applications. Hawaii has the highest per capita penetration of solar water heating in the United States.

Energy Planning and Policy. In the planning and policy area, assistance will be provided in comprehensive energy planning and policy analysis, energy efficiency codes and standards, integrated resource planning, demand-side management analysis, and energy emergency planning to strengthen energy system reliability against damage from natural disasters. Hawaii has developed a comprehensive Hawaii Energy Strategy covering all of these areas and can pass on lessons learned. Notably, the demand-side management measure assessment developed by DBEDT was adopted by three Hawaii utilities, a comprehensive renewable energy assessment of Hawaii could serve as a model for the Philippines, and Hawaii has conducted detailed hazard-mitigation studies and is acting on recommendations from those studies. This document represents participation in the U.S. Environmental Protection Agency's State and Local Climate Program and Hawaii can use its experience in this effort to assist the Philippines in similar work.

The project involves funding from the U.S. Asian Environmental Program and the Philippine government.

Project Activities. The project consists of the following activities:

- In June 1998, a two-day workshop was conducted in Manila with participation from Hawaii and mainland U.S. companies, the National Association of State Energy Officials (NASEO), and the National Association of Energy Service Companies. It was funded by the U.S. Agency for International Development through NASEO.

- A baseline policy analysis of existing energy efficiency policies in the Philippines will be prepared. Building codes and standards will be compared to U.S. and international norms.

- Policy options will be developed and analyzed for their advantages in terms of reducing greenhouse gas emissions, deferred production capacity savings, and deferred energy consumption savings.

- A second workshop will be conducted in Manila in early 1999 to discuss the baseline analysis and to initiate collaborative drafting of specific policy options.

- The State of Hawaii and Philippine public and private entities will assess appropriate model energy building codes and standards, policies to expand the ESCO industry, and ways to implement performance contracting and utility demand-side management using innovative financing and cost recovery methods.

- An assessment of the energy policy development and technology needs of The Philippines.
- Develop a policy framework and mechanism to facilitate the use of more efficient technologies and to improve environmental protection for the Philippines to consider adopting.
- A third workshop will be conducted in Hawaii to introduce Philippine government and private sector officials to specific energy efficiency technologies and programs in Hawaii and to conduct field site visits.
- Report on specific, measurable results, anticipated results, and future opportunities and policy measures to reduce greenhouse gas emissions through increased energy efficiency.
- A final report on key project findings and workshop results will also recommend future collaborative efforts with a focus on U.S. exports of sustainable technology and service, especially for increasing energy efficiency (State of Hawaii 1998b).

14.4.2.3 Comprehensive Assessment of Biomass-to-Energy Potential for the Philippines

The economies of both the State of Hawaii and Republic of the Philippines have an important agricultural component, especially sugarcane and pineapple. The Philippines also has other biomass resources that currently provide biomass as fuel for power production or could be used in the future. These resources include forestry waste, municipal waste, rice hulls, cocowaste, and sugarcane bagasse. Both possess expertise in biomass-to-energy research, development, and commercial production, but are somewhat constrained from reaching the full economic potential of this indigenous, renewable energy resource by limited data and technological uncertainties.

As outlined by the Philippines Department of Energy Act of 1992, it is the declared policy of the government

> To ensure a continuous, adequate, and economic supply of energy to ultimately achieve self-reliance in the country's energy requirements through integrated and intensive exploration, production, management and development of the country's indigenous energy sources, and through judicious conservation, renewal, an efficient utilization of energy to keep pace with the country's growth and economic development with the active

participation of the private sector in various areas of energy resource development.

To rationalize, integrate, and coordinate the various programs of the Government towards self-sufficiency and enhanced productivity in power and energy without sacrificing ecological concerns (ROP-SOH, 1997b).

To help implement this policy the Secretary of Energy of the Republic of The Philippines Department of Energy and Hawaii's Governor signed a Memorandum of Understanding (MOU) on May 19, 1997, for a comprehensive assessment of biomass-to-energy potential for the Philippines.

Hawaii possesses expertise in energy production from biomass resources, especially high-efficiency direct combustion of sugar bagasse (discussed in more detail in Chapter 7) and municipal solid waste-to-energy. At the time the MOU was signed, Hawaii was involved in a research and development project with the U.S. Department of Energy to develop a biomass integrated combined cycle system designed to produce electricity and alcohol fuel from biomass. This effort, however, was terminated due to problems with system components and a lack of additional resources to continue the project.

14.4.2.4 Philippine Biomass Project Scope

The University of Hawaii's Hawaii Natural Energy Institute under the leadership of Dr. Charles M. Kinoshita is conducting the project. The project will include a complete inventory and future projections of the availability of Philippine biomass feedstocks. It is intended to result in recommendations for commercially applying the most economic, environmentally responsible energy conversion technologies for these biomass fuels. The informational database and networking that stem from this effort ultimately will help to identify opportunities and strategies in the Philippines for commercial deployment of bio-energy technologies, products, and services.

Date will be gathered and reported on: (1) locations, present and projected amounts, and uses of bioresidues on a region-by-region basis, and possible combinations of residues to form suitable fuel mixes and costs of supplying the fuel mixes; (2) appropriate existing and emerging technologies to produce electricity from bioresidues, as well as conversion efficiencies, costs, and feedstock requirements of the various conversion alternatives; (3) probable economic and social impacts of utilizing residues for electricity production; (4) potential environmental impacts of diverting residues for electricity generation and of converting residues into electricity; and (5) opportunities for existing and emerging U.S. biomass-electricity technologies. DBEDT has compiled preliminary data on biomass energy and conversion technologies in selected Pacific Rim countries, including the Philippines; that will support the information base being developed in the proposed project.

Two areas are of special emphasis are: (1) identification of bioresidues that can be part of fuel mixes for existing and emerging biomass power systems and projection of the cost of providing year-round supplies of biomass fuels, and (2) delineation of the environmental impacts of collecting and using bioresidues.

Two bioresidue-fueled power-generation case studies will be performed to model the integration of biomass residues. One case study will be based on sugarcane bagasse, supplemented during the off-season by sugarcane leaves and tops and residues from other crops. The second study will be based on rice husks produced at several rice mills and consolidated at a centralized power-generation facility, supplemented by other biomass residues. Fuel properties of individual biomass residues and of mixed residues will be analyzed thermochemically to determine the suitability of the fuels in steam-based and gasification-based power plants, and the cost of supplying the integrated bioresidue mixtures will be determined.

Special emphasis will be placed on determining the potential environmental impacts of collecting bioresidues on field conditions, and of converting bioresidues into electricity (ROP-SOH 1997b). Work started on the project on June 29, 1998 and is scheduled for completion by December 31, 1999.

