Energy Sustainability in the Pacific Basin: Case History of the State of Hawai'i and the Island of O'ahu as an Example

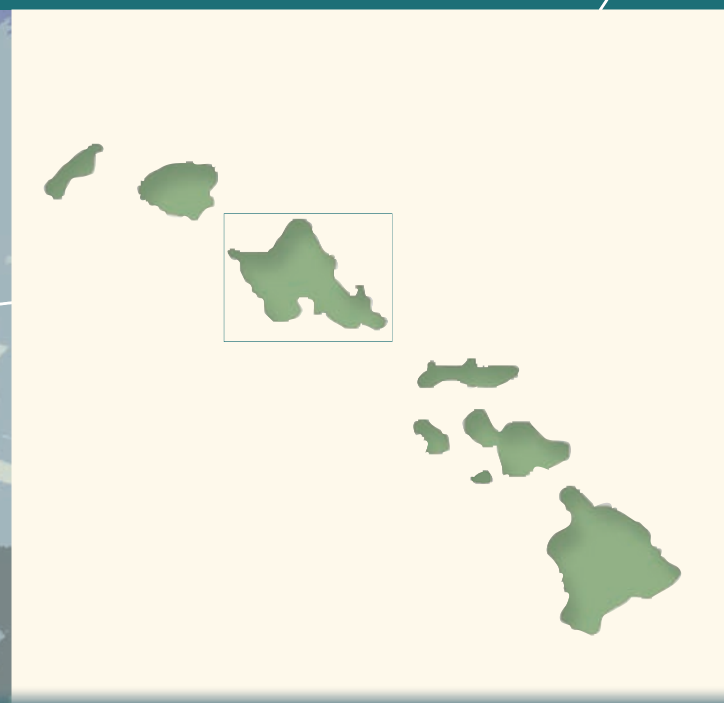

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TABLE OF CONTENTS

PREFACE - Energy Sustainability and Small Pacific Island States

IPAT Equation

As the Earth's population increases to a total of 6.7 billion inhabitants in 2007 and in 2050 to at least 8 billion, all of these individuals will require natural resources to sustain their existence. With the realization that the Earth's resources – air, water, food, energy, minerals, etc. – are being strained to support this unprecedented population growth, the concepts of such sustainability and sustainable development are being examined as a possible remedy to current and future resource problems. Sustainability is defined in many ways, but it implies development (not necessarily growth) that supports human progress not simply in certain places for limited periods of time but for the entire planet far into the future. In this context, development should not come at the expense of future generations and their environment and resource needs.

How do variables such as human population, growth and distribution, degree of affluence and technological innovation impact the Earth's environment and resources? In the early 1970s, Ehrlich and Holdren (1971) suggested that a product relationship between human population (P) and per capita impact function (F) can describe the overall environmental impact (I) that society has on the Earth's environment and natural resources:

$$I = P \times F \qquad (1)$$

After the realization that other factors, such as technology and the affluence of the population, might also play a role in determining the overall environmental impact (I), the equation was altered to:

$$I = P \times A \times T \qquad (2)$$

where P is population, A is affluence, T is technology, and I is overall impact. These equations theoretically can be used to attempt to quantify the impacts of human actions and activities on sustainability.

Importance of Energy to Small Pacific Island States

Looking at the Earth from space, the world's oceans constitute 71 percent of the planet's surface area and land makes up 29 percent. Three primary oceans – Pacific, Atlantic, and Indian – comprise 89 percent of the world's ocean surface area, with the Pacific Ocean having about the same surface area as the Indian and Atlantic oceans combined. The Pacific Ocean includes about 46 percent of the total world ocean area with a wide variety of islands and inhabitants. These islands can be both geographically isolated and devoid of natural petroleum-based energy resources. Because of their distribution and dependence on fossil fuel energy, small island states and Pacific Islanders are particularly susceptible to fluctuations in the global energy market. They share energy-linked vulnerabilities such as:

- pressures imposed on resources by population density.
- limited natural resources.
- geographic isolation from energy distribution centers.

This is not to say that each Pacific Island and its inhabitants are impacted in the same manner and degree by energy requirements. Island to island variations in the relative importance of economic sectors, extent of natural resources, and relative size and distribution of the island population all determine how the future availability and prices of world energy resources will impact Pacific Islanders.

Future Energy Resource Impacts for Small Pacific Island States

From recent modeling projections of Pacific regional climate change for this century, there are several common findings:

- surface air temperatures will increase.
- increased precipitation will occur in some areas and decreased precipitation in others.
- changes in large scale natural climatic variability, such as El Niño, may occur that can impact long-term rainfall and tropical storm frequency and intensity.
- ocean surface temperatures will increase.
- there will be a long-term rise in sea level.

Because of the future problems imposed by climate change such as increasing temperatures and rising sea levels, projected increases in island populations, and the increasing costs of fossil fuels as they become scarcer, the future well-being and way of life of Pacific Islanders are potentially in jeopardy.

Case Study Overview

To investigate how future changes in population will impact the Pacific Islands and their energy resources and needs, this case study focuses on the island of O'ahu, Hawai'i. The island of O'ahu is part of the Hawaiian Archipelago consisting of 132 islands stretching more than 1523 miles from Kure Atoll to the island of Hawai'i (also named the "Big Island of Hawai'i"). The Hawaiian Islands are one the most isolated island systems on Earth, located over 2000 miles from the nearest continental land mass, North America, and the islands of Polynesia in the South Pacific. Due to this isolation, the Hawaiian Islands were one of the last places discovered and colonized by humans. The total population of the Hawaiian Island chain is a little more than 1.2 million. The island of O'ahu is the epicenter of population with approximately 900,000 inhabitants. Honolulu, located on O'ahu, is the state's largest city and also serves as the political and commercial capital.

This case study investigates energy use and sustainability in the state of Hawai'i and specifically on the island of O'ahu. The case study is structured in the following manner:

I. Introduction: Overview of Human Population History, Resource and Energy Usage

II. Hawai'i - Population, Energy, the Economy, and the Environment

III. Sustainability Indicators for Hawai'i's Energy System

IV. Electricity for Hawai'i

V. Improving End-Use Efficiency in Hawai'i's Electricity Sector

VI. Renewable Energy in Hawaiʻi

VII. Improving the Efficiency of Fossil Fueled Electricity Generation

VIII. Can Hawaiʻi Achieve a More Sustainable Energy Future?

The case study leans heavily on information from several sources. Review of the history of the human population and resource use was derived mainly from Our Changing Planet, 3rd edition (Mackenzie, 2003) with updates from other sources. The primary sources of information for Hawaiʻi and its energy situation are the following:

- State of Hawaiʻi and Department of Business, Economic Development and Tourism (DBEDT) – e.g. the 2003 State of Hawaiʻi Databook, the 2000 Hawaiʻi Energy Strategy, the 2004 Annual Energy Resources Coordinator's Report, etc.
- The Hawaiʻi Electric Company (HECO).
- The Gas Company (TGC).
- The United States Energy Information Administration (USEIA).
- The United States Department of Energy (USDOE).

FIGURES

TABLES

APPENDICES - ENERGY CASE STUDIES

A1. Population of Hawai‘i Counties from 1831 to 2000.

A2. Hawai‘i’s Primary Energy by Fuel or Renewable Energy in 2003.

A3. Social (SOC), Environmental (ENV), and Economic (ECO) Energy Indicators for Sustainable Development.

A4. Electricity Generators Producing Electricity for Utility Sale on O‘ahu, 2004.

A5. Electricity Generation for HECO Customers.

A6. HELCO-Owned Electricity Generation for Utility Sale on the Big Island of Hawai‘i, 2005.

A7. IPP-Owned Electricity Generation and Generation Capacity Summary for the Big Island of Hawai‘i, 2005.

A8. Electricity Generation for HELCO Customers (HELCO Annual Report to the PUC and DBEDT Energy).

A9. Electricity Generation for Utility Sale on Kaua‘i, 2005.

A10. Electricity Generation for KIUC Customers.

A11. Electricity Generation for Utility Sale on Maui, 2005.

A12. Electricity Generation for Utility Sale on Lāna‘i, 2005.

A13. Electricity Generation for Utility Sale on Moloka‘i, 2005.

A14. Electricity Generation for MECO Customers.

A15. Additional Energy Efficiency Programs for Consideration.

A16. Summary of High and Medium Emerging Technologies.

A17. Electricity Generated by Renewable Energy Resources in Hawai‘i, 2004.

A18. Renewable Energy Generation Capacity in Hawai‘i, 2005.

A19. A Summary of Major Solar Photovoltaic Projects in Hawai‘i, 2005.

A20. Federal Programs Supporting Renewable Energy.

A21. Other States′ Renewable Energy Policies.

TERMS AND ACRONYMS

AES – Global Energy Cooperation with operations in 27 countries

ANS – Alaska Northern Slope

ANWR – Arctic National Wildlife Refuge

Bagasse – Sugar cane waste burned to create electricity

BTU – British thermal unit. One BTU is equal to the amount of heat required to raise the temperature of one pound of liquid water by 1 degree Fahrenheit at its maximum density, which occurs at a temperature of 39.1 degrees Fahrenheit. One BTU is equal to approximately 251.9 calories or 1055 joules.

DBEDT – State of Hawai'i Department of Business and Economic Development and Tourism

DOE – United States Department of Energy

DNLR – State of Hawai'i Department of Land and Natural Resources

DSM – Demand Side Management

EISD – Energy Indicators for Sustainable Development

EPA – United States Environmental Protection Agency

GSP – Gross State Product

GWP – Global Warming Potential

HB – House Bill

HECO – The Hawaiian Electric Company

HELCO – Hawai'i Electric and Light Company

HRS – Hawai'i Revised Statutes

IAEA – International Atomic Energy Agency

IRP – Integrated Resource Planning

KIUC – Kaua'i Independent Utility Cooperative

kWh – Kilowatt Hours

LPG – Liquid Petroleum Gas

MEC – Model Energy Code

MECO – Maui Electric Company

MW – Megawatts (106 Watts)

MSW – Municipal Solid Waste

OPEC – Organization of Petroleum Exporting Countries (Middle East, Venezuela)

PV – Photovoltaic

RPS – Renewable Portfolio Standards

SB – Senate Bill

SNG – Synthetic Natural Gas

TGC – The Gas Company

USEPA – United States Environmental Protection Agency

USDOE – United States Department of Energy

I. Introduction – Overview of Human History, Resource, and Energy Usage

Prior to the evolution and arrival of humans on Earth, changes in the Earth's atmosphere, lithosphere, hydrosphere, cryosphere, and biosphere had been occurring for billions of years. Global environmental change is nothing new, but what is new are the rates of change that the Earth systems are currently experiencing because of human activities. The rate of change in these systems since the arrival of the human species is more rapid than any other time in history, with the possible few exceptions of massive extinctions that may have been caused by large meteorite impacts. Many, but not necessarily all, of these more recent changes are related to humans and their natural resource needs and requirements. The retrieval, production, distribution, consumption, and disposal of these natural resources along with the continued growth and distribution of the human population on the planet are resulting in drastic changes to the Earth and its environmental ecosystems.

Natural resources are the many different forms of available energy, minerals, and organic matter on Earth that humans can exploit (e.g., iron, coal, wood, oil, etc.). Noncommercial items (e.g., clean air, aesthetic value of landscape, noncommercial organisms that make up an ecosystem) do not necessarily provide monetary gain and ordinarily are not referred to as natural resources. The natural resources that humans are dependent upon may be renewable or nonrenewable. Examples of renewable resources include forests, agricultural crops, and certain types of energy such as wind, solar, tidal, ocean thermal, geothermal, and biomass to name a few. All these resources can be replaced on a short-term basis although that does not necessarily always happen (e.g., deforestation). Other commercial resources such as oil, gas, coal, and minerals are nonrenewable. They are resources depleted by excessive use, because of loss through non-recycling methods of disposal, or because there are fixed supplies of the substance on Earth which take millions of years to replenish by natural processes.

A. Human History and Resource Use

After more than 4 billion years, the first recorded hominids appeared roughly 4 million years ago in Earth's history. The earliest *Homo sapiens* species came on the scene about 400,000 years ago. These early humans were hunters and gatherers, used fire, and made tools. Their population was relatively small and thus had minimal impact on the Earth, its physical and biological systems, and natural resources. Modern humans, Cro-Magnon, evolved 30,000 – 50,000 years ago and developed efficient hunting and gathering skills, thus exerting more control on the habitat and environment in which they lived. In part due to these skills, the species migrated, proliferated, and populated the globe. With the migratory expansion and population growth, the ability of humans to impact their environment also grew in magnitude. At the conclusion of the Pleistocene Epoch 10,000 years ago (Figure 1), the human population was between 250,000 to 5 million people.

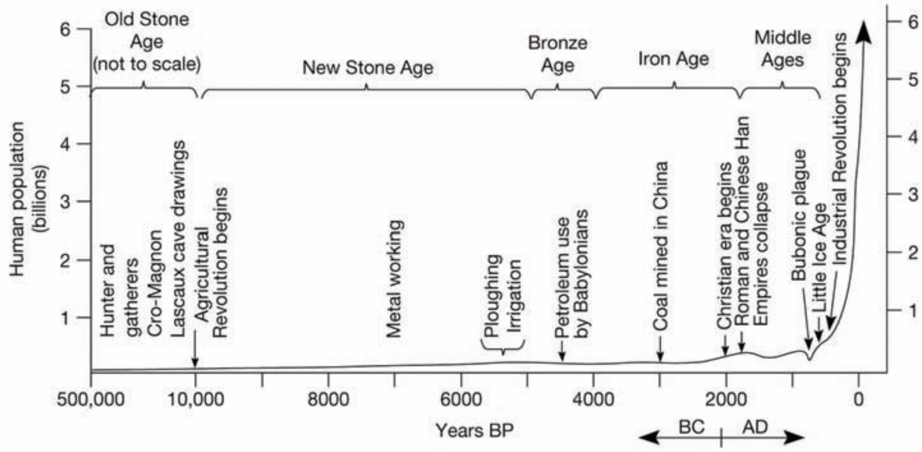

Figure 1. The growth of the world population over the past half million years. Note in particular the rapid rise in population at the dawn of the Industrial Revolution and the decline in population during the Bubonic plague (Mackenzie, 2003).

The Agricultural Revolution (Figure 1) was partly a result of the climatic warming trend at the end of the Pleistocene. Prior to this warming trend, the Earth was in or beginning recovery from an ice-age, which limited the amount of crop growing areas and duration of the crop growing seasons. At the end of the Pleistocene, the human species was just beginning to learn how to manipulate the natural environment for its benefit. This revolution resulted in one of the explosions in human population and the beginning of major, human-induced impacts on Earth's resources. Slash-and-burn techniques were used to create grounds for crop production at the expense of forest land. Animals were domesticated, which in conjunction with the increased agricultural production provided for the dietary needs of a growing population. Both the domestication of animals and agricultural production gave the previous hunter gatherers access to a better and more reliable source of food leading to the establishment of the first permanent settlements about 5,000 years ago. Agricultural communities developed in Pakistan, China, Africa, Egypt, and the Tigris-Euphrates Valley in Iraq.

The change from nomadic hunter gatherer to settlements induced by the Agricultural Revolution allowed more people to live in smaller areas and to establish larger communities. Due to this relatively settled pattern of life, humans could invest their energies in activities other than agriculture, which included development of labor-intensive manufacturing activities such as craft-making and production of goods. In all parts of the world, civilizations developed, advanced, or passed into obscurity during the next few thousand years as evidenced by the history of the Egyptian, Mayan, Incan, Roman, Central Asian, Han, and Grecian empires. The progress made by civilization during the Agricultural Revolution provided the framework for the Industrial Revolution (Figure 1) in the nineteenth century.