14.4.2.5 Potential for Greenhouse Gas Emissions Reduction

Hawaii's sugar industry is the most efficient in the world in cogenerating electricity while refining sugar cane. The typical factory worldwide produces about 10 kWh per metric ton of cane processed. The average factory in Hawaii produces about 62 kWh per metric ton of cane, and the most efficient factory in Hawaii exceeds 120 kWh per metric ton of cane (Kinoshita 1998).

There is a great potential for increases in exportable power from sugar factories. According to Dr. Charles Kinoshita, Research Engineer at the Hawaii Natural Energy Institute. It is estimated that about 1,300 GWh/Year incremental power could be produced in the Philippines from bioresidues, including sugarcane bagasse and rice hulls for a net CO_2 emissions reduction of 730,000 tons CO_2 per year (Kinoshita 1998).

14.4.3 Hainan Province, China, Preliminary Energy Infrastructure Assessment and Sustainable Development Project

During a DBEDT-sponsored trade mission to Hainan Province, Peoples' Republic of China, in March 1997, the Hainan Provincial Government and the State of Hawaii signed a *Letter of Intent for Cooperative Energy and Environmental Project Development*. The two parties agreed to cooperate in the development of an energy infrastructure needs assessment to identify specific energy projects and methods to mitigate these projects' environmental impacts, as desired by Hainan Province, and, where feasible, would utilize the expertise and technologies of Hawaii (HPG-SOH 1997).

14.4.3.1 Sustainable Energy Technology Assessment of Hainan Province

The Sustainable Energy Technology Assessment of Hainan Province will be conducted by the University of Hawaii's Hawaii Natural Energy Institute as part of the larger infrastructure assessment planned jointly by the Hainan Foreign Affairs Department and DBEDT. Dr. Charles M. Kinoshita will lead the HNEI team. The assessment effort began in November 1998 in conjunction with a DBEDT-sponsored trade mission to Hainan Province and will take about seven months to complete.

Hainan Province, as China's highly visible exploration in market economic reform, is unique within China. Hainan maintains Special Economic Zone authority; enjoys more economic incentives than any other free trade zone, including preferential tax rates and duty-free status; and maintains a high degree of governmental autonomy. The combination of progressive economic policies and a wealth of natural and human resources has made Hainan among the most rapidly developing provinces in China. For growth to continueHainan must keep its energy supplies and demand in balance while maintaining an environment that continues to make the region an attractive to businesses and visitors.

To meet the challenges posed by rapidly growing demand for electric power, maintaining economic growth and employment, and controlling the negative environmental impacts often associated with power generation, China has developed a plan to accelerate the expansion of electric generation capacity (a fourth of which is expected to be established by international firms), improve power plant efficiency and energy conservation programs, utilize cleaner fossil fuels, and develop renewable energy resources.

Better management and use of renewable energy resources and improvements in energy efficiency, in particular, can help bring electricity production and utilization into balance while maintaining a healthy economy, employment, and environment. However, renewable energy resources are largely underutilized at this time. Hainan's hydropower potential has yet to be fully exploited. With more than one-half of the economy in Hainan being based on agriculture (rice, sugar, wood, fruits, coffee, and spices), large biomass resources, presently untapped, might be available for energy conversion. As a result, the provincial government has expressed an interest in modernizing the sugar industry and in developing biomass-to-energy technologies.

Other renewable resources such as wind, solar, tidal, and geothermal energy, as well as municipal solid wastes may have the potential to be significant factors in the overall energy mix. Such resources, often being dispersed in nature, are particularly ideally suited for meeting the objectives advanced in the recent Chinese Ninth Five-Year Economic Plan, which emphasize economic development of rural areas. Moreover, a national sustainable development strategy, outlined in China's Agenda 21 Report and to be included in the Chinese Ninth Five-Year Plan, heightens environmental awareness, further promoting renewable energy systems.

The favorable business climate, rich human and natural resources, projected growth in the power sector, and potential penetration of renewable energy technologies in Hainan create a promising market for U.S. businesses. An assessment of the renewable energy potential and energy-efficiency needs will provide Hawaii-based businesses with valuable information so that opportunities can be effectively evaluated, and if deemed profitable, aggressively pursued.

14.4.3.2 Objective and Scope

The overall objective of the assessment is to assist Hawaii businesses in evaluating sustainable energy business opportunities in Hainan Province. This objective will be met by assessing the renewable energy potential and energy-efficiency needs of Hainan in relation economic growth projections, infrastructure plans, and findings and conclusions from DBEDT's preliminary scoping mission. This effort will be an integral element in the more comprehensive assessment of the energy infrastructure needs of Hainan, which is being proposed by DBEDT to the International Trade Administration, U.S. Department of Commerce.

Information acquired by the March 1997, DBEDT mission to Hainan will form the basis for the assessment. The project team will with Hainan officials and collect information relating to Hainan's renewable energy resources and sustainable technology needs. Data and information to be completed include:

- Survey of the present energy resource mix (from indigenous resources and imported);
- Survey of projected energy demand in Hainan;
- Analysis of electricity generation in Hainan, including generation capacity and infrastructure;
- Assessment of renewable energy resources (biomass, hydro, geothermal, solar, wind, ocean) and their potential contribution to the energy mix;
- Survey of current and planned energy initiatives;
- Assessment of energy conservation programs and needs in Hainan; and
- Identification of specific opportunities for Hawaii companies in renewable-energy production and energy conservation.

A final report and public presentation documenting the findings of the assessment will complete the project.

14.4.4 RECOMMENDATION: Emphasize Sustainable Development Projects Supporting Greenhouse Gas Emissions in the STMAD Program

Using technology transfer through commercial efforts and technical exchange, STMAD projects complement Hawaii's own efforts to reduce greenhouse gas emissions and take advantage of Hawaii's R&D expertise, particularly in the area of biomass-to-energy, energy efficiency, and other energy and environmental infrastructure technology and services.

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APPENDIX C THE ENERGY 2020 MODEL

C.1. ENERGY 2020 -- The Energy Model

ENERGY 2020 is a system dynamics model developed by Systematic Solutions, Inc. (SSI), and designed especially for comprehensive energy planning at a regional level.

The complete ENERGY 2020 model integrates energy demand, energy supply, and the economy, allowing policy analyses to be performed. Specifically, ENERGY 2020 simulates the major departments of regulated electric and gas utilities, other energy supply sources, and the major components of energy demand, including transportation demand, in a single comprehensive framework connected by several important feedback responses. The interactions between all the components of the energy system are consistently represented.

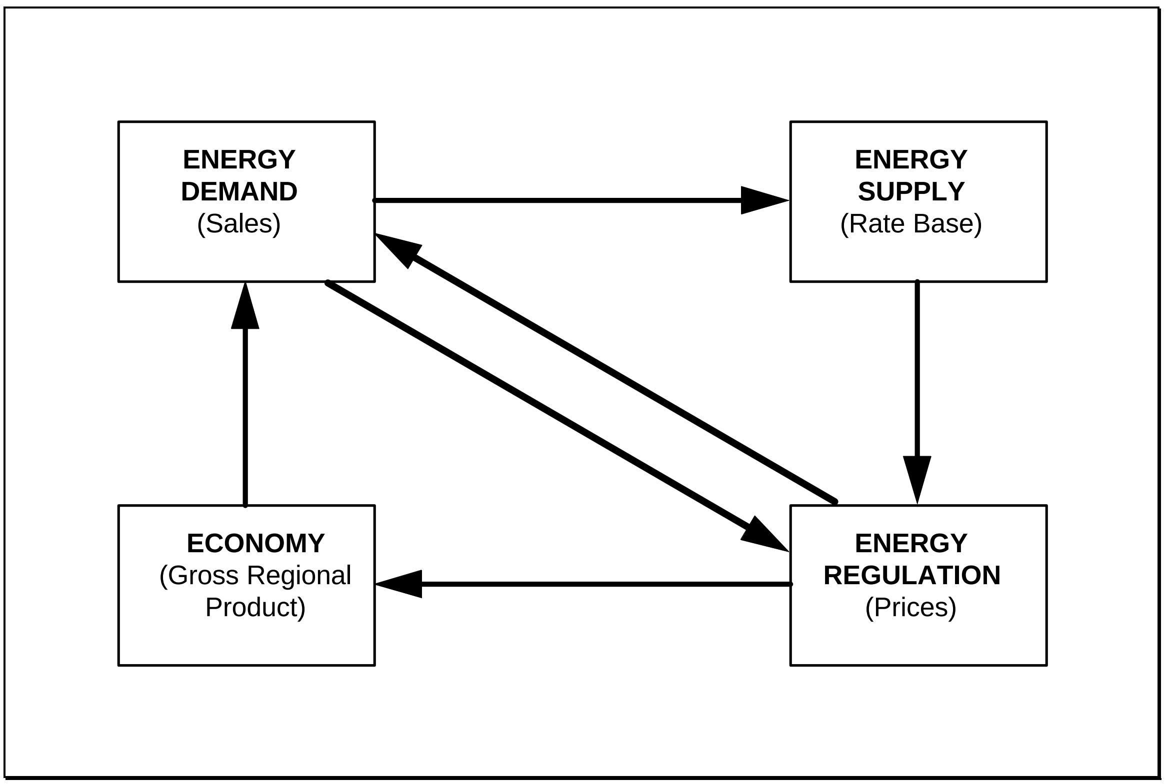

Figure C-1. Feedback Loops Linking the Components of ENERGY 2020

Figure C-1 illustrates the basic feedback loops in ENERGY 2020. Through causal modeling, in combination with econometric, engineering, and system dynamics techniques, the closed loop system is simulated. There are many interconnections between the four segments (boxes). These result in feedback which must be taken into account. Some relationships reinforce behaviors, while others stabilize and control the system by countering any disturbance. In some instances, the response to policies and programs will have the opposite effect in the long-term relative to the short-term. Thus, for robust planning, it is important that dynamic behaviors over time be explicitly addressed.

C.1.1. Structure of ENERGY 2020

The structure of the ENERGY 2020 model, representing how decision-makers act, determines the model results. The ENERGY 2020 model is calibrated to replicate history. This is important because, unless a model can reproduce history, the user will have little confidence that it can legitimately represent the future. However, because ENERGY 2020 simulates how participants in an energy system make decisions, it is also able to determine how decision makers may act when they are faced with conditions for which there is no historical precedent.

In an internally consistent manner, the ENERGY 2020 scenario framework integrates all three major components of the energy system: the county/utility service area economy, the energy demands of county/utility service area consumers, and energy supplies.

Each of these components is represented by one or more sectors. Four detailed demand modules -- one each for the counties of Hawaii, Kauai, and Maui, and the City and County of Honolulu -- were linked with the corresponding Regional Economic Models, Inc. (REMI) macroeconomic models. These were also linked to explicitly modeled electric utility, ground transportation, and both bottled and utility gas sectors. Oil refining, air transportation, and marine transportation were modeled at the state level. Demand was divided into four customer classes -- residential, commercial, industrial, and transportation -- which were in turn disaggregated into numerous end-use groups.

ENERGY 2020 models the demand for energy services and the detailed components of that demand. It takes into account many factors affecting energy choices including: both device and process efficiency choices; the consumer's budget constraints; preferences; information requirements; economic growth impacts; technology changes; and take-back dynamics. ENERGY 2020 causally formulates the energy demand equation. ENERGY 2020 explicitly identifies the multiple ways price changes influence the relative economics of alternative technologies and behaviors, which in turn determine consumer demands. In this sense, price elasticities are outputs, not inputs, of ENERGY 2020. The model recognizes that price responses vary over time and depend upon factors such as the rate of investment, age and efficiency of the capital stock, and the relative prices of alternative technologies. Figure C-2 illustrates the basic demand configuration of the Hawaii version of ENERGY 2020.

The basic supply sector of ENERGY 2020 provides price feedback to the demand and economy sectors. The supply sector includes not only the energy producing and delivering companies, but also the regulators and market mechanisms.