Until the last few centuries, between the start of the Agricultural Revolution and the start of the Industrial Revolution, most environmental change and resource use as a result of human activities had been a regional phenomenon and also occurred at a relatively slow pace. The Industrial Revolution's genesis was in Europe and North America and the development of energy-intensive machinery resulted eventually in the mass production of goods and supplies. Energy in the form of wood, coal, and oil was used in these newly developed industries. The steam and internal combustion engines provided power to replace the previous labor-intensive and simple manufacturing techniques developed and used for thousands of years during the Agricultural Revolution. Additional workers and natural resources were needed to sustain the new industrial system and the needs of the growing populations and societies in most areas of the world. More forest area was converted to farmlands and pasture, and energy and food production increased. The overall balance between birth and death rates of previous times shifted towards lower death rates due to the advent of new effective medicines combined with better disease and sanitation controls. All the while, birth rates were relatively constant, which led to continuous world population increase and the demand for conversion of natural resources into energy and commodities for the expanding population increases.

In the early twenty-first century, the world is generally split into developed (i.e., industrialized nations) and developing third world countries. An adequate, if not high (compared to human history) standard of living exists for a majority of people in the industrialized world. The developing world still strives to improve its living conditions and economic status. The latter few decades of the developed world's twentieth century is termed the Technological Revolution, fueled by production and use of seemingly abundant energy, mainly from fossil fuels (coals, oil, and gas), modern advanced agricultural techniques, modern medicines, products of biotechnology, computerized systems, and reliable and efficient communication and transportation systems. Since World War II, resource consumption has dramatically increased and the rates of anthropogenic influences on Earth systems have increased significantly, if not dramatically. Today, natural oil and gas resources are being rapidly consumed and there are estimates that the world production of oil will peak in the first decade of the twenty first century. The stresses on the Earth's natural resource base continue to increase as developed nations try to maintain their prior rate of growth and the developing third world countries try to reach an affluence level approaching that of the developed world.

B. Population Growth

Demography is the study of population and the factors that change its size and distribution. Estimates of world population size around the time of the Agricultural Revolution about 10,000 years ago are between 250,000 and 5 million people. At the time of Christ, the world population was roughly 200 million people and by 1650 A.D. was 500 million. It was not until 1850 that the world's population reached 1 billion. Only eighty years later by 1930, the world's population had doubled again to 2 billion. Forty-five years later, in 1975, the population had doubled again to 4 billion. By 1987, the world population reached 5 billion. At the time of publishing this case study, the world population is estimated at around 6.7 billion people. The future of the world's population is difficult to project because it is a function of a variety of factors, such as future fertility and mortality rates that are difficult to predict. Figure 2 depicts past and present population growth of the underdeveloped, developed, and total world and their future growth based upon current best projections.

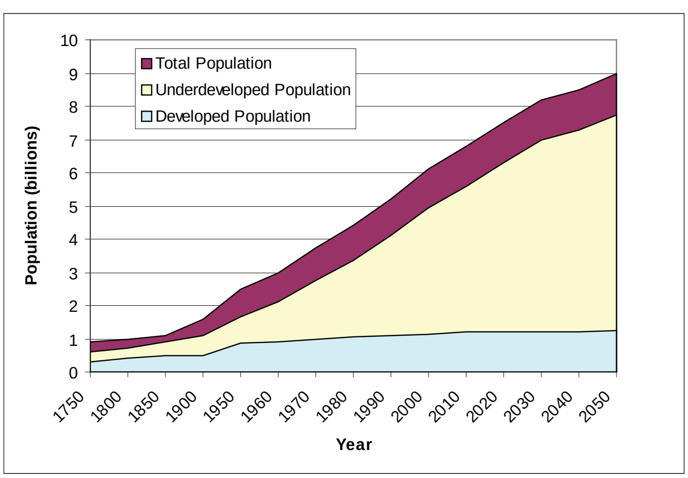

Figure 2. Historical and projected path of total world, underdeveloped nations, and developed nations population growth to the year 2050. Note the large expansion in the underdeveloped nation population after 1950 (After United Nations: www.un.org/esa/population/publications/WPP2004/2004Highlights_finalrevised.pdf).

The growth rate of the world's population peaked in the late 1960s at 2.1 percent per year and has since fallen to presently around 1.3 percent per year.

The doubling time of human population is an example of exponential growth. Exponential growth at a constant growth rate (r) can be described by the following relationship:

$$N_{(t)} = N_{(0)}e^{rt}. \quad (1)$$

N(t) is the number of people at time t, N(0) is the number of people at some starting time = 0, t is time, and e is the natural logarithm with the value of 2.718. In a population experiencing exponential growth, the doubling time can be calculated by:

$$N_{(t)}/N_{(0)} = 2 = e^{rt} . \quad (2)$$

Taking the natural logarithm of both sides gives:

$$0.69 = r \times t \qquad \text{or} \qquad t = 0.69 \times 1/r \quad (3)$$

where t is the doubling time in years and r is the population growth rate. So for example, at the present and constant growth rate of the world's population of 1.3 percent per year, the time to double is:

$$t = 0.69/(0.013) = 53.07 \text{ years.} \quad (4)$$

The projected increase in world population will be distributed unevenly among the world's nations. The more affluent countries are generally experiencing slow rates of population growth and even declining populations, whereas the less affluent, poorer nations are experiencing the greatest gains in population (Figure 2).

C. Energy Resources and Use

During the past 10,000 years or so, humans have tapped into various forms of energy and natural resources. During the Stone Age, the sun was the primary source of energy, as it indirectly provided food via photosynthesis that, in turn, provided energy and nourishment for physical labor. As primitive industries began to appear, muscle power was not enough and so energy sources such as wind, water, wood, and fossil fuels were tapped. As early as 2500 B.C., the Babylonians were using petroleum and by 1100 B.C., China was mining and using coal and gas. Large-scale use of coal, with natural gas and oil quickly following, was ushered in with the resource and energy demands of the Industrial Revolution during the early 1800s. Use of the energy resources – coal, oil, and natural gas – allowed for the refining of metals such as copper, gold, silver, lead, tin and iron by many societies. Presently, commercial goods (food, shelter, water, health care, and clothing), transportation, communications, and the many luxuries of more affluent societies require energy. Figure 3 shows how commercial energy use in the United States has substantially changed over the past 200+ years.

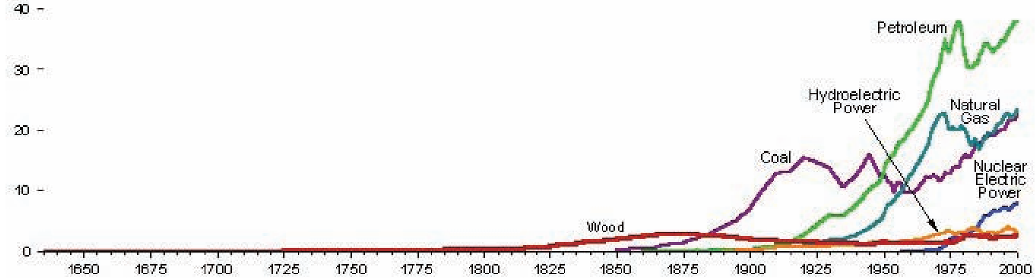

Figure 3. U.S. consumption of commercial energy (in units of quadrillion BTU) from 1650 to 2000 by fuel type (After Energy Information Administration: http://www.eia.doe.gov/emeu/aer/eh/frame.html).

1. Energy Resources

Commercial fuels, traded in commercial market places, include coal, oil, gas, nuclear power, and hydropower and to a lesser extent solar power, wind power, and geothermal power. Production and consumption figures for commercial energy show that fossil fuels account for nearly 90 percent (oil 40 percent, coal 30 percent, gas 20 percent) of the global commercial energy used, and that approximately 5 percent each is derived from nuclear and hydropower (Figure 4). The developed nations consume the vast majority of this energy. With only 25 percent of the world population, the developed nations use more than 70 percent of the global energy budget. With 75 percent of the world population, the developing nations consume only about 30 percent of the current global energy budget (Figure 5).

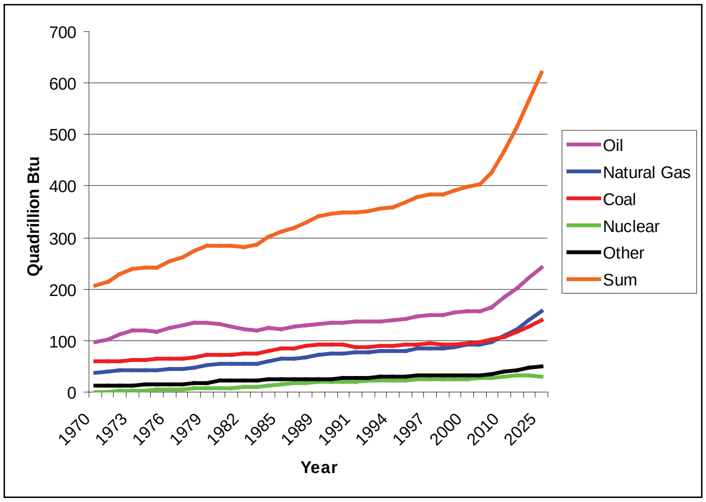

Figure 4. World consumption of commercial energy between 1960 and projected to the year 2020 by fuel type (After Energy Information Administration: http://www.eia.doe.gov/oiaf/ieo/world.html).

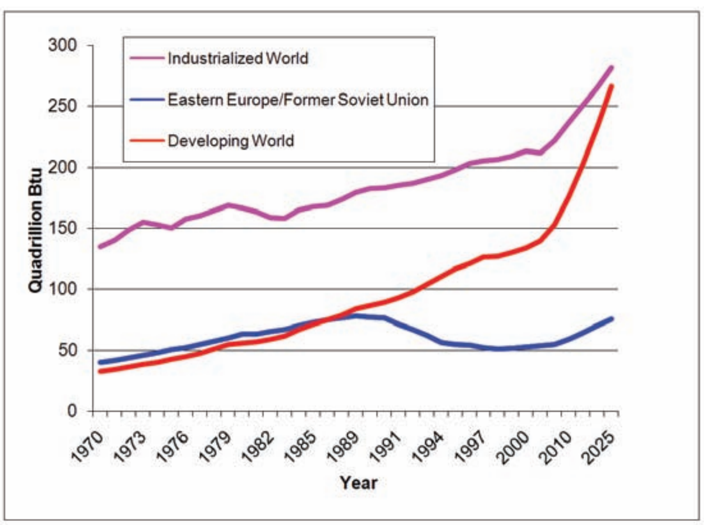

Figure 5. Past commercial energy consumption, 1970 to 2005, and projected energy consumption, 2006 to 2025, by region (After Energy Information Agency, 2004: International Energy Outlook 2004: http://www.eia.doe.gov/oiaf/ieo/index.html).

Developing countries (compared to developed countries) tend to rely more on noncommercial fuels, those not traded commercially, collectively defined as biomass (firewood, charcoal, and animal and crop residues). More people in the world depend on biomass for fuel than any other energy source, although the world's total energy consumption is dominated by fossil fuel. It is difficult to determine exactly how much noncommercial energy is used, but the estimates for the late 1990s suggest that biomass accounted for 11 to 14 percent of the world's total energy consumption. Biomass energy is the main energy source for 2.5 billion or roughly 45 percent of the world's population.

2. Nonrenewable Resources

To sustain the world's large and growing population and demand for adequate living standards, large amounts of energy are needed. Unfortunately, there is only a limited amount of the primary energy resource – fossil fuels – used to provide the energy necessary to drive today's developed countries and their economies.

a. Fossil Fuels

Sedimentary rocks (primarily sandstones and carbonates) are the source rocks for fossil fuels – e.g., oil, natural gas, and coal. The remains of dead animals and plants are encased in the sedimentary rocks and subjected to increased temperatures and pressures via burial during millions of years. When combusted, these fossil fuels release their stored energy. Since the fossil fuels are a product of animals and plants, their combustion releases carbon dioxide, sulfur dioxide, and other previously contained substances to the atmosphere. These emitted substances are the major cause of air pollution and regional air quality problems and acid rain. Fossil fuel burning is also the main source for anthropogenic greenhouse gas emissions. The atmospheric accumulation of these greenhouse gases has led to an enhanced greenhouse effect and global warming.

Out of coal, oil, oil shale, and natural gas, coal is the most abundant fossil fuel. This black combustible rock is comprised primary of carbon, oxygen, and hydrogen (Table 1). Coal deposits were formed from the remains of land plants which first evolved during the Silurian Period (Figure 6) 438 million years ago, and lived mainly in coastland and lowland swamps. The most abundant coal deposits are from the Carboniferous and Permian periods roughly 360 to 286 million years ago and 286 to 245 million years ago, respectively. These deposits are located in the Northern Hemisphere, mainly in the United States and Europe. The second most abundant deposits are found in the former USSR and China and were formed during the Cretaceous Period (144 to 65 million years ago). Figure 7 shows the geographical distribution of the world's coal reserves.

Element	Oil	Natural Gas	Wood	Peat	Lignite	Coal (Bituminous)	Coal (Anthracite)
Carbon	82 – 87	65 – 80	49.6	55.4	72.9	84.2	93.5
Hydrogen	12 –14	1 – 25	6.2	6.3	5.2	5.6	2.8
Nitrogen	0.1 – 1.5	1 – 15	0.9	1.7	1.3	1.5	0.97
Oxygen	0.1 – 4.5	none	43.2	36.6	20.5	8.7	2.7
Sulfur	0.1 – 5.5	> 0.2	none	none	none	0.1 - 6	none

Table 1. Elemental composition of oil, natural gas, wood, and coal. All values are weight percent (adapted from Mackenzie, 2003).

Coal is the most abundant fossil fuel and the world's second largest source of energy. It is a cheap energy source and likely to increase in use throughout the world, especially in countries like China that: (1) have limited petroleum availability, (2) are growing economic powers, and (3) need natural resources to fuel their growth. The coal reserves could last between 200-500 years. The primary problem with coal is that it is a dirty fuel due to the amounts of sulfur, carbon dioxide, and soot released from burning. Central Europe has suffered extensive adverse environmental and human health effects due to their use of coal as a primary fuel source for the past century. Even with the Central European story as a warning to the perils of coal use, China and the United States have indicated every intention of using their massive coal deposits to fuel their growth. "Clean coal" is a misnomer unless the CO_2 emissions derived from its consumption are sequestered. The present day air pollution problems that China experiences are, in large, part due to its coal use.

Eon	Era	Period	Epoch	Millions of years ago
				Today
Phanerozoic	Cenozoic	Quaternary	Holocene	
				0.01 (10,000 years ago)
			Pleistocene	
				1.6
		Tertiary	Pliocene	
				5.3
			Miocene	
				23.7
			Oligocene	
				36.6
			Eocene	
				57.8
			Paleocene	
				65.0
	Mesozoic	Cretaceous		
				144
		Jurassic		
				208
		Triassic		
				245
	Paleozoic	Permian		
				286
		Carboniferous		
				360
		Devonian		
				408
		Silurian		
				438
		Ordovician		
				505
		Cambrian		
				545
Precambrian:				
•Proterozoic				
				2500
•Archean				
				~3800
Hadean				
				4600

Figure 6. Geologic time scale (Mackenzie, 2003).

Petroleum, which includes oil and natural gas, is created by the decomposition of microscopic marine plants and animals. Petroleum is primarily composed of carbon, hydrogen, and oxygen (Table 1). Petroleum deposits are mostly found (60 percent of the oil discovered so far) in Cenozoic and Mesozoic rocks accumulated in underground pools of porous and permeable sedimentary rocks. Petroleum provides 60 percent of the world's commercial energy and drives the world's transportation needs.