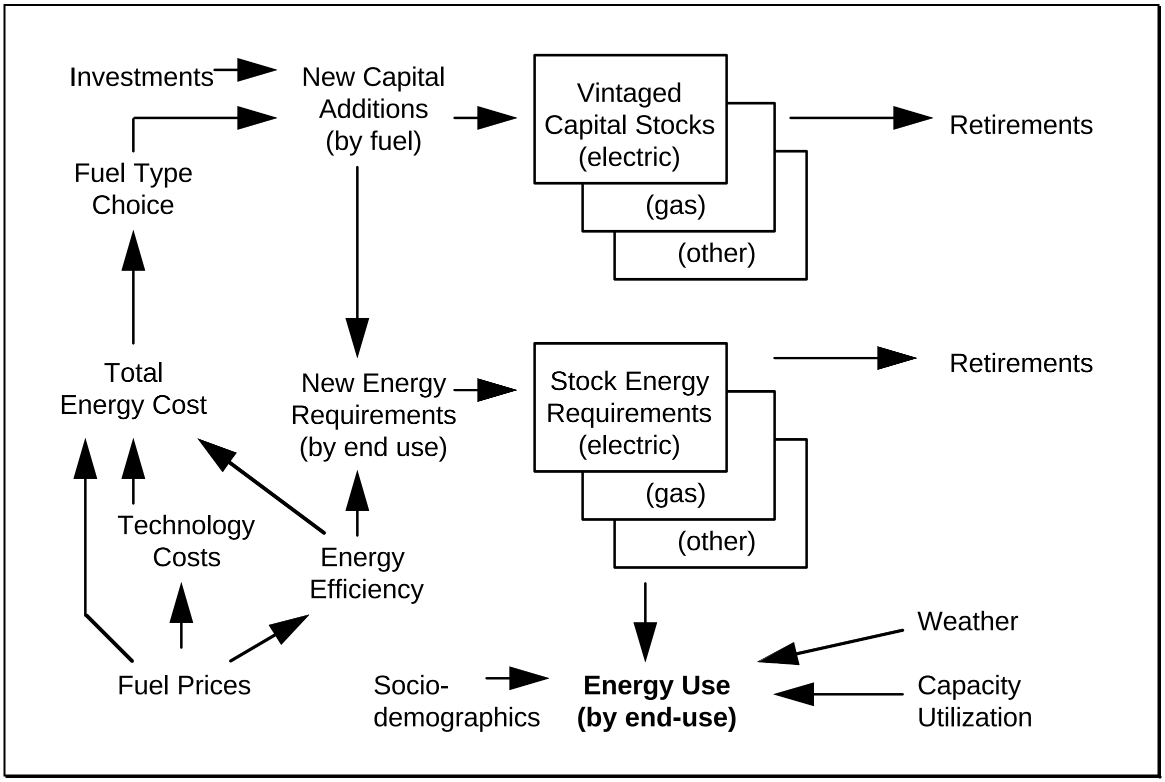

Figure C-2. ENERGY 2020 Demand Configuration

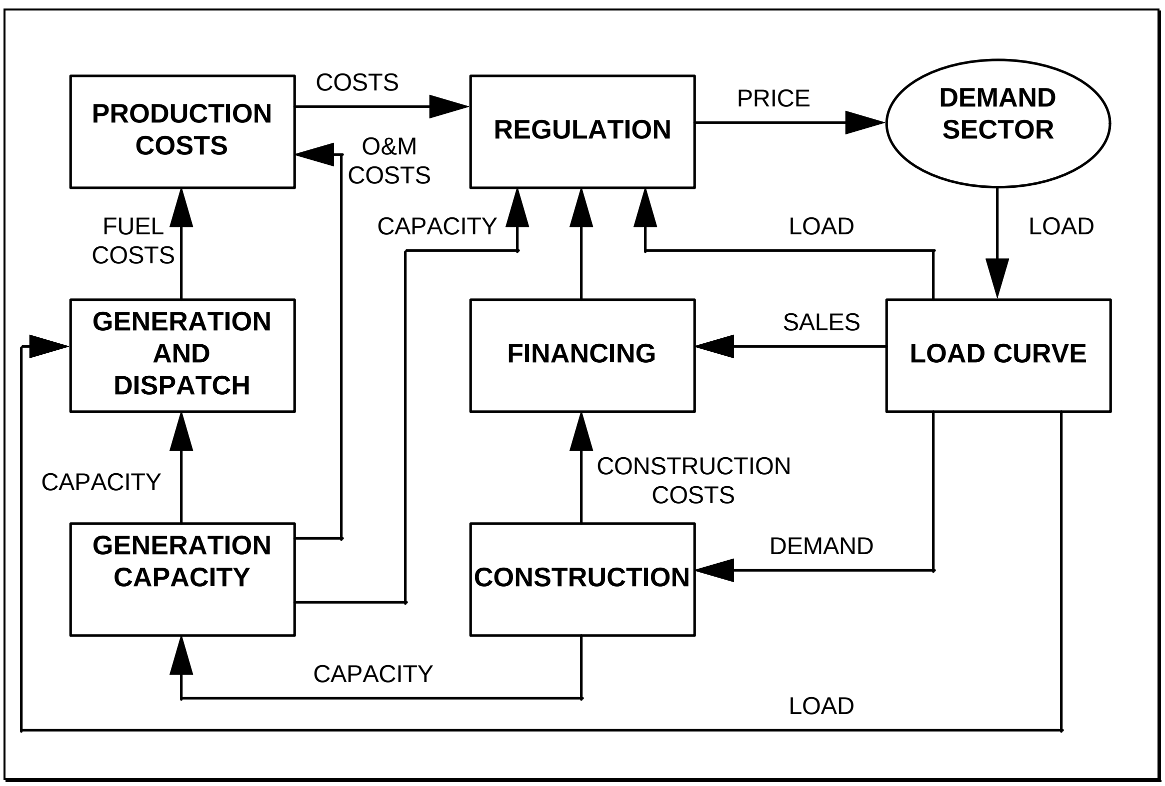

Figure C-3. Basic ENERGY 2020 Electric Sector

ENERGY 2020 also simulates the detailed operation of Hawaii's four regulated electric companies and one regulated gas company operating. Figure C-3 depicts the basic ENERGY 2020 electric utility sector. The model endogenously forecasts capacity needs, as well as the planning, construction, operation, and retirement of generating plants and transmission facilities. In the model, revenues, debt, and the sale of stock finance each step. Like their real-world counterparts, the simulated utilities pay taxes. The model also generates a complete set of accounting books. In ENERGY 2020, the regulatory function is modeled as a part of the utility sector. The regulator sets the allowed rate of return, divides revenue responsibility among customer classes, approves rate base, revenues and expenses, and sets fuel adjustment charges. Detailed supply sectors for oil refining on Oahu, and air and marine transportation statewide, were also explicitly modeled.

ENERGY 2020 has a pollution or emission accounting module to keep track of pollution generation by end-use and fuel from the demand sector; and supply/plant type from the utility sector. ENERGY 2020's pollution accounting module also tracks energy-related pollution in the transportation sector by mode, and in the industrial sector by two digit SIC code. The greenhouse gasses CO_2, CH_4, and N_2O are also tracked. The pollution generation levels are fed back to the supply sectors, which allows policies to be introduced that adjust production to meet environmental constraints.

C.1.2. ENERGY 2020 Data Sources

ENERGY 2020's internal national and state databases contain historical economic, price, and demand data by economic sector, fuel, and end-use. Region and utility-specific data override and supplement aggregate data when available. The Hawaii configuration of ENERGY 2020 used the reports from HES Projects 2, 3, 4, and 5, FERC Forms 1, FERC Annual Reports, and utility Integrated Resource Plans (IRPs), as well as other local data supplied by DBEDT to model the economy, demand, and supply sectors. The ENERGY 2020 data files were fully documented with all data sources noted.

C.2. ENERGY 2020 and the REMI Economic Model

The Regional Economic Models, Inc., macroeconomic forecasting model is used to create the specific economic drivers for ENERGY 2020's energy forecast. The current state population and economic forecast (State of Hawaii, 1997b) was used to calibrate the REMI model, and REMI was used to forecast economic drivers. The REMI service-area-specific model simulated the competition between the local service area and the "rest-of-the-world" for markets, business, and population. ENERGY 2020, when linked to REMI, captures the feedback impacts of rates, construction, and conservation programs on local economic growth, employment, and energy use.

C.2.1. The REMI Model and Its Relationship to ENERGY 2020

Four integrated economic and energy models representing the four counties Honolulu (Oahu), Maui (including Molokai and Lanai), Hawaii, and Kauai were developed. Each has a REMI model simulating the economic future of that county and an appropriate version of ENERGY 2020 simulating that county's energy markets. When all four county models are run simultaneously, inter-county interactions are captured, as the forecast is executed a year at a time.

ENERGY 2020 is fully linked with the REMI model which allows the energy prices and price changes generated in ENERGY 2020 to dynamically interact with REMI's economic forecast. The economic forecast changes then flow back to ENERGY 2020, affecting future demand, utility rates, and resource planning.

Personal income and gross output by industry from the REMI model are the principal drivers for ENERGY 2020. Other REMI variables used in the ENERGY 2020 databases include population, new capital investment, gross regional product (GRP), and employment. The different sectors of ENERGY 2020 in the Hawaii model include: residential, commercial, industrial, and transportation demands; electric utility; regulated utility and unregulated gas service; and oil refining. Each is driven by one or more economic variable. For example, personal income is the principal driver for the residential sector, while gross output by industry is the principal driver for the commercial and industrial sectors. Policies developed for the regulated and unregulated energy sectors cause energy price changes and possible direct changes in employment which, when fed back into the REMI model, affect the drivers of the other sectors. REMI outputs drive ENERGY 2020, and ENERGY 2020 outputs, in turn, influence the REMI simulations.

Prior to the Hawaii Energy Strategy project, ENERGY 2020 and REMI were linked principally through energy price feedback loops that allowed the simulation of economic changes from changing electricity and gas prices. As the Hawaii version of the ENERGY 2020 model required more detail, new feedback loops from utility policy simulations (e.g., supply side, DSM, and economic impacts from transportation policies) were developed and incorporated into the linkage structure. Therefore, the baseline economic forecasts described include any economic alteration from the feedback effects of ENERGY 2020's baseline outputs. As energy policies are developed, changed, and implemented, the model captures these effects and causes the baseline economic simulation to change accordingly.

C.2.2. Structure of the REMI Model

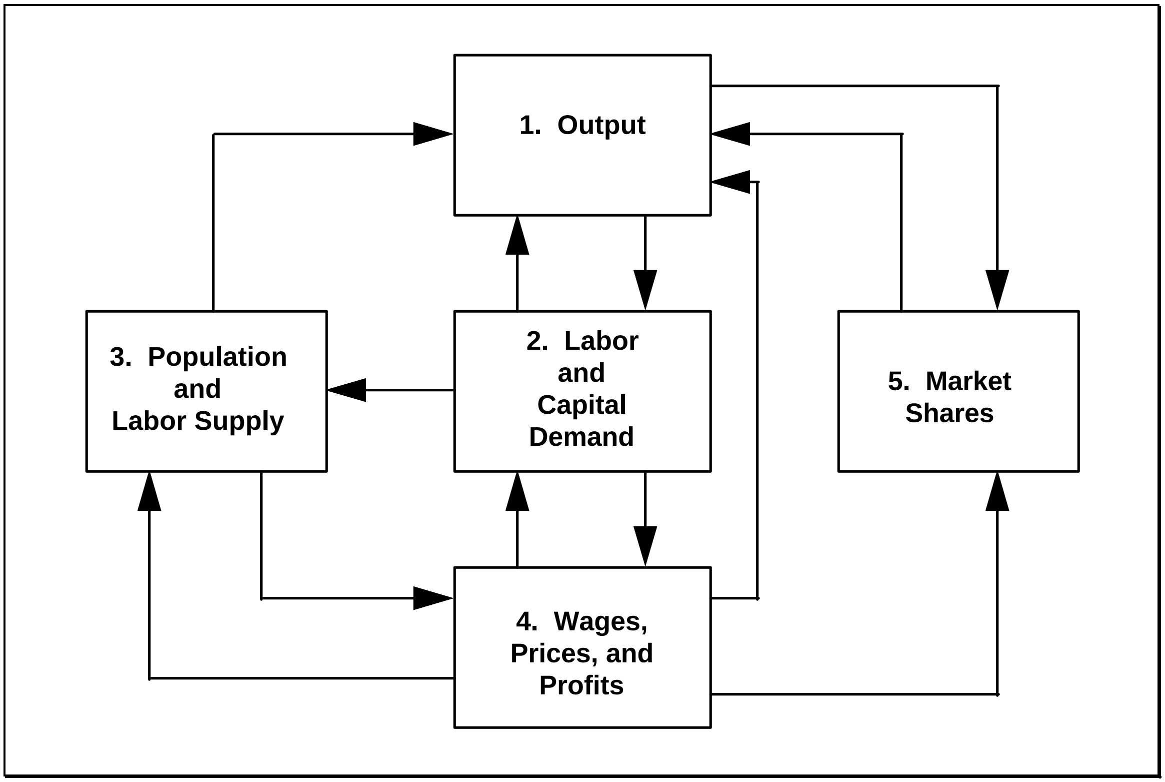

Figure C-4. Structure of the REMI Model

The basic structure of the REMI model is shown in Figure C-4. The REMI model is composed of five sectors or linkages as REMI calls them: output; demand (for both labor and capital); supply (of population and labor); market share; and wage linkage (including prices and profits). These parts are linked to each other through common variables. The local demand for components of personal consumption determined in the output linkage is a function of real income, investment, and government expenditures. Investment demand is also endogenously determined and is a function of both relative factor prices and expected economic activity. Government expenditures depend in part on the size of the local population. When coupled with export demand, these demands determine industry demand by sector and the industry output of the model.