Petroleum is also used to heat homes, for industrial energy needs, and to produce chemical fertilizers, Styrofoam products and plastics. Petroleum reserves are distributed around the globe, but are highly concentrated in a few specific areas. Ninety-five percent of the known reserves are found in only 20 countries. The Arab states control more than 55 percent of these reserves (Figures 8a and 8b).

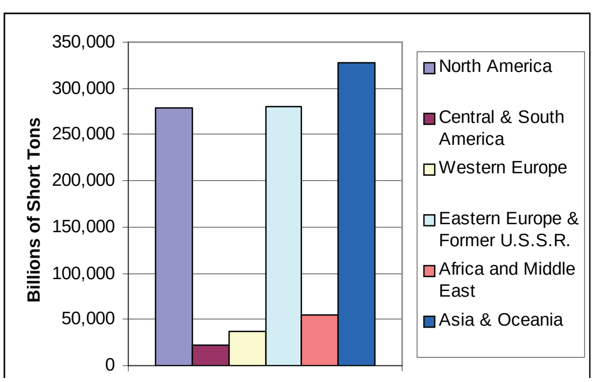

Figure 7. Geographical distribution of the world's coal reserves. One short ton equals 200 pounds equals 0.909 metric ton. Note that Oceania includes New Zealand and Australia (After International Energy Annual, 2003: http://www.eia.doe.gov/iea/).

To date, the world has used more than 500 billion barrels of oil and gas (oil and gas calculated as equivalent). The estimated total reserve for the world is 1.5 trillion to 3 trillion barrels (oil and gas), which includes both the discovered and undiscovered producible petroleum resource. This estimated reserve will be consumed within the next 100 years at the current world consumption rate.

Oil use has been steadily climbing worldwide. Oil provides about 40 percent of the commercial global energy use. The current global oil reserves are about 990 billion barrels and the average estimate of undiscovered producible oil is about 550 billion barrels. The total reserve is thus around 1.5 trillion barrels. During the 1990s, the world oil consumption rate was 22 billion barrels per year. At this rate, the world's known reserves (990 billion barrels) will be consumed within 40 years

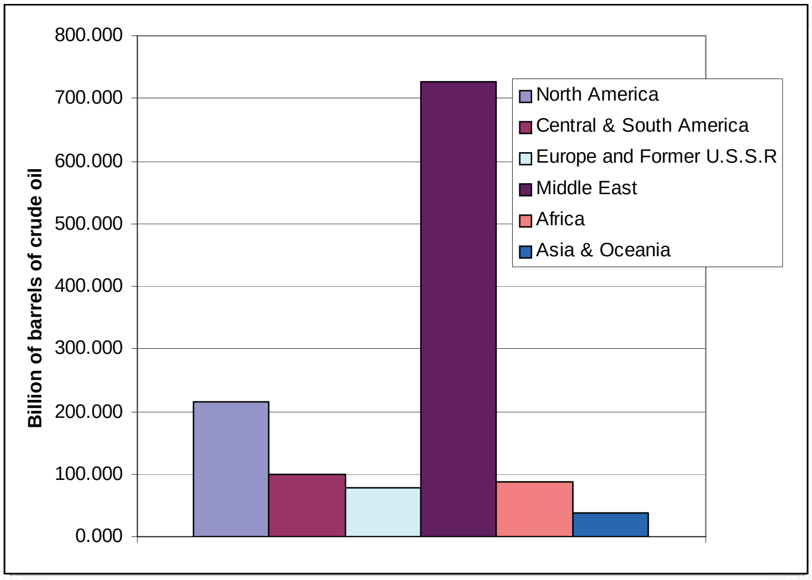

Figure 8a. Geographical distribution of the world's reserves of crude oil from Oil & Gas Journal estimates (After International Energy Annual, 2003: http://www.eia.doe.gov/iea/).

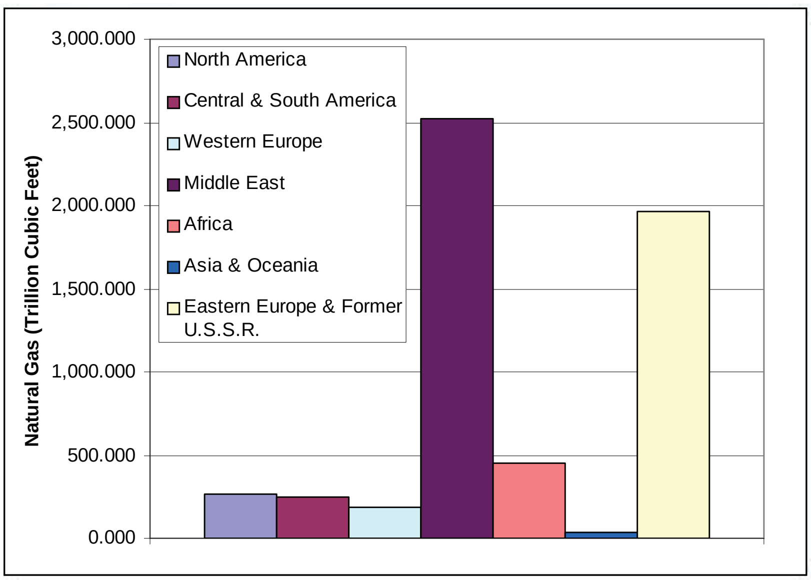

Figure 8b. Geographical distribution of the world's reserves of natural gas from Oil & Gas Journal estimates (After International Energy Annual, 2003: http://www.eia.doe.gov/iea/).

and the total reserve (1.5 billion barrels) will be consumed within 60 years. At the present consumption rate, which is 4.5 barrels of oil per person per year, about 0.4 ton of carbon is emitted per person per year to the atmosphere. More than 50 percent of the world's oil use is by the developed countries, with the United States, Japan, and Western Europe (minus the United Kingdom and Norway) as the main importers of oil. The United States accounts for 25 percent of the world's yearly oil consumption. Sixty-six percent of the oil consumed by the United States is within the transportation sector. Developing nations are finding that their oil needs are increasing as they strive for more affluent societies. In turn, they are incurring a heavy debt to fund this oil use as they spend a great deal of their foreign exchange currency on oil imports. This foreign debt creates a dependency that makes these developing nations susceptible to political and economic pressures from oil-exporting countries. Finally, the United States is currently heavily reliant on foreign oil imports for around 60 percent of its oil needs.

According to the most recent attempts to forecast future oil production, the world's oil production will soon peak ("peak oil" event). One model predicts that the world's oil production peaked in 2005 and will permanently decline in the future (Figure 9). The oil production of the Organization of Petroleum Exporting Countries (OPEC), mostly Persian Gulf countries and Venezuela, has exceeded that of non-OPEC nations around 2007 (Figure 9) and thus is the dominant source of oil to fuel the world's economies. The United States currently receives around 27 percent of its oil needs from OPEC. Much has been made of the Arctic National Wildlife Refuge (ANWR) as a secure source of oil for the United States, but estimates are that the refuge only has between 2 to 5 billion barrels of oil or 1 year's supply at the current consumption rate of the United States. The United States will be heavily dependent on OPEC oil in the future if the status quo is held.

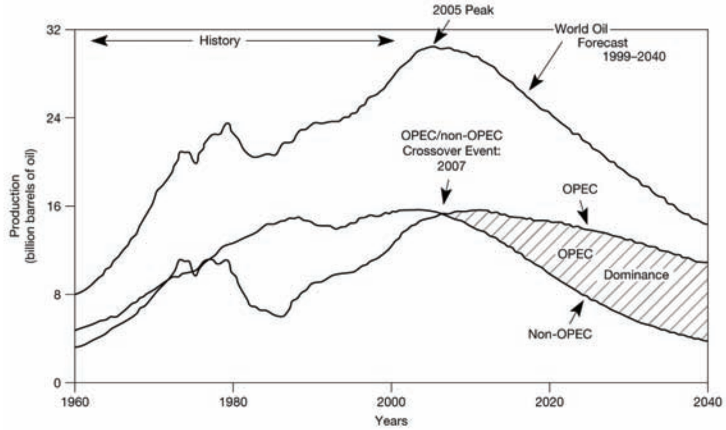

Figure 9. Past and future oil production in billions of barrels per year for the world, Organization of Petroleum Exporting Countries (OPEC), and non-OPEC countries. Note that (1) the peak oil production is around 2005, after which global oil production falls, and (2) production for OPEC and non-OPEC countries intersect around 2007, after which OPEC countries will out produce non-OPEC nations (After Duncan, 2001).

Natural gas is relatively abundant, mostly as methane, and supplies 20 percent of the world's commercial energy needs. Long neglected, natural gas is the fastest growing energy source and can be used as an alternative to oil in a number of fuel sectors. The natural gas reserves may last for up to 60 years. Relatively clean when burned for a fossil fuel, its combustion only emits half of the carbon dioxide that coal does and it also does not contribute to acid rain problems due to its lack of sulfur content.

b. Nuclear Energy

Nuclear energy could be an inexhaustible source of energy. Nuclear reactors provide energy by creating steam that drives turbines and produces electricity. Nuclear energy provides approximately 5 percent of the world's commercial energy needs. In 2000, there were 435 nuclear reactors operating in 25 countries. France, Belgium, Hungary, Sweden, and South Korea get at least half of their electrical power from nuclear energy. There are many individuals that envision nuclear power as a viable solution to future world energy problems. Unfortunately, highly publicized accidents like the 1979 Three Mile Island reactor partial meltdown and the 1986 Chernobyl disaster, the world's worst nuclear accident to date, have resulted in a general unease in many citizens of the United States towards more use of nuclear power. In addition, there is the problem of nuclear reactor waste disposal.

3. Renewable Resources

Only one percent of the total global energy budget is comprised of renewable energy sources. These sources include solar, geothermal, wind, and ocean, but do not include hydropower or biomass. Hydropower and biomass account for 7 percent and 11 to 14 percent of the global total energy budget, respectively. Renewable energy source development is in large part driven by costs and the marketplace. In the short-term, it is currently cheaper economically to use fossil fuel sources of energy compared to renewable sources. The ease of using fossil fuels has retarded investment in research and development in renewable sources of energy. With the eventual depletion and continued elevation in price for oil, renewable sources of energy will likely become more competitive in the world energy market facilitating their increased use in the future.

a. Solar Power

Solar power is an unlimited source of energy, which, if harnessed effectively, could provide an enormous and relatively constant source of energy. In the United States, the relatively cheap costs of oil along with the reduction of government incentives – e.g., dropping of tax credits in the United States for alternative energy research – have been to the detriment of research in solar power during the 1980s and 1990s, but this situation is changing today. Photovoltaic cells are devices that convert sunlight into electricity. These cells have no moving parts for maintenance and produce no pollution, so they are a very promising energy source for the future. In developing countries with abundant sunshine, the cost of installing these cells is often less than the installation of power stations and power lines. The commercial production of photovoltaic cells has increased by 265 percent since 1995.

b. Geothermal and Wind

Geothermal energy is derived from the upper five kilometers of the Earth's crust and is equivalent to 40 times the energy contained in the world reserves of oil and gas. Unfortunately, only a small part of the potential geothermal energy can be exploited. Geothermal steam reservoirs tend to be found near plate boundaries, such as Iceland on the mid-Atlantic ridge, or oceanic hotspots, such as the Big Island of Hawai'i. The steam produced by the reservoirs can power electric-generating plants. Geothermal plants exist in Japan, the former USSR, New Zealand, Africa, Mexico, Iceland, Italy, and the United States.

Harnessing of wind energy has increased in its development and use as the costs to implement have continued to decrease. For example, tiny Denmark is the world's leader, producing more than 20 percent of its electricity from wind power. One drawback of wind energy is the unreliability of wind conditions necessary to produce baseload power, and because of this, wind energy must be supplemented with energy from other sources.

c. Hydropower

The water cycle, which gets its impetus from the sun's energy, provides hydroelectric power. Hydroelectric power is roughly seven percent of the global commercial energy budget. Hydroelectric power is a constantly renewable energy source as long as global precipitation patterns are not significantly altered, which could occur with future global climate change. To harness this source of energy, dams must be built on rivers. The force of water moving through the dam spins a turbine, which in turn creates electricity. Some developing countries, like those in Latin America, have a large potential for hydroelectric power due to their extensive river systems. Hydroelectric power does have its problems though. For example, the river basin populations must be relocated and fertile lands are lost if an area is flooded when a dam is built, such as is occurring with the construction of China's huge Three Gorges dam.

d. Biofuels

Biomass fuels account for 11 to 14 percent of the total world energy use. Wood, organic waste, and other biomass are used to produce energy. Fuelwood is the primary and sometimes only source of energy for half of the world's population. Biomass is not referred to as a commercial energy source because it is difficult to assess how much is used by the global community. Therefore data and estimates regarding the world's commercial energy resources and budget must be assessed with this caveat in mind, given that half of the world uses a semi-quantifiable energy source. Biomass fuel is used in developing nations where other fuels, such as fossil fuels, are too expensive to use. Fuelwood is a renewable source, provided that new trees are planted when mature ones are harvested. Unfortunately, in many areas this does not happen as forests are felled for fuelwood faster than they are replaced – it takes about 30 years to replace wood as a resource. In sub-Saharan Africa, fuelwood use accounts for 80 percent of the total energy consumed. This (over) use has resulted in the severe loss of forests, environmental deterioration, and ultimately desertification.

D. Conclusions

During the time of humans, energy and resource consumption has profoundly impacted and shaped human welfare and populations. As the global human population grew, its activities impacted local, regional, and global aspects of the environment. Beginning around 10,000 years ago, the Agricultural Revolution and resultant growth in population altered local and regional climate, resources, and the environment of many regions around the world. For example, as huge tracks of forest were felled for energy and to make way for agriculture to support growing populations, the pre-Agricultural Revolution Mediterranean hydrological cycle and climate were altered from a wet to the present relatively dry climate.

In the past half century, the growing human population has continued to increase its rate of resource consumption. The dependence of the world's population and economies – past, present, and near future – on nonrenewable energy resources such as fossil fuels and fuelwood to fuel their economic production and growth will lead to a host of problems. These problems include but are not limited to environmental degradation (e.g., acid rain, rainforest destruction, etc.), climate change, energy resource depletion, elevated energy resource costs, political, economic and social pressures, etc. The transition to a more renewable energy-based economy is essential to mitigate these future problems, especially for isolated, nonrenewable energy resource-deficient entities such as island states.

The purpose of the rest of this case study is to investigate: (1) the impact of past, present, and future population growth and affluence on global resource consumption; (2) the dependence of past, present, and future generations on nonrenewable energy sources, especially islands like O'ahu, Hawai'i; and (3) how island states such as Hawai'i can mitigate future energy resource dependency issues. In addition, in order to quantify the statements made in this study, we supply the reader with a significant number of figures and tables in the text and appendices.

II. Hawaiʻi – Population, Energy, Economy, and Environment

Hawaiʻi is one of the world's most remote groups of islands, with the nearest continental land mass being over 2000 miles away. Hawaiʻi's climate is also one of the most diverse on the planet. Of the major biomes on Earth, only the tundra biome is not found in Hawaiʻi. The surrounding tropical ocean supplies moisture to the air year-round. This supply of moisture acts likes a thermostat and keeps seasonal temperature variations to a minimum. The warmest months are August to September and the coolest months are January to February. The islands are usually bathed in northeasterly trade winds due to a semi-permanent atmospheric high pressure cell situated northeast of the islands.

The elevation of Hawaiʻi's mountains and ridges significantly influences the local weather and climate. In Hawaiʻi, rainfall amount and distribution closely follow the topographic contours of the islands. Rainfall is greatest at ridges and windward areas (northeast slope of ridges and mountains) and is least in leeward lowlands. Mt. Waiʻaleʻale on the island of Kauaʻi is one of the wettest places on Earth, receiving 400 inches of rain per year. Elevated windward sides of the islands can receive more than 200 inches per year, and leeward areas can receive as little as 15 inches per year. The leeward areas have mostly dry, warm months and receive most of their rainfall accumulation during storms that occur during the winter months. The windward regions tend to show smaller seasonal variations, because persistent trade wind showers govern their rainfall accumulation. El Niño conditions usually disrupt these patterns, resulting in drought conditions for the entire state and more frequent hurricanes and tropical storms.

Described by Mark Twain as "the loveliest fleet of islands that lies anchored in any ocean," Hawaiʻi is comprised of 137 miles of islands encompassing a land area of 6,442 square miles. There are 8 major Hawaiian Islands: Kauaʻi, Oʻahu, Lānaʻi, Molokaʻi, Maui, Niʻihau, Kahoʻolawe, and Hawaiʻi (sometimes referred to as the "Big Island of Hawaiʻi"). The islands were discovered by Polynesian explorers between the 3rd and 7th century AD and later by the British Captain James Cook in 1778. Hawaiʻi became the 50th state in the U.S. union in 1959. Honolulu, the state's capital city, is located on the island of Oʻahu.

A. Population History

The Hawaiian Islands were settled between 300 and 750 A.D. by Polynesian voyagers arriving in double-hulled canoes. Population estimates vary from 100,000 to more than one million people before Western society discovered the islands with the arrival of Captain Cook in 1778. With Cook and his sailors came measles, influenza, diarrhea, whooping cough and venereal diseases. All these maladies had a detrimental impact on the population. The first census was taken by missionaries in 1831 and the population was around 130,000 (Appendix A1). The state's population decreased until the early 1870s when the total was approximately 57,000. Since then it has steadily increased. Upon entrance into the United States union in 1959, the State of Hawaiʻi was politically divided into counties (Figure 10) of which Oʻahu is the most populated.

The state resident population in 2004 was estimated as more than 1.275 million with 899,593 residing on the island of Oʻahu and population growth at about 1.0 percent per year (DBEDT, 2004), thus, with a doubling time of about 70 years (see eg. 1). The gross state

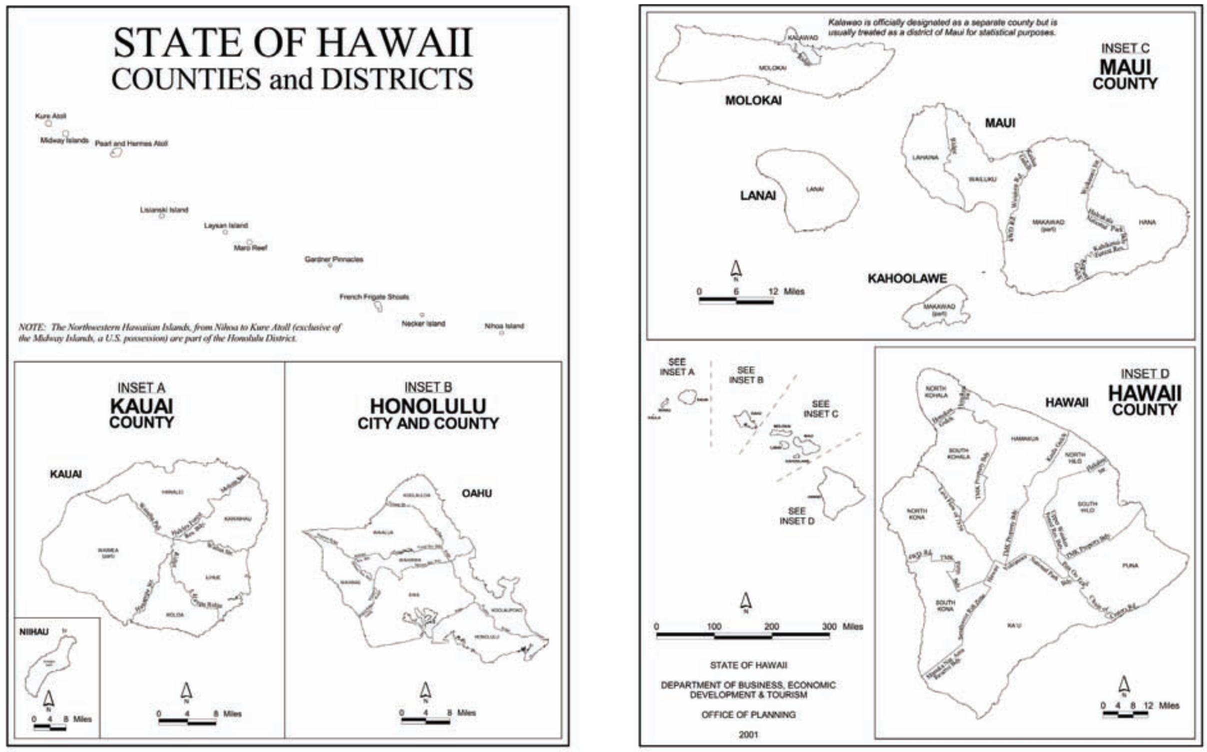

Figure 10. State of Hawai'i counties (DBEDT, 2004).

product in 2004 was 50.1 billion US dollars and the annual per capita income (in 2004) was $32,606 (DBEDT, 2004). Age breakdown for Hawai'i in 2004 was: Under 18 (23.7 percent), 18-64 (62.7 percent), 65+ (13.6 percent). The median age is 37.7 years old. All this information is available at http://www.hawaii.gov/dbedt/info/economic/databook/.

B. The Need for Energy

Energy is essential to modern life. Hawai'i's citizens use energy for transportation, hot water, refrigeration, heating, air conditioning, ventilation, lighting, cooking, operating office and industrial machines, running appliances, and other essential uses. Hawai'i depends on energy to bring visitors from overseas, to sustain its tourism industry and for residents and visitors to travel between the islands. Such travel is principally by air. Energy is needed to bring imports into Hawai'i and to send its exports abroad and to the mainland United States. Hawai'i's people use less energy per capita than the citizens of only three other states, primarily because of Hawai'i's comfortable climate and short driving distances leading to less air conditioning use and gas consumption (DBEDT, 2000). Hawai'i's total energy use of 230.3 million BTU per capita ranked 48th of the states and District of Columbia in 2001 (the latest comparison) – only New York, California, and Rhode Island used less (USEIA, 2004).

C. Energy and Hawai'i's Economy – Renewables, Efficiency, and Risks

Energy is used by the jets carrying visitors and residents to and among the islands. The visitor industry needs energy to provide ground transportation, air conditioning, hot water, and lights to make tourists comfortable. Energy supports Hawai'i's military installations and their operations. Energy is needed to produce agricultural products. Energy lights Hawai'i's stores, refrigerates and cooks food, and provides a myriad of other services. Energy use by Hawai'i's residents is a major component of economic activity and energy-related companies make up a large segment of Hawai'i's economy.

Due to a number of factors, Hawai'i's economy is highly dependent on oil for almost 90 percent of its energy needs. Substantial exports of money are needed to pay to import crude oil and some refined products. These amounts increased significantly during the last few years as oil prices moved up and now seem to have reached a new, higher plateau. Money paid for imports is not used to further develop Hawai'i's economy and does not have local economic multiplier effects. Since much of Hawai'i's energy demand is inelastic, when energy prices rise, more money is used to meet energy needs at the expense of other sectors of the economy.

Renewable energy and energy efficiency offer the economic benefits of keeping money in the local economy and providing greater levels of employment per unit of energy. This results in multiplier effects that enhance the local economy. Energy efficiency and renewable energy can reduce energy bills paid by consumers and businesses, who may then shift their spending to sectors that employ more workers per dollar received (Geller et al., 1992). Hawai'i's residents and visitors use oil to meet 88 percent of their energy needs. Hawai'i's dependence on oil poses risks to its economy from sudden price increases or from supply problems, as were experienced in 1973, 1979, 1991, 1992, 2003, and 2005-2007. An oil price spike can produce considerable short-term economic dislocation and reduce personal income and gross state product.

D. The Links between Hawai'i's Energy Use, the Economy, and the Environment

Hawai'i enjoys a beautiful natural environment that provides pleasant living conditions for residents. Many regard it as "paradise." Hawai'i's economy is based upon its beautiful environment attracting visitors to come to the islands. The challenge is to protect Hawai'i's environment while meeting the energy needs of Hawai'i's people for jobs, income, and a developing economy. Over the long term, energy use in Hawai'i degrades air quality, poses the risk of water and land pollution, and is Hawai'i's major human-caused contribution to greenhouse gas emissions that contribute to global climate change.

1. Energy Use and Air and Water Quality

Hawai'i's air quality meets federal and state environmental health standards because Hawai'i's trade winds and the lack of major polluting industries reduce the buildup of air pollution over the islands (Juvik and Juvik, 1998). Most emissions from energy use are highly regulated by federal and state laws. Transportation fuel use in Hawai'i likely has greater effects than electricity generation and industrial uses, because about twice as much fuel is used for transportation than for the other sectors.

Although the risk of oil spills looms large, the main risk to water quality from energy use is non-point source pollution. Recent implementation of higher standards for fuel storage tanks reduced the potential for leaks, but spills and leaks of small amounts of transportation fuels and lubricants onto pavement or earth can eventually find their way into bodies of standing water or into aquifers.

2. Energy Use, Greenhouse Gas Emissions, and Climate Change

The Earth's weather and climate are driven by energy from the sun. Water vapor, carbon dioxide, and other gases in the atmosphere trap some of the energy from the sun creating a natural "greenhouse effect" (USEPA, 1998a). There is no doubt that due to industrialization, energy use, other human activities, and population growth that greenhouse gas concentrations in the atmosphere have increased. The greenhouse gases (primarily CO_2, CH_2, N_2O, and chlorofluorocarbons) are implicated in the global warming of the Earth's atmosphere.

The climate is expected to continue to change in the future. By 2100, average surface temperatures could increase 1.1 to 6.4 degrees C or 2.0 to 11.5 degrees F and sea level could increase 0.18 to 0.59 meters or roughly 7 to 23 inches (IPCC, 2007), and perhaps as much as one meter. Significant changes in air and ocean circulation patterns could significantly alter global climate and the ecological balance among species.

3. Climate Change and Hawaiʻi

Honolulu's average temperature has increased by 4.4 degrees F over the last century, most likely mainly due to the urban heat effect. Rainfall has decreased by about 20 percent over the past 90 years. By 2100, average temperatures in Hawaiʻi could increase in all seasons. It is not yet clear how the intensity of hurricanes might be affected, but it is expected that there would be more frequent and more severe thunderstorms. Table 2 lists some of the possible impacts of future projected climate change on Hawaiʻi.

Areas	Possible Impacts of Projected Climate Change
Effects on Human Health	• Increased rates of heat-related death and illnesses, increased respiratory illnesses, and viral and bacterial contamination of fish and shellfish habitats. • Expansion of the habitat and infectivity of disease-carrying insects could increase the potential for malaria and dengue fever.
Sea Level Rise	• Flooding of low-lying property, loss of coastal wetlands, beach erosion, saltwater contamination of drinking water, and damage to coastal roads and bridges. During storms, coastal areas would be increasingly vulnerable to flooding.
Water Resources	• Increased evaporation and changes in rainfall. • While increased rainfall could recharge aquifers, it could also cause flooding. • Frequent and long droughts due to climate variability.
Agriculture and Forestry	• Agriculture might be enhanced by climate change, unless droughts decrease water supplies. • Forests may find adapting to climate change more difficult.
Ecosystems	• 70 percent of U.S. extinctions of species have occurred in Hawaiʻi, and many species are endangered. Climate change would add another threat. • Higher temperatures and acidic seas could damage or kill coral reefs.
Economy	• A combination of higher temperatures, changes in weather, and the effects of sea-level rise on beaches make Hawaiʻi less attractive to visitors. • Adapting to sea-level rise could be very expensive, as it may necessitate the protection or relocation of coastal structures.

Table 2. Possible impacts of climate change on Hawaiʻi (USEPA, 1998a).

E. Meeting Hawaiʻi's Energy Needs

1. Hawaiʻi's Energy Requirements

In 2003, Hawaiʻi used 319 TBTU (10^{12} BTU) of energy (See Appendix A2 for a summary of Hawaiʻi's primary energy use by fuel or renewable energy in 2003). Renewable energy sources including hydroelectricity, bagasse, municipal solid waste (MSW), wind, geothermal, solar water heating, and solar photovoltaic were 5.6 percent of Hawaiʻi's

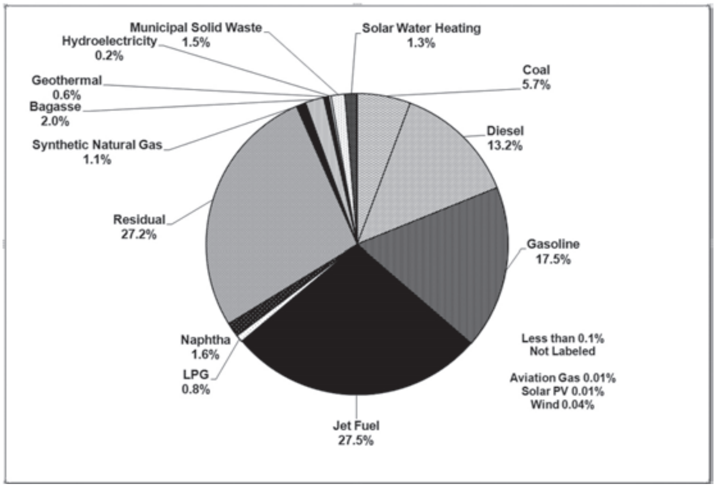

Figure 11. Hawaiʻi Primary Energy Use by Fuel and Sector, 2003 (DBEDT Energy Database, 2003).

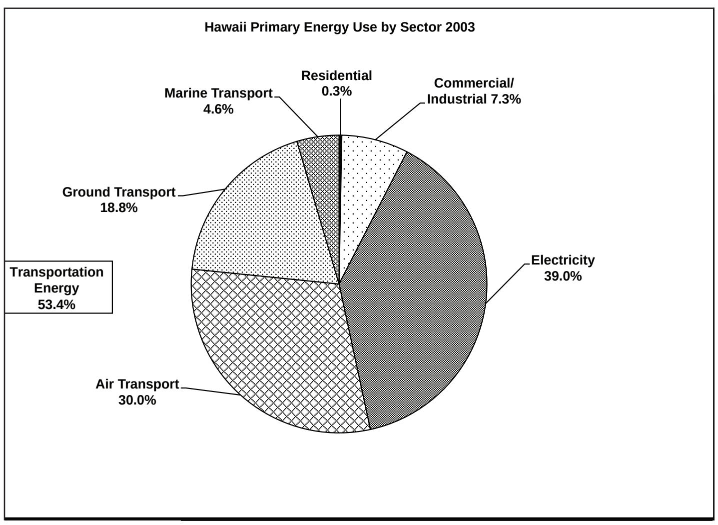

Figure 12. Hawaiʻi Primary Energy Use by Sector, 2003 (DBEDT Energy Database, 2003).

primary energy consumption. Coal provided 5.7 percent and oil, led by jet fuel, residual fuel oil, and gasoline, provided for 88.7 percent of Hawaiʻi's energy (Figure 11).

Hawaiʻi's dependence on oil is the major threat to the economic and environmental sustainability of its energy system. Figure 12 shows primary energy use by sector in 2003: the electricity sector led with 39 percent followed by air transportation at 30 percent and ground transportation using 18.8 percent. Of these three high use sectors, Hawaiʻi is likely to be able to best manage sustainability in the electricity and ground transportation sectors. The residential sector energy use depicted is utility gas and propane. Commercial and industrial uses shown are also direct uses that include self-generation, engine driven mechanical equipment, process heat, and off-road vehicle use. Residential and commercial industrial use of electricity is included in the electricity sector.