The employment demand by industry and occupation is a function of both local output determined in the output linkage and the number of employees per dollar of output. The latter is determined in part by the relative costs and substitutability of all the factors of production.

Labor supply and population are closely linked. Population by age and sex in the REMI model is calculated in the demographic/migration module from interactions of natural causes (e.g., births and deaths) and migration shifts (for economic or other reasons). Therefore, population depends on migration (retirement, military, international, and economic) as well as the cohort survival aspects of population change. Natural population changes are derived from appropriate fertility and survival rates. Economic migration further depends on expected income, which is calculated from the employment/labor force ratio, the real wage rate and the mix of industries.

The wage rates are determined by the aggregate employment/labor force ratio and occupation specific demand and supply conditions.

Market shares, both locally and in the export market, depend on selling prices and profitability--the ability to compete. Competitive pricing depends on factor costs including labor costs.

C.2.3 REMI Data Sources

C.2.3.1 Primary Historical Data

A complete documentation of the data sources used in REMI (definitions, descriptions and estimation procedures for missing data) can be found in Chapter IV *of Model Documentation for the REMI EDFS-53 Forecasting and Simulation Model,* July 1993, Volume 1. The primary historical data source is the Bureau of Economic Analysis (BEA) employment, wage and personal income series covering the years from 1969 and is available for counties at the one digit SIC code level. A secondary source is the Bureau of Labor Statistics (BLS) annual average employment and total annual wages at the two-digit SIC code level for counties (ES-202 data). Supplementary data sources, such as County Business Patterns (CBP), data were also used when available.

C.2.3.2 Supplemental Historical Data

State-specific fuel cost data came from the Energy Information Administration (EIA) State Price and Expenditure Report. Fuel weight data by SIC code came from 1982 Census of Manufacturers--Subject Series; Table 3 was used for manufacturing and other census data for construction, service, retail and wholesale trade, and agriculture. EIA data were used for transportation and public utilities.

Tax data used to calculate the cost of capital, and to estimate residential and non-residential capital stock, came from the Government Finances (Revenue) publication and the *Survey of Current Business.*

Gross State Product (GSP) data came from BEA and BLS (U.S. input-output table) and the *Survey of Current Business.* Data on housing prices came from the Census of Housing (1970, 1980, 1990).

C.2.3.3 National Forecast Data

The primary set of projections used in the REMI model came from the BLS Outlook 2005 projections published in the November 1991 issue of the *Monthly Labor Review.* Data for compiling the output time series for manufacturing industries are in the Census and the Annual Survey of Manufacturers. For non-manufacturing industries, a variety of sources were used including Service Annual Survey, National Income and Products Accounts data, IRS Business Income Tax Receipts, and other sources.

The 1990 Bureau of Census Survey provides initial population data which were normalized to data from the BEA. Data from Current Population Reports provides fertility and survival rates and five-year cohort rates as well as data on international immigration. Birth and death rates came from the *Statistical Abstract of the United States.* Other sources of data were used for specific components of migration. A complete listing of all data sources and an explanation of how population growth was estimated can be found in Chapter 12 of Volume 1 of the REMI Documentation.

REMI uses a linearly trended forecast from 1990 to 2005. After 2005, the BLS moderate-growth labor force participation rates and the Census Bureau's middle population projections for the U.S. were used to forecast the labor force. Business cycles were added to the U.S. forecast from the short-term national forecast from the University of Michigan's Research Seminar in Quantitative Economics (RSQE). Occupation demands were derived from a fixed-proportion occupation by industry matrix based on the BLS 1990 and projected 2005 National OES Matrices.

C.2.4 Adjustments to REMI Default Data

When available, REMI data from national sources can be overridden with better local data. For the initial REMI forecast, most of the default data were used with the following exceptions.

Local estimates of military employment were used in place of the REMI default data. The national trend is a reduced presence of the military in most local economies. However Hawaii, because of its strategic location, has not experienced the downsizing of the military to the same extent as the rest of the United States. The military employment estimates from the utility IRPs were used to override the default REMI data.

State and local government employment was altered to account for local sentiment against the growth of this sector. The population-driven REMI variable was modified to reflect the trend toward a smaller government presence in the counties where the initial REMI percentages were relatively higher.

Hawaii's tourism-driven economy makes forecasting tourist arrivals very important. The REMI model alone does not forecast visitor census (although it is a policy variable in the model). However, the REMI/ENERGY 2020 interface produces a visitor census calculation and a forecast of defacto population but it is derived in a post-processing routine. As proxy variables for number of tourists, the service industry variables simulated by REMI were evaluated and compared with tourist projection growth rates.

Hotel sales were altered, if necessary and when possible, to grow at a rate compatible with the rate that is forecasted for future tourists. These tourists come from two main markets, Japan and the mainland U.S., even though other Pacific rim countries are increasing in importance and Canada sends a significant number of tourists to Hawaii every year as well. The increase in sales reflects both the anticipated increase in tourist numbers and the different spending patterns of Japanese and U.S. tourists.

In addition to these specific changes, the initial REMI forecast was further altered by the changes caused by the feedback loops in ENERGY 2020 which modify energy prices. Many energy policies simulated in the model resulted in relatively small changes to the baseline economic forecast. These differences were generally ignored.

APPENDIX D HAWAII CLIMATE CHANGE ACTION PLAN WORKSHOP

D.1 The Hawaii Climate Change Action Plan Workshop

The Hawaii State Department of Business, Economic Development & Tourism (DBEDT) and Department of Health (DOH) conducted a Hawaii Climate Change Action Plan Workshop on October 30, 1997 under the sponsorship of Representative Terry Nui Yoshinaga, Chair of the Energy & Environmental Protection Committee of the House of Representatives.

The workshop, which was held in the State Capitol, was part of a project to develop, implement and evaluate a greenhouse gas reduction strategy for the State of Hawaii as part of the U.S. Environmental Protection Agency's State and Local Climate Change Partners' Program. In the first phase of the project, a statewide greenhouse gas inventories for the base line year, 1990, was developed. The second phase, which is currently underway, will prepare a Hawaii Climate Change Action Plan to reduce future emissions at the lowest resource and social costs.

The purpose of the workshop was to report on progress of the state’s effort and to provide an opportunity for interested citizens to provide their views on goals and methods for reducing greenhouse gas emissions. About 100 citizens participated.

The workshop was opened with remarks by Representative Terry Nui Yoshinaga; Maurice H. Kaya, DBEDT Energy, Resources, and Technology Program Administrator; and Dr. Bruce Anderson, Deputy Director, DOH.