Figure 13 depicts Hawaiʻi's energy system. Most energy imports including crude oil, refined products, and coal (for AES Hawaiʻi which is part of AES: The Global Energy Company) are delivered by ship, principally to Oʻahu. Liquefied petroleum gas or LPG and coal (for Hawaiian Commercial & Sugar on Maui) are brought in directly to neighbor island ports. The coal imported to Oʻahu goes directly to the AES Hawaiʻi coal plant via a dedicated conveyor system at Barbers Point Harbor. Some of the refined product imports are used for electricity generation and other refined product imports are sold or distributed to end-users, principally in the transportation sector.

Crude oil imports go to the refineries where they are made into refined products for distribution and sale to end-users. Some refined products such as residual fuel oil and diesel fuel oil are sold to transient vessels as bunker fuel. Some light byproducts of the refining process at the Tesoro Hawaiʻi's refinery are used as feedstock for synthetic natural gas (SNG) production at the adjacent The Gas Company (TGC) manufacturing plant. The SNG is sold to utility gas customers. Diesel fuel oil, naphtha and residual fuel oil are sold to the electric utilities and independent power producers. The remaining refined products are distributed or sold to end-users.

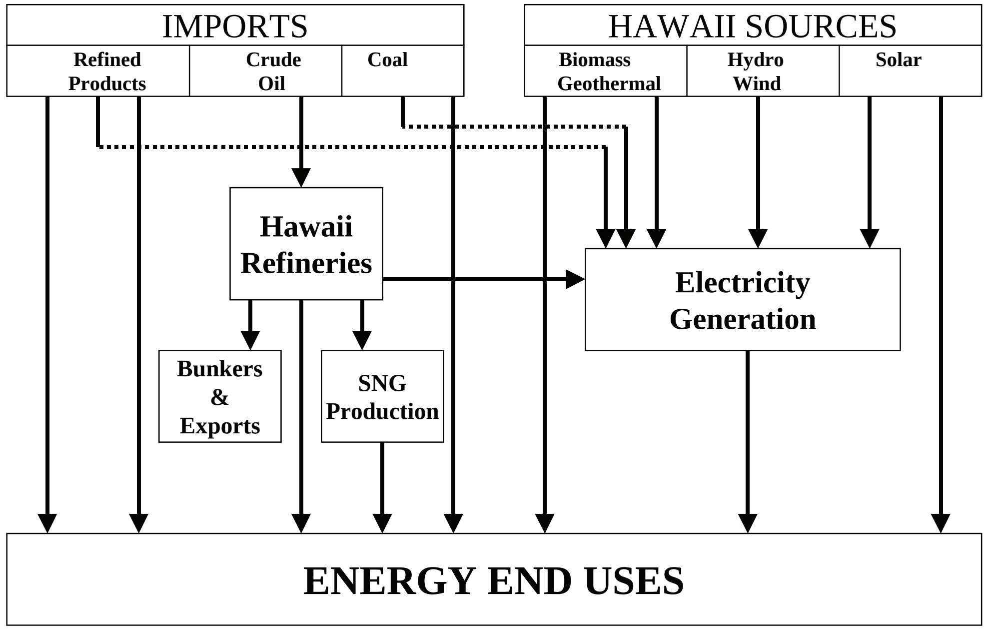

Figure 13. Hawai'i's Energy System (DBEDT, 2000).

It should be noted that the system is fairly well-balanced. To a certain extent, the refineries rely upon electric utilities to use the heavy fuel oil they produce, while emphasizing jet fuel and gasoline production. If the utilities did not use the heavy fuel oil, it would likely have to be shipped to Asia for use as a feedstock in the chemical industry. It is not clear whether or not heavy fuel oil could be shipped to Asia at a profit.

Naphtha is another refined petroleum product that was not previously needed locally. However, beginning in 2000, Kaua'i Power Partners began using naphtha as a fuel in its combustion turbine. Hamakua Energy Partners on the Big Island of Hawai'i also uses naphtha as the fuel for a 62 MW dual train combined cycle unit. Naphtha is less expensive than diesel and was previously shipped to Asia for use as a chemical feedstock.

Hawai'i's renewable energy resources, including biomass (sugar bagasse, municipal solid waste, etc.), geothermal, hydroelectricity, wind, and solar photovoltaic provide electricity generation. Note that while solar water heating does not produce electricity, it reduces the amount of electricity that would be required to provide for water heating if an electric water heater was used instead. In addition to serving as a renewable fuel for electricity generation, sugar bagasse also provides process heat for the sugar mill.

2. Crude Oil and Refined Product Imports

Hawai'i has no fossil fuel energy resources. In 2003, Hawai'i imported almost 43 million barrels of crude oil, down almost 24 percent from a high of more than 55 million barrels in 1994. Seventy-eight percent of the oil came from foreign sources and only 22 percent came from domestic sources, principally Alaska. In 2003, refined product imports amounted to 14 million barrels. Imports of refined product were 33 percent of the volume of crude oil imports. High-sulfur fuel oil, naphtha, and distillates were exported in relatively large amounts in the 1990s. Naphtha was usually sold to Asian customers for use as a chemical feedstock. Both the Hamakua Energy Partners on the Big Island and the former Kaua'i Power Partners unit now owned by Kaua'i Island Utility Cooperative (KIUC) now use naphtha as the primary fuel for their combustion turbines, providing a significant local market.

3. Oil Products Refined in Hawaiʻi

Hawaiʻi has two refineries that are both located at the Campbell Industrial Park, Barbers Point at Kapolei, Oʻahu. The Chevron-Texaco refinery started up in 1962 and now has a capacity of 55,000 barrels per day. The second refinery, which is now owned by Tesoro, began operation in 1970 and now has a capacity of 95,000 barrels per day. The refineries operate at about 85 percent to 90 percent of their nameplate capacity (Stillwater Associates, 2003a). Chevron Hawaiʻi maximizes gasoline production for the Hawaiʻi market and provides residual fuel oil to the Hawaiian Electric Company (HECO) (Stillwater Associates, 2003a). Tesoro Hawaiʻi's refinery supplies jet and marine fuels to the trans-Pacific transportation industry. It also supplies gasoline and diesel fuel to the Hawaiʻi market and light naphtha, which is used as feedstock for the manufacture of synthetic natural gas. Each refiner uses its own single point mooring system to offload crude oil and refined products and to load refined products for export. Table 3 compares the typical product slate for the two Hawaiʻi refineries with the average product slate of US refineries. Note how different the Hawaiʻi refineries' percentages are from the national average.

Typical Product Slate for Hawaii Refineries and U.S Average

Product (barrels per day)	ChevronTexaco	Tesoro	Hawaii Percent	US Percent
Asphalt	500	500	1%	3%
Diesel	5,000	14,000	14%	24%
Gasoline	14,000	14,000	20%	52%
Jet Fuel	13,000	26,000	28%	10%
Naphtha	6,000	7,000	9%	3%
Propane	1,500	1,500	2%	4%
Residual	14,000	23,000	26%	4%
	54,000	86,000	100%	100%

Table 3. Typical Product Slate for Hawaiʻi Refineries compared to the U.S. Average.
Sources: Stillwater Associates, 2003a and USEIA, 2005a.

4. Synthetic Natural Gas Production

TGC provides all utility gas service in Hawaiʻi. It serves approximately 36,000 customers through distribution networks on Oʻahu, Hawaiʻi, Maui, Molokaʻi, and Kauaʻi. The largest group of TGC customers is on Oʻahu. Through its main Honolulu distribution network, customers are provided with SNG produced at the TGC plant in Kapolei, Oʻahu. Outside of urban Honolulu, and on Molokaʻi, Maui, the Hilo area of the Big Island of Hawaiʻi, and Kauaʻi, TGC utility gas customers are served with a propane/air mixture through pipelines supplied from storage tanks (TGC, 1999).

The SNG plant manufactures SNG from a feedstock provided by the adjacent Tesoro refinery. The SNG plant can produce 150,000 therms per day (one therm = 100,000 BTU) or 5.475 million BTU per year.

5. Coal Supply

Very low sulfur (0.4 percent) and low ash (5 percent) coal for the AES Hawaiʻi 180 MW atmospheric fluidized bed coal power plant is imported under a long-term contract from Indonesia's Kaltim Prima mine. Coal for Hawaiian Commercial & Sugar's (HC&S) Puʻunene Mill is generally imported from Australia.

6. Hawai'i's Renewable Energy Sources

Only about 5.5 percent of Hawai'i's primary energy was produced by indigenous renewable energy sources in 2003. Biomass, municipal solid waste, geothermal, hydro electricity, solar water heating, solar photovoltaics, and wind were used to produce electricity. Biomass was also used to produce process heat and solar energy was used for food drying and to heat water.

F. Balancing Energy Needs, Economic Growth, and Environmental Protection to Create a Sustainable Energy System

The challenge faced in creating a sustainable energy system in Hawai'i is how to balance energy needs, economic growth, and environmental protection. A reliable energy system is essential to economic growth. In general, efforts to improve energy efficiency can reduce energy costs and permit businesses and consumers to spend their money in ways more productive for the local economy. By investing in efficiency measures and alternative energy resources within the state, expenses may not necessarily be reduced. However, more of the money spent will remain in Hawai'i's economy, creating more jobs and protecting the environment.

G. Conclusions

Hawai'i is one of the most remote island chains in the world. The proximity of the ocean along with the varied geography creates a wide range of climates, ecosystems, and natural beauty that is desirable to both residents and tourists. Hawai'i's isolation and lack of natural fossil fuel resources, in combination with its population and subsequent need for energy create an interesting energy situation. The climate and short driving distances in Hawai'i mean that its residents use less energy per capita than the citizens of all but three other states. The problem that cannot be avoided, though, is that the economy of Hawai'i uses imported oil for approximately 90 percent of its energy needs. The money expended for importing this fossil fuel energy could be put to better use developing the local economy. Renewable energy use and increases in efficiency offer the benefits of keeping money in the local economy and providing greater levels of employment per unit of energy expended. At this point, renewable forms of energy only account for approximately 6 percent of the state's energy use. In addition, renewable energy use offers the ability for the state to reduce its overall fossil fuel emissions that contribute to climate change. Because tourism is an important component of Hawai'i's economy, any negative impact of climate change on the appeal of Hawai'i (e.g., sea-level rise on beaches) would be devastating to the economy. Hawai'i has many reasons to continue progress towards a more sustainable and reliable energy system. The state has access to many renewable energy sources (e.g., winds, waves, solar, geothermal) that would provide greater sustainability, more benefit to the local economy, and more energy independence, at the same time reducing its contribution to global climate change.

The next section of this study will evaluate Hawai'i's energy sustainability and provide an additional description of Hawai'i's system using the Energy Indicators for Sustainable Development created by the International Atomic Energy Agency (IAEA) in cooperation with the United Nations Department of Economic and Social Affairs, International Energy Agency, Eurostat, and the European Environmental Agency.

III. Sustainability Indicators for Hawai'i's Energy System

In this section we examine a set of sustainability indicators in the context of Hawai'i's energy system. These Energy Indicators for Sustainable Development (EISD) were the result of a cooperative, international effort led by the International Atomic Energy Agency in cooperation with the United Nations Department of Economic and Social Affairs, International Energy Agency, Eurostat, and the European Environmental Agency. One goal of this international effort was to provide users with a set of definitions, guidelines, and methodologies for a single set of energy indicators. The authors recognized that no set of indicators can be final and definitive for all regions of the world. It is expected that the indicators will evolve over time and become specific to local conditions, priorities, and capabilities (IAEA, 2005). The indicators are divided into three classifications – social (SOC), economic (ECO), and environmental (ENV). Although intended particularly for use at the national level, due to Hawai'i's geographic isolation, they are useful for examining and describing Hawai'i's energy sustainability. It is expected that through consideration of the indicators in this case study, users may be able to refine the application of the indicators to Hawai'i's situation.

A. Uses of the Energy Indicators for Sustainable Development

Some of the EISD are measures of progress that clearly distinguish between desirable and undesirable trends. Most of the social and environmental indicators fall into this latter category, including such indicators as SOC4 (accident fatalities), ENV3 (air pollutant emissions from energy systems) and ENV6 (rate of deforestation attributed to energy use). However, some of the EISD also must be taken in context. For example, depending on the development choices made, there may be a temporary rise in undesirable effects until a higher level of development is achieved, representing a larger benefit that could outweigh the interim disadvantages. Another example is that when the availability of commercial fuels in developing countries increases, the share of a household's income spent on energy increases (SOC2). This may not be completely positive from a social perspective, since the collection increases of non-commercial fuelwood often involves significant losses of productive time, can contribute to deforestation, and the burning of the wood often has important negative health consequences by creating indoor air pollution. However, in Hawai'i, a state with a modern energy infrastructure and energy services, increasing cost is not desirable.

Other indicators are not intended to be the basis of a qualitative judgment; they merely describe an aspect of energy use. Any of the economic indicators fall into this category. They include ECO1 (energy use per capita) and ECO3 (efficiency of energy conversion and distribution). Energy use per capita might be low in a given country because that country is very poor and can afford little energy. Or, as in the case of Hawai'i, there is high energy efficiency because of a favorable climate and an economy based on services rather than on heavy industry. The indicators need to be evaluated in the context of Hawai'i's economy and energy resources (IAEA, 2005).

As each of the EISD for Hawai'i is described, we provide an evaluation to characterize our view as to the nature of Hawai'i's situation from a sustainable development situation. The areas we believe Hawai'i is doing well in will be characterized as "good". Other areas for which the indicators suggest there will be challenges to Hawai'i's sustainability now or in the future will be marked "concern" or "major concern." Other indicators are marked "no data" or "not applicable" as appropriate. These evaluations will be summarized at the end of this section. The following discussion summarizes some of the major areas of concerns regarding Hawai'i's energy system in terms of each applicable indicator. The remainder of the EISDs and extensive discussion are included in Appendix A3, should the reader want further information and to review them.

B. The Energy Indicators for Sustainable Development

Table 4 below lists the EISD. As mentioned previously, they are divided into three classifications – social (SOC), economic (ECO), and environmental (ENV). Each of the indicators is also classed according to theme and sub-theme. Although it would be desirable to use the same year's data to evaluate each indicator, consistent annual data sets are

Social			
Theme	**Sub-theme**		**Energy Indicator**
Equity	Accessibility	SOC1	Share of households (or population) without electricity or commercial energy,
	Affordability	SOC2	Share of household income spent on fuel and electricity
	Disparaties	SOC3	Household energy use for each income group and corresponding fuel mix
Health	Safety	SOC4	Fatal accidents produced in energy fuel chain
Economic			
Theme	**Sub-theme**		**Energy Indicator**
Use and Production Patterns	Overall Use	ECO1	Energy use per capita
	Overall Productivity	ECO2	Energy use per unit of GDP (GSP)
	Supply Efficiency	ECO3	Efficiency of conversion and distribution
	Production	ECO4	Reserves-to-production ratio
		ECO5	Resources-to-production ratio
	End Use	ECO6	Industrial Energy Intensities
		ECO7	Agricultural Energy Intensities
		ECO8	Services/Commercial Energy Intensities
		ECO9	Household Energy Intensities
		ECO10	Transport Energy Intensities
	Diversification of Fuel Mix	ECO11	Fuel shares in energy and electricity
		ECO12	Non-Carbon shares in energy and electricity
		ECO13	Renewable energy shares in energy and electricity
	Prices	ECO14	End-use energy prices by fuel and by sector
Security	Imports	ECO15	Net energy import dependency
	Strategic Fuel Stocks	ECO16	Stocks of critical fuels per corresponding fuel consumption
Environmental			
Theme	**Sub-theme**		**Energy Indicator**
Atmosphere	Climate Change	ENV1	Greenhouse Gas emissions from energy production and use per capita and per unit of GDP
	Air Quality	ENV2	Ambient concentrations of air pollutants in urban areas
		ENV3	Air pollutant emissions from energy systems
Water	Water Quality	ENV4	Contaminant discharges from liquid effluents from energy systems including oil discharges
Land	Soil Quality	ENV5	Soil area where acidification exceeds critical loads
	Forest	ENV6	Rate of deforestation attributed to energy use
	Solid Waste Generation and Management	ENV7	Ratio of solid waste generation to units of energy produced
		ENV8	Ratio of solid waste properly disposed of to total generated solid waste
		ENV9	Ratio of solid radioactive waste to units of energy produced
		ENV10	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste

Table 4. Energy Indicators for Sustainable Development (IAEA, 2005).

not available. To the extent possible, 2003 or 2004 data will be used. In addition, some EISD simply do not apply to Hawai'i or not enough information is available to draw any conclusions.

1. The Social Energy Indicators for Sustainable Development

Hawai'i is fortunate to be a rich state and part of a rich country where energy and electricity are readily available and relatively affordable. In the global context, the availability of energy has a direct impact on the quality of life and whether people are rich or poor. Energy availability affects a person's employment opportunities and his or her mobility, comfort, exposure to pollution, health, and other aspects of life. Hawai'i's energy is relatively clean, safe, reliable and affordable compared to many poor countries where wood and dung are used for cooking and heating.

Equity and health are two themes of the social dimension. Social equity relates to the fairness and inclusiveness of energy distribution, accessibility, and affordability. Ideally, energy should be available to all at a fair price. Hawai'i meets the equity test since virtually all residents of Hawai'i have access to energy. Many might say that energy prices are too high, but most people can meet their basic energy needs. Low income people can receive payments to help meet their energy needs under certain circumstances. Nevertheless, lower income households typically pay a larger portion of their income for energy than wealthier households. In addition, other factors may add to the energy costs of a low income household. For example, if they own a car, it may be older and less efficient than a car of similar size owned by a richer household. In many cases, household appliances in low income households may require more energy to operate than those owned by richer households. Due to the age of their appliances or lower first cost of relatively new, but less efficient appliances, many low income households will often have less efficient equipment.

The health theme of the social dimension is based upon the premise that the use of energy should not damage human health, but should improve health by improving living conditions. However, the production of energy from fossil fuel or nuclear power has the potential to cause injury or disease through pollution generation or accidents.

2. The Economic Energy Indicators for Sustainable Development

Hawai'i has a modern economy and depends upon a reliable and adequate energy supply. All sectors of the economy — residential, commercial, industrial, transportation, and electricity — require modern energy services. These energy services are the very basic infrastructure that allows economic and social development by raising productivity and enabling local income generation. The availability of energy and its cost affects jobs, productivity, and development.

The economic indicators have two themes: (1) Use and Production Patterns, and (2) Security. The Use and Production Patterns theme has the sub-themes of Overall Use, Overall Productivity, Supply Efficiency, Production, End Use, Diversification (Fuel Mix) and Prices. The Security theme has the sub-themes of Imports and Strategic Fuel Stocks. The first two economic indicators are similar measures of efficiency, or energy intensity.

3. The Environmental Energy Indicators for Sustainable Development

The production, distribution and use of energy create pressures on the environment. The environmental impacts depend greatly on how energy is produced and used, the fuel mix, the structure of the energy systems, and related energy regulatory actions and pricing structures. Environmental indicators can be divided into three themes: Atmosphere, Water and Land. The sub-themes for the Atmosphere are Climate Change and Air Quality. Land is more than just physical space and surface topography; it is in and of itself an important natural resource, consisting of soil and water, essential for growing food and providing habitat for diverse plant and animal communities, that is, ecosystem services that can be priced. Energy activities may result in land degradation and acidification that affect the quality of water and agricultural productivity. Water quality is affected by the discharge of contaminants in liquid effluents from energy systems (IAEA, 2005).

C. Conclusions

Table 5 summarizes our evaluation of the Energy Indicators for Sustainable Development for Hawaiʻi. Again the reader is directed to Appendix A3 for more detailed discussion. The indicators for which we believe Hawaiʻi is doing well are characterized as "good". Other areas for which the indicators suggest challenges to Hawaiʻi's sustainability now or in the future are marked "concern" or "major concern." Other indicators are marked "no data" or "not applicable" as appropriate.

Evaluation of Energy Indicators for Sustainable Development for Hawaii		
Social Indicators		
Indicator	**Description**	**Evaluation**
SOC1	Share of households without electricity or commercial energy	good
SOC2	Share of household income spent on fuel and electricity	**concern**
SOC3	Household energy use for each income group and corresponding fuel mix	no data
SOC4	Fatal accidents produced in energy fuel chain	**concern**
	Economic Indicators	
Indicator	**Description**	**Evaluation**
ECO1	Energy use per capita	good
ECO2	Energy use per unit of GDP (GSP)	good
ECO3	Efficiency of conversion and distribution	**concern**
ECO4	Reserves-to-production ratio	not applicable
ECO5	Resources-to-production ratio	not applicable
ECO6	Industrial Energy Intensities	no data
ECO7	Agricultural Energy Intensities	no data
ECO8	Services/Commercial Energy Intensities	no data
ECO9	Household Energy Intensities	no data
ECO10	Transport Energy Intensities	no data
ECO11	Fuel shares in energy and electricity	**major concern**
ECO12	Non-Carbon shares in energy and electricity	**major concern**
ECO13	Renewable energy shares in energy and electricity	**concern**
ECO14	End-use energy prices by fuel and by sector	**major concern**
ECO15	Net energy import dependency	**major concern**
ECO16	Stocks of critical fuels per corresponding fuel consumption	no data
	Environmental Indicators	
Indicator	**Description**	**Evaluation**
ENV1	Greenhouse Gas emissions from energy production and use per capita and per unit of GDP	**major concern**
ENV2	Ambient concentrations of air pollutants in urban areas	**concern**
ENV3	Air pollutant emissions from energy systems	**concern**
ENV4	Contaminant discharges from liquid effluents from energy systems including oil discharges	**concern**
ENV5	Soil area where acidification exceeds critical loads	no data
ENV6	Rate of deforestation attributed to energy use	good
ENV7	Ratio of solid waste generation to units of energy produced	no data
ENV8	Ratio of solid waste properly disposed of to total generated solid waste	no data
ENV9	Ratio of solid radioactive waste to units of energy produced	not applicable
ENV10	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste	not applicable

Table 5. Evaluation of Energy Indicators for Sustainable Development for Hawaiʻi. Details of evaluation are in Appendix A3.

The following section will briefly discuss the indicators of concern and major concern and suggest a general course of action to enhance Hawaiʻi's sustainability in these areas.

1. Indicators of Major Concern

The indicators of major concern include the following:

a. ENV1 Greenhouse Gas Emissions from Energy Use

Due to growing use of fossil fuels, Hawaiʻi has made little progress in reducing its GHG emissions. While Hawaiʻi's contribution to total global GHG is extremely small, Hawaiʻi will likely be affected by the consequences of global climate change as outlined above. Reduction of fossil fuel use will help reduce GHG emissions.

b. ENV4 Contaminant Discharges from Liquid Effluents from Energy Systems Including Oil Discharges

Pollution of either water resources or ocean beaches could degrade Hawaiʻi's drinking water, reefs, and beaches. A large oil spill could cause a major environmental and economic disaster for Hawaiʻi.

c. ECO11 Fuel Shares in Energy and Electricity

In 2003, 88 percent of Hawaiʻi's energy came from oil, the highest share in the United States. In the electricity sector, about 76 percent of Hawaiʻi's electricity was generated using oil, also the highest share in the United States. Hawaiʻi's extreme dependence on oil makes it more difficult to move to other fuels or renewable options.

d. ECO13 Renewable Energy Shares in Energy and Electricity

Hawaiʻi's renewable energy use was, until recently, in decline. The renewable portfolio standard law, passed in 2004, seeks to increase renewable energy use, but only projects that were under development prior to the passage of the law are nearing construction. There is much room for improvement and more concerted action in this area is critical to sustainability.

e. ECO14 End-Use Energy Prices by Fuel and by Sector

For most types of fuel, Hawaiʻi's prices are among the highest, if not the highest in the U.S. This poses a major problem to the economy, making fuel costs displace expenditures in other categories of commodities and products. Moreover, due to Hawaiʻi's presently major dependence on imported oil, there is little that can be done to mitigate the volatility of world oil markets other than to reduce Hawaiʻi's requirements for oil.

f. ECO15 Net Energy Import Dependency

Hawaiʻi is 100 percent dependent upon imports for its fossil fuels with attendant issues regarding costs and energy security.

2. Indicators of Concern

The indicators of concern include the following:

a. SOC2 Share of Household Income Spent on Fuel and Electricity

With the rise in fuel prices in recent years, the share of household income spent on fuel and electricity in Hawaiʻi has increased. It is expected to increase in the future, placing a burden on not only the poor, but on middle income households. Measures such as the gas price cap law are expected to have little effect.

b. SOC4 Fatal Accidents Produced in Energy Fuel Chain

While Hawaiʻi has had few fatal accidents in its energy system over the years, it cannot ignore fatal accidents in fuel chains elsewhere, which occur when providing oil and coal to the world market.

c. ECO3 Efficiency of Conversion and Distribution

Hawaiʻi's electric utilities have generally reduced the losses to their systems. Further improvement can be realized, especially within the HELCO system, through application of distributed energy resources and new technologies for transmission and distribution systems.

d. ENV2 Ambient Concentrations of Air Pollutants in Urban Areas and ENV3 Air Pollution Emissions from Energy Systems

While Hawaiʻi's climate tends to reduce the concentration of air pollutants, emissions from energy systems can create localized problems and efforts should be continued to reduce such emissions.

3. General Courses of Action to Reduce Concerns and Major Concerns and to Enhance Hawaiʻi's Energy Sustainability

It is clear that Hawaiʻi has some issues regarding energy use and sustainability. Its general dependence upon fossil fuels and high transportation energy use are some of the driving factors for these issues. Hawaiʻi can address these areas of concern and major concern by:

- Increasing the efficiency of energy end uses (Chapter V).
- Increasing the use of renewable energy (Chapter VI).
- Increasing the efficiency of existing and future fossil energy systems (Chapter VII).

Before we proceed to the courses of action that will make it possible to reduce the impacts of the areas of major concern (Chapters V, VI and VII) we will take a look in the next chapter at Hawaiʻi's electricity sector.

IV. Electricity for Hawaiʻi

A. Introduction

As discussed in the previous chapter, Hawaiʻi's energy system is doing well in providing electricity and commercial energy to its people (SOC1). Energy use per capita (ECO1) and energy use per unit of GSP (ECO2) are improving (declining) even as electricity use per capita and electricity use per dollar of GSP are increasing. The increase in electricity use is not necessarily negative since a variety of new electro-technologies provide improved services. The other area in which Hawaiʻi is doing well is avoiding deforestation (ENV6). Of course, with a modern energy system, Hawaiʻi's people are not gathering firewood to meet their basic energy needs.

The concluding section of the previous chapter outlined a number of areas in which Hawaiʻi faces challenges, which were described as areas of concern and of major concern. The general courses of action to deal with these challenges include:

- Increasing the efficiency of energy end uses (Chapter V).
- Increasing the use of renewable energy (Chapter VI).
- Increasing the efficiency of existing and future fossil fuel energy systems (Chapter VII).

What will motivate the people of Hawaiʻi to meet these challenges? In addition, what is necessary to make changes that will result in increased efficiencies and more use of renewable energy? We do not claim to have all of the answers and this case study will not attempt to provide an integrated strategy. However, we will look at a number of challenges, opportunities, and current and possible future options to make the electricity sector of Hawaiʻi's energy system more sustainable. These are offered in this case study for the readers′ use to supplement their own examination of possible options.

We believe the combination of economics, policy, environmentalism and environmental regulation, security concerns, plus existing and new technologies will help lead Hawaiʻi towards a more sustainable future. As in 1973, when the Arab oil embargo and the formation of the Organization of Petroleum Exporting Countries (OPEC) created oil shortages and a rapid run-up of prices, the world faces concerns about availability of oil and rapidly rising prices. The way to reduce the costs of oil and the risks to oil supply is to reduce the need for oil through end-use efficiency, improving the efficiency of existing and future fossil fuel energy systems, and the use of renewable energy.

The 1970s energy crisis led to creation of many government policies and incentives to encourage efficiency and renewable energy, which have been built upon over the last nearly four decades. The environmental movement and the creation of the U.S. Environmental Protection Agency and laws and regulations, which affect energy systems, also tend to encourage efficiency and energy. There are new policies, laws and regulations, and incentives that continue this effort.

While economics help motivate efficiency in the face of rising prices, environmental concerns and environmental regulation also tend to support efficiency and renewable energy. In many cases, however, new technology is required to enable the delivery of necessary energy services with potentially lower cost and less environmental impact.

This chapter will discuss the electricity sector, as it is the largest energy-using sector in Hawai'i and is also the sector showing the greatest increase in energy use and intensity over the past three decades. In addition, it is the sector most able to be influenced by policy as the electric utilities are regulated by the State of Hawai'i Public Utilities Commission (PUC), which is subject to policy guidance from the governor and the legislature. We will not detail the other energy sectors to keep the scope of this case study manageable.

B. Hawai'i's Electric Utilities: Current Status and Challenges for the Future

Hawai'i has four electric utilities serving six major islands. Hawaiian Electric Company, HECO, serves the island of O'ahu, which is also the City and County of Honolulu. It is the largest of the four utilities and is the parent company of its subsidiaries, the Hawaiian Electric Light Company (HELCO - serving the Big Island of Hawai'i), and Maui Electric Company (MECO - serving Maui County including the islands of Lāna'i, Moloka'i, and Maui). MECO operates a separate system on each island. The Kaua'i Island Utility Cooperative (KIUC) serving Kaua'i is an independent cooperative owned by its ratepayers. As we explore solutions to enhance sustainability of the electric system, it should be noted that there are a number of aspects of the Hawai'i utilities that make them unique in comparison to almost everywhere else. As noted above, the utilities operate six independent systems. This presents a special challenge in that they are not interconnected. If a generator fails on one of the systems, it must be backed up by available reserves on the island. Accordingly, each of the utilities typically maintains a high reserve margin. Generally, the minimum load service criteria is to have enough reserve for the largest unit to be on maintenance and for the next largest unit to have an unscheduled outage and still be able to meet peak demand. If there is renewable energy from intermittent sources, such as wind, solar, and run-of-the-river hydro, each island system must provide its own reserves. If the wind is not blowing, or the sun is not shining, or river flow is decreased due to lack of rain, and a renewable energy system is not producing on one island, replacement generation cannot be provided from another island.

We will first focus on the Hawaiian Electric system serving O'ahu. It is the largest system and has recently completed a draft of its integrated resource plan which provides useful information for consideration. It is also facing potential difficulties in meeting near-term peak demand, which may present opportunities for actions that will both meet near-term peak demand requirements and enhance sustainability over the long-term.

C. The Hawaiian Electric Company (HECO)

1. The Current HECO System

HECO serves the island of O'ahu, which is also the combined district of the City and County of Honolulu. HECO is the largest of the Hawai'i electric utilities, and is the parent company of its two subsidiaries, HELCO and MECO. HECO itself is a subsidiary of Hawaiian Electric Industries, which also owns American Savings Bank and Hawai'i Renewables, Inc. HECO-owned generators are fueled by low sulfur fuel oil and low sulfur diesel fuel. HECO does not own any renewable energy systems. HECO-owned units have a maximum capacity of 1,263 Megawatts (MW). In 2004, they produced 4.919 million MWh. HECO purchased an additional 3.247 MWh, or about 40 percent of the electricity ultimately sold to customers, from Independent Power Producers (IPPs) that operated generators with a total capacity of 433 MW. Renewable energy came primarily from the H-POWER waste-to-energy plant with some additional renewable energy from the use of tires and waste oil as a supplemental fuel in the AES Hawai'i coal plant. Appendix A5 lists the location, unit designator, type, fuel, and capacity of the electric generators producing electricity for utility sale on O'ahu in 2005.