To provide a context for the workshop, Steven Alber, DBEDT Climate Change Action Program Manager, reviewed the findings of the Intergovernmental Panel on Climate Change which predict the negative consequences of growing concentrations of greenhouse gases for the planet. A summary of possible effects on Hawaii was also presented.

Denise Mulholland, of the U.S. Environmental Protection Agency’s Office of Policy, presented a review of international and national efforts to control greenhouse gas emissions and mitigate their effects.

The results of Phase I of the program, the Inventory of Hawaii Greenhouse Gas Emissions, Estimates for 1990, were presented by Steven Alber to set the baseline for emission reduction efforts and to provide a better understanding of the sources of Hawaii’s emissions. Under the baseline, Hawaii’s emissions included only civilian uses of energy and other activities in Hawaii. Overseas air and marine, and military uses were excluded. Energy uses dominated with 44% of emissions coming from electricity generation, 36% from transportation uses, and 8% from residential, commercial, and industrial non-electricity uses. Emissions from municipal waste management were also significant at 8%.

The remainder of the workshop sought participant input for use in developing the Hawaii Climate Change Action Plan. A discussion of greenhouse gas emission goals for Hawaii was led by Dr. John Tantlinger, DBEDT Energy Planner. Much of the discussion was centered on the nature of the problem with an apparent reluctance on the part of participants to set specific goals. A transcript of participant comments follows this summary.

The workshop was held shortly after President Clinton had stated the preliminary United States position for then upcoming Third Conference of the Parties to the Framework Convention on Climate Change in Kyoto (held December 1-10, 1997). Some felt the President's stated position proposed too moderate an effort, but there seemed to be a general consensus that Hawaii should not set goals independent of national goals or international agreements. Based upon the discussion, a commitment was made by workshop staff to suggest to the Governor that a letter be sent to the President in support of the President's position. The Governor sent the letter in late November.

The final session of the workshop was a discussion of potential measures to reduce greenhouse gas emissions, facilitated by Steven Alber. Participants discussed each greenhouse gas emission sector in order of its contribution to the problem. Discussions were supplemented by a short overview of the energy sector by Steven Alber, a presentation of energy-efficient building design by Virginia Macdonald, AIA, and a review of ground transportation measures by Maria Tome, DBEDT Alternative Energy Engineer. A wide range of proposals was made in each area. Some proposals were conflicting, reflecting the divergent views of the participants. A transcript of these discussions is included below. The suggestions will be considered in developing the final Hawaii Climate Change Action Plan, and all will be included for the record in the final report.

Work continues on the Hawaii Climate Change Action Plan, which is scheduled to be completed in the first half of 1998. It will suggest options for Hawaii for short-range actions to 2005 and longer-range actions to 2020 to contribute to efforts to reduce greenhouse gas emissions to reduce the negative effects on Hawaii and the rest of the world.

D2 Hawaii Climate Change Action Plan Workshop Discussion

The following is a summary of ideas contributed by participants to the Workshop. The summary is based upon notes taken by recorders during the discussion. These notes have been expanded for clarity and organized topically. They do not reflect the participants' statements verbatim, but attempt to capture their meaning based upon fragmentary notes. In some cases, amplifying information has been added.

Inputs from the workshop will be researched and those that appear to offer benefits will be included in the Hawaii Climate Change Action Plan. At time of the workshop, no more public meetings were planned, but participants were promised a copy of the Plan. Participants were also advised that action would require more work than just issuing a plan. Legislative and citizen action is needed to implement the recommendations.

D.2.1 Discussion of Greenhouse Gas Emission Goals for Hawaii

This discussion ultimately focused on issues and did not result in setting of goals. On the basis of the discussion, a letter was prepared for the Governor to President Clinton in support of the President's position on climate change in preparation for the Kyoto Conference in December. The letter was signed by the Governor and sent in November.

- How much are utilities spending (annually) to reduce energy use?
- Economic benefits of local sources of energy need to be considered.
- Set targets first, not goals.
- Establish legislative position on renewable energy tax credits.
- State must set specific objectives to (policies), e.g., "clean-up regulatory process."
- State should lead the way by improving its own facilities.
- Support sequestering carbon dioxide in green forests (rainforest sinks).
- Other vegetative systems (grasses) more effective in sequestering CO_2. Don't focus only on traditional means.
- Preservation is important.
- What is possible with systems now in place?
- Have United Nations goals been set?
- The time scale is important. Fossil fuels won't last forever. A short-term goal is to "reduce." Reaching the 1990 level is an important intermediate goal.
- Would like to see empirical data on costs and technological systems to gauge benefits.
- An independent third party is needed in the integrated resource planning (IRP) process. Utilities should not be doing their own IRPs.
- State's efforts should be regional and international to efficiently respond to outside impacts.

- Goals/policies are in place (refers to state energy policy). Just need to implement them. Keep qualitative goals, but don't set quantitative goals. There is not enough information.
- Real problem is people and increasing population.

D.2.2 Discussion of Potential Measures to Reduce Greenhouse Gas Emission Emissions in Hawaii

D.2.2.1 Electricity Generation

- Real objective to reduce energy use, and thereby carbon emissions, not necessarily power.
- HECO has action plans under integrated resource planning for efficient generation.

D.2.2.2 Increase Renewable Energy Use

- Hawaii can demonstrate renewable energy technologies.
- OTEC should have renewed support. Reported that Navy is considering OTEC for its facility at Diego Garcia in the Indian Ocean. Offers electricity generation, fresh water production, and cold water for air conditioning.
- Net metering of home energy systems (e.g., rooftop photovoltaic systems) would foster renewable energy systems. Utilities remain opposed.
- Electricity rate structure should encourage small renewable energy use and demand-side management measures.
- Small renewable generators reduce demand for fossil-fueled utility generation.
- Hydroelectric, wave generation, and pumped storage hydro should be considered.

D.2.2.3 Increase Energy Efficiency

- Information on passive cooling and other energy conservation techniques should be made available by DBEDT.
- Time of use rates would foster more efficient energy use by reducing peak demand. At a minimum, electricity customers should be better informed by the utilities about the nature of peak demand, the relative inefficiency of generation at peak, and that avoidance of peak could contribute to reduced electricity rates.
- Environmental benefits and benefits to the economy.
- Demand-Side Management (DSM) creates jobs.