Appendix A5 provides a summary of significant aspects of electricity generation sold to HECO customers in 2004, including the net generation, the amount of fuel and units, the total cost of fuel for HECO-owned units, the cost of fuel only for HECO-owned units, and the greenhouse gas emissions in global warming capacity or Tons CO_2-Equivalent (Tons CO2E). Similar information is provided for the IPPs who sell electricity to HECO under power purchase agreements. Fuel prices paid by IPPs are not available or, in the case of renewable energy, may be zero. Instead, the total price paid for the purchased power per kWh is provided. For firm power units, this price generally involves a payment for the energy received by the utility (kWh) and for the capacity (MW) offset by the IPP that the utility does not need to provide.

The total generation shown in Appendix A5 — 8,168,946 MWh — represents the amount of electricity generated and measured prior to transmission on HECO's grid. Ultimately, 7.7 million MWh were delivered to customers after losses of 4.8 percent in the transmission and distribution system.

About 40 percent of the electricity generated for HECO was produced by IPPs under power purchase agreements with HECO. The power purchase agreements have unique terms for payment for energy (kWh) and where the agreement is for continuous delivery of power (except for maintenance periods), a capacity credit is also paid. In some cases, the IPP is also paid for a portion of the value of the fuel inventory that HECO does not have to maintain as the IPP has similar contractual requirements to maintain a certain number of days' fuel on site in reserve. There is also value to HECO in that unit additions did not have to be financed from company resources. For these reasons, there is not enough data to directly compare utility fuel costs with the payments to IPPs on a per kWh basis.

HECO's greenhouse gas emissions were the highest of the four utilities in both absolute value and in amount per kWh at 1.93 pounds CO2E. IPPs on the HECO system produced 1.74 pounds per kWh and the system average, including both utility and non-utility generation, was 1.85 pounds per kWh.

2. HECO's Market

Table 6 provides a general profile of HECO's market. Since 1990, the number of residential customers has increased by 15 percent, accounting for 28 percent of sales and 32 percent of revenues in 2004. Total residential sales increased by 29 percent. The average residential customer used 8,437 kWh, an increase of 11 percent over 1990, and paid $1,113 at a rate 69 percent higher per kWh than 1990 and 74 percent higher than the U.S. average for 2004. HECO's July 2005 residential rates, not including customer charges, were 9 percent higher than the 2004 average and 84 percent higher than 1990.

In the small to medium-sized business market, the number of customers increased by 8 percent over 1990. These businesses accounted for 32 percent of sales and 33 percent of revenues in 2004. They paid an average of $0.1395 per kWh. HECO's large commercial/industrial customers actually declined 3 percent in number from 1990 to 2004 and total sales in this category declined by 2 percent. However, the commercial/industrial sector represents

HECO Market Profile						
Type of Account	Number of Accounts	Sales (MWh)	% of Sales	Revenues	Percent of Revenues	2004 Revenues/ kWh
Residential	253,671	2,140,188	28%	$ 333,262,596	32%	$ 0.1557
Small/Medium Business	33,233	2,447,594	32%	$ 341,487,580	33%	$ 0.1395
Large Commercial/Industrial	354	3,110,732	40%	$ 361,263,126	35%	$ 0.1161
Total	**287,258**	**7,698,514**		**$ 1,036,013,302**	**Average**	**$ 0.1346**

Source: HECO FERC Form 1

Table 6. HECO Market Profile (HECO FERC 1).

only 40 percent of the market and 35 percent of sales revenue. The average rate of $0.1161 per kWh was 68 percent higher than in 1990 and 127 percent higher than the U.S. 2004 average industrial rate.

In September 2003, HECO reported to its IRP Advisory Group that it had 60 accounts representing 42 different customers in 2002 with billings more than $1 million. Together, these accounts represented more than $180 million in billings and used nearly as much energy as all O'ahu residential customers. These included eight Navy accounts, seven Army accounts, and five State of Hawai'i Department of Transportation airport accounts. Such accounts are obviously worthy of a focused effort to identify ways to reduce electricity use.

D. The Hawai'i Electric Light Company (HELCO)

1. The Current HELCO System

HELCO is the third largest electric utility in Hawai'i in terms of sales, but it has the largest service territory of the four utilities. The Big Island of Hawai'i is larger than all of the other islands combined. Appendix A6 shows the HELCO-owned generation on the system. HELCO operates 62.2 MW of medium-sulfur fuel oil (MSFO) fired steam units and 84.9 MW of diesel-fueled combustion turbines. The most recently installed combustion turbine units, Keahole 4 and 5, will be supplemented by a steam recovery generator scheduled for installation in 2009 to create a nominal 60 MW combined cycle unit. HELCO also operates 26.7 MW of internal combustion diesel engine generators. HELCO currently owns and operates several renewable energy resources, including about 2.28 MW of wind at Lalamilo Wells and 2.25 MW of run-of-the-river hydroelectricity above Hilo.

The data from Appendix A7 show the generation operated by IPPs on the Big Island of Hawai'i as well as summarizing the amount of capacity of both the HELCO and IPP systems. HELCO buys two-thirds of the electricity that it sells from IPPs (principally Hamakua Energy Partners), which operates a 60 MW dual train combined cycle unit that runs on naphtha and produces about 37 percent of HELCO sales.

Puna Geothermal Venture (PGV) provides up to 30 MW of geothermal power, which is the largest amount of renewable energy produced on the Big Island. In the past, PGV produced as much as 29 percent of the island's electricity, but in 2004 it produced about 17.4 percent due to problems with its steam source. PGV is a base load power plant, which means its power is available at all times unlike intermittent sources such as wind and solar. The owners of PGV, Ormat Technologies, would like to double its capacity to 60 MW.

In 2005, Apollo Energy concluded a power purchase agreement with HELCO, which will involve re-powering the existing wind farm at South Point with just over 20 MW in new wind turbines. Installation was to be completed in mid-to-late 2006, but has yet to be finished. A new wind farm at Hāwī added about 10.5 MW of new capacity to the Big Island in 2006.

In Appendix A8, there is a listing for Hilo Coast Power, or HCPC, which is not listed in Appendix A7 because it ceased operations when its power purchase agreement expired at the end of 2004. HCPC operated a former 22 MW sugar mill steam unit that burned coal to produce electricity after agricultural operations ended in 1995.

HELCO Market Profile							
Type of Account	Number of Accounts	Sales (MWh)	% of Sales		Revenues	Percent of Revenues	2004 Revenues/ kWh
Residential	58,073	408,963	38%	$	97,764,608	41%	$ 0.2391
Small/Medium Business	11,864	444,354	41%	$	100,696,281	42%	$ 0.2266
Large Commercial/Industrial	61	229,490	21%	$	42,485,974	18%	$ 0.1851
Total	**69,998**	**1,082,807**		**$**	**240,946,863**	**Average**	$ 0.2225

Sources: HELCO Annual Report

Table 7. HELCO Market Profile (HELCO Annual Report to PUC).

Table 7 provides more details on the electricity sold to HELCO customers in 2004. HELCO owned units had greenhouse gas emissions averaging 1.45 pounds of CO2E per kWh. The newer Hamakua Dual-train combined-cycle (DTCC) unit produced only 1.31 pounds CO2E per kilowatt hour, in part because its steam recovery generator uses waste heat from the combustion turbines to generate additional electricity. Due to the large amount of renewable energy produced by IPPs, the overall IPP greenhouse gas emissions are only 1.11 pounds CO2E per kWh. The HELCO system had the lowest emissions of the four utilities at 1.23 pounds CO2E per kWh. Note that while the amount paid to IPPs by HELCO per kilowatt hour on average was a little bit larger than HELCO's average cost of fossil fuel, the amount was probably lower than HELCO's overall generation costs.

Small and medium businesses accounted for 41 percent of HELCO sales, while residential units represented 38 percent of sales. These were trailed by 61 large commercial industrial users who together accounted for 21 percent of sales. Residential sales were up 47 percent since 1990, while sales to businesses were up 53.3 percent. HELCO's electricity costs are the highest of the three HECO utilities and are exceeded in Hawaiʻi only by those borne by Kauaʻi Independent Utility Cooperative member/customers.

E. Kauaʻi Island Utility Cooperative (KIUC)

Until it was purchased from Citizens Utilities in 2002, KIUC was Kauaʻi Electric, a division of Citizens Utilities. A group of citizens on Kauaʻi who led the purchase effort wanted more ratepayer control over the utility's actions. They also hoped that by not seeking a profit and through access to low interest loans guaranteed by the federal government available to cooperatives, they could work to reduce Kauaʻi's electricity rates which were and remain the highest in Hawaiʻi. KIUC's rates are in part higher due to its small size and consequent lack of economies of scale. The ratepayer/owners are also paying off the costs of extensive repairs to the system which resulted from the devastation caused by Hurricane Iniki in 1992.

KIUC's costs are also increased by its extensive use of diesel fuel. When the Oil Pollution Act of 1990 took effect, the utility stopped importing medium sulfur fuel oil for its steam units. MSFO presents a greater potential liability than diesel in the event of an at-sea spill. KIUC operates virtually all of the fossil fuel generation on the island and a small capacity hydroelectric unit that was inherited from Līhuʻe Plantation when it closed in 2000.

Appendix A9 shows the generators owned by KIUC and IPPs that provide power for utility sale on Kauaʻi. The utility's latest unit, a naphtha-fueled 26.4 MW steam-injected combustion turbine, was initially installed by an IPP and was sold to the utility in 2004. This unit increases the efficiency of the KIUC system through the lower heat rate of the steam injected unit and the greater proximity to the main load center at Līhuʻe in comparison to Port Allen. KIUC also operates two additional combustion turbines with a total capacity of 42.9 MW as well as a 10 MW steam unit and nine internal combustion diesel engines driving generators totaling 43.65 MW. In total, KIUC's firm capacity is over 122 MW.

KIUC also operates two small run-of-the-river hydro plants formerly owned by Līhuʻe Plantation totaling 1.3 MW. Līhuʻe Plantation also operated a sugar mill with an 11 MW steam generator that produced electricity using bagasse, but the plantation closed in 2001.

The last remaining sugar plantation on Kauaʻi, Gay & Robinson Sugar, produces electricity primarily for its own use by burning bagasse in a steam unit and operating a small hydro plant. It also has a diesel generator which it only uses for emergency purposes. Additional hydro plants are operated by Kauaʻi Coffee and the Agricultural Development Corporation. These plants are legacies of sugar mills that closed in the mid-1990s.

Appendix A10 shows that in 2004, IPPs produced 7.8 percent of electricity sold to KIUC customers. KIUC's cost for diesel fuel is the highest of the four utilities. Its revenues per kWh are also the highest.

KIUC- owned generators produced 1.56 pounds of CO2E per kWh and the IPPs, which were all renewable, produced no greenhouse gas emissions, bringing KIUC system emissions

KIUC Market Profile

Type of Account	Number of Accounts	Sales (MWh)	% of Sales	Revenues	Percent of Revenues	2004 Revenues/ kWh
Residential	25,180	156,399	35%	$ 42,052,500	36%	$ 0.2689
Small/Medium Business	7,648	124,055	28%	$ 33,688,638	29%	$ 0.2716
Large Commercial/Industrial	121	166,469	37%	$ 41,009,618	35%	$ 0.2463
Total	**32,949**	**446,923**	**100%**	**$ 116,750,756**	**Average**	**$ 0.2612**

Sources: KIUC Annual Report

Table 8. KIUC Market Profile (KIUC Annual Report to PUC).

down to third highest in the state at 1.44 pounds CO2E per kWh. The KIUC market profile in Table 8 shows that residential customers purchase 35 percent of total sales followed by small and medium businesses at 28 percent and 37 percent goes to large commercial and industrial businesses. The average revenues per kWh were the highest in the state.

F. Maui Electric Company (MECO)

1. The Current MECO System

MECO is the second largest electric utility in Hawaiʻi and the second largest of the three HECO companies. MECO serves the three islands of Maui County – Maui, Molokaʻi, and Lānaʻi – with three independent systems.

a. Maui Division

The largest of the three systems, the Maui Division, operates two power plants. Appendix A11 shows the generation for utility sale on Maui from MECO units and from the only IPP on the MECO system, Hawaiian Commercial & Sugar Company. The oldest MECO power plant, at Kahului, has four oil-fired steam units that use medium sulfur heavy fuel oil with a combined generating capacity of 34.2 MW. The larger plant at Maʻalaea includes 15 internal combustion diesel generators that total 97.4 MW, a 58.6 MW dual train combined cycle unit, and two 20.8 MW combustion turbines that are scheduled to be supplemented in 2006 by an 18.2 MW steam recovery generator to create a second DTCC. The current total capacity at Maʻalaea is 215 MW. In addition, the Maui Division operates two 1 MW internal combustion diesels in a distributed generation role at Hana. These are principally used to provide power when transmission lines to Hana are undergoing maintenance or are down for other reasons.

Hawaiian Commercial & Sugar's (HC&S) Puʻunene Mill is the largest remaining sugar mill in Hawaiʻi. It has three steam generators with a total capacity of 44 MW that use sugar bagasse, coal, MSFO, diesel, waste oil, and, occasionally, propane to produce power. The steam generators use renewable sugar bagasse as fuel for about 80 percent of their generation. HC&S substitutes fossil fuels when sugar bagasse is not available in sufficient quantity to meet the requirement of the HC&S power purchase agreement, which is to provide 12 MW of firm power to MECO. HC&S also operates 5.9 MW of run-of-the-river-hydro.

b. Lānaʻi Division

As shown in Appendix A12, MECO operates 10.4 MW of internal combustion diesel at Miki Basin on the island of Lānaʻi.

c. Molokaʻi Division

MECO has a 2.5 MW combustion turbine plus nine internal combustion diesel generators with 12.7 MW in aggregate capacity on Molokaʻi, for a total of 15.2 MW as shown in Appendix A13.

2. Electricity Generation for MECO Customers

Appendix A14 shows the amounts of electricity produced by MECO (including all three islands) in 2004. Note that while the residual fuel oil used by MECO is 80 percent as costly as diesel fuel, its higher carbon content and the inefficiencies of old, oil-fired steam units result in greenhouse gas emissions 2.36 times greater than for the MECO diesel units. MECO-owned generation produced an average of 1.85 pounds CO2E per kWh. HC&S, MECO's sole IPP, produced 0.87 pounds of CO2E per kWh. The MECO system emissions were second highest in the State at 1.78 pounds CO2E per kWh.

3. The MECO Market Portfolio

The market portfolio depicted in Table 9 is for all three divisions of the MECO system. Residential customers account for 35 percent of sales and 37 percent of revenues, while small and medium businesses purchase 32 percent of the MWh and pay 34 percent of revenues. Large commercial and industrial customers use 33 percent of electricity, but only pay 29 percent of revenues due to rates that favor bulk use of electricity. MECO's average revenues per kilowatt hour in 2004 were third highest in the state at 20.87 cents for residential customers, 21.22 cents for small/medium business, and 17.73 cents per kilowatt hour for large commercial/industrial customers.

MECO Market Profile						
Type of Account	Number of Accounts	Sales (MWh)	% of Sales	Revenues	Percent of Revenues	2004 Revenues/ kWh
Residential	52,481	439,507	35%	$ 91,709,969	37%	$ 0.2087
Small/Medium Business	9,229	400,320	32%	$ 84,965,358	34%	$ 0.2122
Large Commercial/Industrial	136	406,088	33%	$ 72,011,365	29%	$ 0.1773
Total	**61,846**	**1,245,915**		**$ 248,686,692**	**Average**	**$ 0.1996**

Sources: MECO FERC Form 1

Table 9. MECO Market Profile (MECO FERC 1).