D.2.2.4 Make Buildings More Energy-Efficient

- Louvers for ventilation in the past, moving to more air conditioning. Temperatures are hotter, and there are more burglaries (facilitated by louvered windows).
- Noted that a commitment to high rise buildings is a commitment to air conditioning. Suggested a renewed look at cold seawater air conditioning. The Hawaii State Convention Center designers reportedly researched this and found the payback period to be four years. (Editor's note: cold seawater air conditioning was not built into the Convention Center.) Makai Ocean Engineering was cited as a source for studies.
- The use of cold seawater at the Hawaii Natural Energy Laboratory Authority facility at Keahole on the Big Island was cited as an example.
- It was asserted that 40% of elect in Waikiki is for air conditioning.

D.2.2.5 Tax Credits for Renewable Energy and Emission Reduction

- Support President Clinton's proposed tax incentive for renewable energy resources as outlined in his October 1997 speech.
- Reduce fossil energy demand by using solar, heat pumps, ocean thermal energy conversion (OTEC), etc. An energy investment tax credit is essential.
- Hydrogen and wind generation should also be supported by tax credits (wind is).
- Energy Tax credits are self-regulating.

D.2.2.6 State Government Leadership Needed

- Legislature, executive branches need to be educated on issues.
- Departments should coordinate efforts: E.g., DOH - clean air and health; Consumer Advocate – competition; DBEDT Energy, Resources, and Technology energy efficiency and renewable energy; ERT; Department of Land and Natural Resources – permitting; Department of Agriculture - reforestation, forestry, and agriculture; Department of Transportation – transportation planning, and Department of Accounting and General Services: energy use in state facilities and state vehicle fleets.
- Legislature and Governor should renewable energy tax credit extension to help economy and reduce greenhouse gas emissions.

- State Department of Transportation is part of the problem. Focus is on increasing transportation use, not finding ways to reduce energy use in transportation.
- State should support organic farming to reduce import and use of pesticides, to reduce algae bloom affecting coastal waters and reefs from fertilizer run off, to provide a carbon sink, and to keep drinking water aquifers clean. It would also provide for world-class organic cuisine for the tourist industry and reduce post-consumer waste. Additional jobs would be created and money would be kept in Hawaii's economy rather than exported. Food transportation costs and emissions from food transportation from overseas and the mainland would also be reduced.
- Do we need a State Department of the Environment? Mike Wilson (Director, Department of Land and Natural Resources) did not try to attempt to influence President's statement on Climate Change.
- Reduce or eliminate the subsidy of low-cost parking for state employees in state lots.

D.2.2.7 Transportation Energy Efficiency

- Car maintenance is important to making cars run more efficiently. This includes tune-ups, use of steel-belted radial tires, maintaining proper tire pressure, etc., which can reduce gasoline use (and emissions) by 10-15%.
- Transportation energy use should be considered in land use planning.
- Better public transportation needed, especially on neighbor islands. E.g., hours of service are inadequate on the Big Island, and county and state are not interested in providing service.
- The "More pavement - more cars, pave the way solution" should be rejected.
- Bicycles work!
- Alternate fueled vehicles and new technologies needed. Alternate fuel vehicles, fuel cells, gas turbines powering flywheels, etc.
- Turbo-prop aircraft for interisland transportation are just not time-efficient verses compared to jets (A response to facilitator statement that turbo-prop aircraft may be more efficient on a passenger-mile basis for the short interisland routes).
- Coastal ferries to replace land transportation have been proposed, but it is not clear whether they are more fuel-efficient or workable.
- Set vehicle emissions standards and test at emissions stations.

D.2.2.8 Municipal Solid Waste Management

- Garbage to Energy. Honolulu's H-Power garbage-to energy facility has been effective in reducing landfill (and consequent CH_4 emissions), but there has been a downward trend in waste since 1990. Unlikely to be able to justify cost of additional facilities on Oahu for at least ten years.

- With proper sorting at source, there is no need to increase landfill.
- Greenwaste needed on Big Island. State should subsidize/take over composting. Locally produced compost contributes to the economy by reducing imports.
- County responsibility, but counties need help from state.
- Use cloth bags for groceries (reusable).
- Backyard mulching should be encouraged.
- Economic multiplier effect of recycling should be kept in mind.
- Employ welfare recipients in recycling programs funded by welfare funds.

D.2.2.9 Animal Waste Management

- Aerobic treatment of manure is more energy intensive than anaerobic.

D.2.2.10 Land use Management – Planning and Zoning

- Land Use Commission should not be abolished. Needed to coordinate land use on all islands.
- Land use planning changes are needed. Allow unified local areas to set boundaries and framework for land use. Counties would issue building permits; there would be no planning departments.
- Liberalize zoning laws to allow more mixed uses. Small home business would be allowed in residential areas. Light commercial areas could include residences.
- Transportation corridors should be more carefully developed. Provisions would be made for non motorized transportation.
- Set boundaries of urban areas. Other urban area would be far enough apart to allow agriculture, etc. in between rather than solid development.

D.2.2.11 Land Use Management – Forestry

- Modern forestry techniques should be used. As done currently, tree farming is unhealthy and detrimental to the environment.
- Forestry offers an opportunity to use lands in a manner that offsets CO_2 emissions.
- Rainforest trees being cut, but their CO_2 sequestration value cannot be replaced with grass.

- Examine whether fallow land or planned plantings offer greater offset of CO_2 emissions.
- Forestry can serve as watershed. Need to plant diversified tree crops and use selective cutting to harvest timber. Trees offer benefits beyond just offsetting CO_2 emissions. The State's top-down management has not been accountable to the public in developing forestry projects. For example, the Big Island rain forest is being lost for papaya farming. We need to sequester rainforest.
- Single species forests are not good. Clear cutting can ruin watershed and animal habitats. The growth of some species, e.g., Koa, takes a long time. A better option would be diversified forest and use of selective harvesting.
- Not right to clear cut in a forest-every plant has a function.
- Cut trees/plants but leave roots to capture rain.
- An example was cited of a Dutch requirement for a power company to plant trees to offset emissions. In this case, the trees were planted in South America. (Note: AES Hawaii took similar action in 1991, establishing an offset by preserving a forest area in Paraguay from development.
- Big Island rainforest should be preserved. Need incentives or law to protect the rainforest. Need to protect native species and provide rainforest to sequester CO_2 emissions.

D.2.2.12 Practice Organic Farming

- Reduces fuel and greenhouse gas emissions involved in shipping food to Hawaii and between the islands.
- Reduces packaging required as less protection is required during short distance shipping.
- Growing crops serve as carbon sinks.
- No need for chemical fertilizers that release NO_x and cause algae blooms.
- Provides mulch and greenwaste and uses these byproducts instead of fertilizers.
- Increases sustainability of state and provides in-state employment.

D.2.2.13 Miscellaneous

- Educate the next generation.
- Not using clean technologies does not pay in the long run as the social costs mount up.