G. *Utility Integrated Resource Plans (IRP) for the Future*

On October 28, 2005, HECO filed its Integrated Resource Plan for 2006-2025, also known as IRP-3, since it is the third IRP issued, with the Public Utilities Commission. As stated in the introduction to HECO's plan:

> Integrated Resource Planning (IRP) is the process required of each energy utility in the State of Hawai'i to systematically and thoroughly develop long range plans for meeting Hawai'i's future energy needs. IRP evaluates, integrates, and balances both resources that supply resources and resources that reduce or better manage the demand for electricity. The purpose of achieving this balance is to ensure reliability and affordability of electric power for residential and business customers, to support the State's growing economy, and to protect our unique island environment. Because the planning process must proceed in a context of uncertainty, the proposed balance of resources needs to be diverse, flexible, and to reflect community preferences. (HECO, 2005b)

Currently, the other three Hawai'i electric utilities are engaged in various stages of the IRP planning process and will soon produce plans. Chapter VIII contains a discussion of the IRP process, the HECO IRP and its implications for the future of O'ahu's electricity system.

H. *Conclusions*

Hawai'i has four electric utilities (HECO – O'ahu, HELCO – Big Island, MECO – Maui, Lāna'i, and Moloka'i, KIUC – Kaua'i) serving the six major islands. HECO is the parent company of subsidiaries HELCO and MECO. KIUC is an independent cooperative owned by its ratepayers. Any solution for a more sustainable energy system must take into account the aspects that make these utilities unique. First and foremost, the utilities are not connected. The lack of connection means that if a generator fails on one system, it must be backed up by available reserves on that island and not reserves from another utility, as is common practice in other states. Because of this, each utility maintains a large reserve margin to safeguard a loss of power supply in these situations. All the electric utilities presently incorporate renewable energy into their power generation capabilities, but significant increases in new renewable capacity is needed to reduce the state's dependence on imported oil. As previously mentioned, increasing efficiency is another way to reduce energy use. The next chapter focuses on improving end-use efficiency in Hawai'i's electricity sector.

V. Improving End-Use Efficiency in Hawai‘i’s Electricity Sector

A. *Introduction*

According to Bill Prindle, Deputy Director of the American Council for an Energy-Efficient Economy (ACEEE), energy efficiency has been a key to economic and energy security. Efficiency reduces energy intensity. Without existing energy efficiency, the United States would be paying $400 billion more for energy and energy costs would be 10 percent of GDP instead of the current 6 percent. The US would have to use four million more barrels of oil per day, which means energy efficiency has reduced oil requirements by 20 percent. In addition, carbon emissions would be 30 percent higher.

Energy efficiency is something that takes a multitude of different approaches and using only one approach will not be enough. With hundreds of different end-uses, systematic approaches must be used and a variety of policy, incentive, informational, and technological measures must be applied.

The combination of energy end-uses in Hawai‘i creates the total energy demand. In the electricity sector, the end-uses are primarily in buildings, both residential and commercial, and, to a lesser extent, in a limited number of industrial operations. The peak demand, which in Hawai‘i is mostly driven by the residential sector, establishes the amount of electricity generation that the electric utilities must maintain to serve their customers.

There are many barriers to energy efficiency. In the past and present, energy prices do not reflect the full cost of energy use. There is a lack of awareness, expertise, and time on the part of the facility managers, homeowners, and others needed to make good decisions that enhance energy efficiency. In many cases, the first cost of energy-efficient equipment is very high. It may not be apparent to prospective purchasers that the life cycle cost may be much lower. Also, builders, landlords, and purchasing agents typically pay only the first cost and not operating costs and are thus not concerned about energy efficiency from an economic

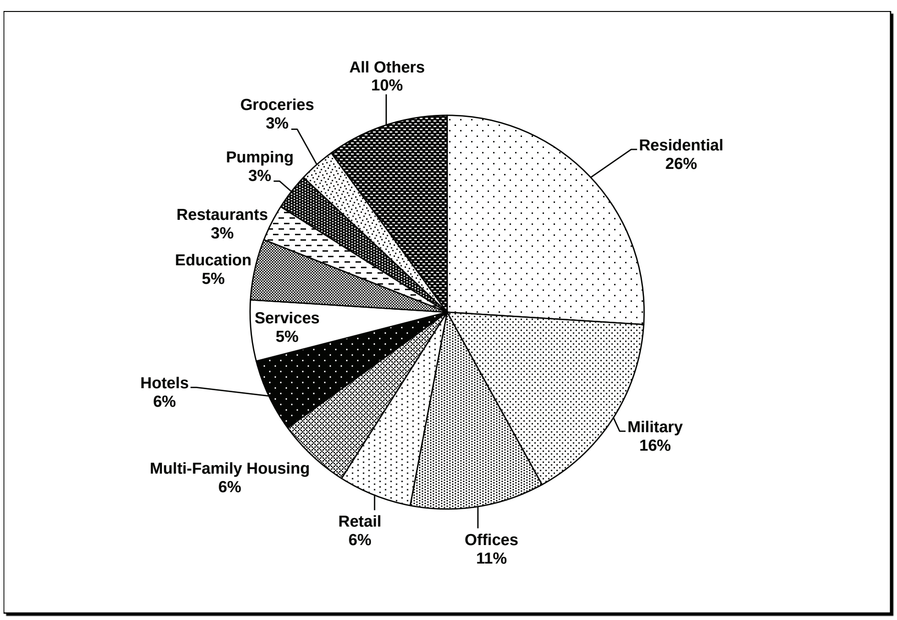

Figure 14. HECO Sales in 2002 by End-Use (HECO, 2005b).

standpoint. It is also difficult to reach members of the building industry with information or to ensure that energy-efficient measures are installed on new construction projects or major remodeling efforts.

B. Hawai'i and Energy Efficiency

In Hawai'i, most electricity is used in buildings. Figure 14 shows the percentages of HECO sales in 2002 by sector. This information is useful in terms of understanding the sources of HECO's electricity demand. Although the residential sector is the largest, it also has the largest number of customers with diverse, individual needs, who present a challenge in designing measures and taking action to reduce demand. It is a very important sector because it drives peak demand, which occurs generally between 6 p.m. and 8 p.m.

Estimated HECO Peak Demand and Energy Use 2004-2025								
	2004	2010	2015	2020	2025	% Increase 2004-2025	% of Total 2004	% of Total 2025
Peak Demand (MW)								
Residential	555	599	655	703	743	134%	44%	45%
Commercial	651	707	759	794	827	127%	51%	50%
Industrial	68	74	79	83	87	128%	5%	5%
Total	**1,274**	**1,380**	**1,493**	**1,580**	**1,657**	**130%**	**100%**	**100%**
Energy (GWh)								
Residential	2,935	3,202	3,517	3,763	3,952	135%	39%	40%
Commercial	4,045	4,459	4,828	5,049	5,220	129%	54%	53%
Industrial	510	562	608	636	658	129%	7%	7%
Total	**7,490**	**8,223**	**8,953**	**9,448**	**9,830**	**131%**	**100%**	**100%**

Table 10. Estimated HECO Peak Demand and Energy Use for 2004-2025 (HECO, 2005b).

Table 10 shows estimated HECO peak demand energy use in the residential, commercial, and industrial sectors from 2004 through 2025. As can be seen, commercial end-uses slightly lead the peak demand and were a higher percentage of electricity sales compared to the other two categories. However, in the early 21st century the residential sector was growing more rapidly than the other two sectors.

If we look at the end-uses in each sector, we can see where demand-side management (DSM) measures might be best applied. DSM is a general term to describe a set of utility programs aimed at modifying customer use of energy to reduce electricity demand.

HECO Residential End-Use Splits		
End-Use	Peak Demand (kW)	Annual Energy Use (kWh)
Space Cooling	23%	12%
Water Heating	14%	17%
Refrigeration	22%	19%
Lighting	17%	19%
Other Appliances	13%	18%
Miscellaneous	11%	15%
	100%	100%

Table 11. HECO Residential End-Use Splits (HECO, 2005b).

Table 11 shows the splits among the end-uses in the residential sector on the HECO system in terms of current contribution to peak demand and energy use or sales. To date, most residential sector demand-side management measures and state tax incentives in Hawai'i have focused on converting electric water heater to solar water heaters. These efforts have enjoyed some considerable success, with approximately 80,000 solar water heaters operating statewide. Solar water heating is generally considered to be a demand-side measure since it is owned by the customer and produces heat rather than electricity. Electricity displaced by solar water heating is also counted as renewable energy.

Distribution of samples to encourage purchase of compact fluorescent lighting is another measure that shows promise. At various times, there have been campaigns to encourage customers to get rid of their second refrigerators that are typically far less efficient than their newer, primary refrigerators and are generally only used to keep beverages cold. Very few houses are air-conditioned in Hawai'i, but the use of air conditioning is increasing. In response, HECO has distributed rebate coupons to encourage purchase of more efficient room air conditioners. As we shall see below in its current integrated resource planning process and a docket on DSM before the Public Utility Commission (PUC), HECO is proposing additional measures to reduce residential peak demand for the future.

Table 12 shows the percentage of energy use by end-use in the commercial sector on the HECO system. While lighting is the largest end-use, it is closely related to ventilation and interior lighting. Typically if interior lighting can be made more efficient, temperatures are reduced in the building, thus reducing cooling and ventilation requirements. Thus, it is more important in commercial buildings to treat the building as a system in planning energy efficiency measures. As Table 13 shows, the majority of peak demand and annual energy use in the industrial sector comes from motors.

HECO Commercial End-Use Splits		
End-Use	Peak Demand (kW)	Annual Energy Use (kWh)
Lighting	43%	31%
Miscellaneous	28%	28%
Cooling	17%	25%
Ventilation	7%	10%
Refrigeration	4%	4%
Water Heating	1%	2%
	100%	100%

Table 12. HECO Commercial Sector End-Use Splits (HECO, 2005b).

HECO Industrial End-Use Splits		
End-Use	Peak Demand (kW)	Annual Energy Use (kWh)
Lighting	3%	3%
Miscellaneous	10%	10%
HVAC	2%	2%
Process Heat	2%	2%
Refrigeration	4%	4%
Motors	79%	79%
	100%	100%

Table 13. HECO Industrial Sector End-Use Splits (HECO, 2005b).

By constructing new residential and commercial/industrial buildings with energy efficiency as an objective, or by retrofitting and modifying old buildings with energy efficiency measures, significant savings in energy can be achieved. An energy-efficient building is also likely to be more comfortable, easier to maintain, and less costly to operate compared to an inefficient building. For more information about what is being done and can be done to make Hawaiʻi buildings more energy-efficient, see the DBEDT web site.

As mentioned above, a variety of approaches are necessary to enhance Hawaiʻi's energy sustainability through energy efficiency. These include a variety of energy efficiency policies including energy codes, energy policies, research, development, demonstration projects, tax and other financial incentives. Programs providing information on tools, appliance and equipment standards, and a variety of voluntary programs such as labeling, ratings, benchmarking, will also help to reduce emissions.

We will now briefly discuss each of these areas and how they impact Hawaiʻi's energy use.

C. Government Energy Policies

The state, county, and federal governments have developed laws, policies, and rules which will likely enhance the sustainability of Hawaiʻi's energy system. Those related to energy efficiency are briefly summarized below. For additional details on state law, consult the Hawaiʻi State Legislature Bill Status and Documents web site at http://www.capitol.hawaii.gov/site1/docs/docs.asp?press1=docs.

1. Energy Codes — The Hawaiʻi Model Energy Code

The Hawaiʻi Model Energy Code (MEC) sets building energy efficiency standards for the State of Hawaiʻi. The MEC includes requirements for the energy-efficient and cost-effective guidelines for buildings and building systems. These requirements are intended to apply cost-effective design practices and technologies which minimize energy consumption without sacrificing either the comfort or productivity of the occupants.

The current Hawaiʻi Model Energy Code is based on the ASHRAE 90.1-1989 Code Compliance Manual, but is also influenced by the most recently adopted California codes (Title 24), ASHRAE 90.2P and the United States Department of Energy (USDOE) standards for non-residential buildings. In addition, many parts of the code have been developed specifically for the unique conditions of the islands such as the requirements for natural ventilation.

To become effective, the County Councils must make the MEC part of their county building codes. Each county has adopted a version of the commercial MEC and the City and County of Honolulu has also adopted a residential energy code.

By reducing peak energy demand, the model energy code also tends to postpone the need for new power plants. About 2.8 MW of new capacity is avoided each year. The avoided capacity is estimated to have reached 25 MW by 2001 and to hit 50 MW in 2011.

The estimated cost of bringing new building construction into compliance with the commercial standard statewide is about $3.9 million each year. The energy efficiency results in a simple payback on investment of 3.6 years or a rate of return of more than 25 percent.

The average cost for saved energy is 3.3 cents per kWh during a 10-year period (HECO, 2005b) compared to the July 2005 average electricity cost on O'ahu of $0.1171 to $0.1691 per kWh (depending on rate schedule and not including customer or demand charges) for commercial buildings (HECO, 2005c). The Federal Energy Policy Act of 2005 includes a provision requiring states to include a section on code implementation (ACEEE3).

2. Renewable Energy Portfolio Standard (RPS)

In her campaign and State of the State address in 2004, Governor Linda Lingle called for 20 percent of energy to be renewable by the year 2020. Act 95, from the Session Laws of Hawai'i, 2004 was a compromise bill to put this vision into action. While the focus was on renewable energy, the RPS recognized the contribution that solar water heating and energy efficiency made to sustainability by crediting them against the RPS standard, and broadly defining renewable energy in Section 269-91 HRS to include a wide variety of renewable energy technologies and the following provisions for energy efficiency measures:

> 'Renewable energy' also means electrical energy savings brought about by the use of solar and heat pump water heating, seawater air-conditioning district cooling systems, solar air-conditioning and ice storage, quantifiable energy conservation measures, use of rejected heat from co-generation and combined heat and power systems excluding fossil-fueled qualifying facilities that sell electricity to electric utility companies, and central station power projects.

This broad definition was part of a compromise to reduce utility concerns about possible difficulties in complying. The RPS law will be discussed in more detail in the section on renewable energy.

3. Facilitating Energy Efficiency in State Government

Hawai'i's governor has issued administrative directives to state departments and agencies to improve their energy efficiency. One of these directives is: *Administrative Directive No. 06-01, Energy and Resource Efficiency and Renewable Energy and Resource Development* (http://www1.eere.energy.gov/solar/ush2o/pdfs/hi_admindirectiveno06-01.pdf).

The following is a list of resources created to provide information and assistance to the state government entities in complying with the directives:

- *State of Hawai'i Facilities on O'ahu Energy Benchmarking Study*: http://www.hawaii.gov/dbedt/info/energy/publications/benchmarking/benchmarking.pdf

- *Hawai'i Guidelines for Energy Efficiency of Commercial Buildings*: http://www.archenergy.com/library/general/hawaiigl

- *Hawai'i High Performance Schools Guidelines*: http://www.hawaii.gov/bedt/info/energy/publications/schools/guidelines.pdf

- *Energy Star Products/Purchasing: http*://www.energystar.gov

- *The Database for Energy Efficient Resources (DEER)* contains extensive information on energy-efficient technologies and measures, including estimates of the average cost and energy-savings potential: http://www.energy.ca.gov/deer/

4. Performance Contracting

Performance contracting is an innovative method for purchasing energy-saving improvements in buildings. The 2004 Hawai'i Legislature amended Section 36-41, HRS, to extend the period of energy performance contracts from 15 to 20 years. This will enable energy efficiency and renewable technologies with a longer payback period to be implemented through third party financing. In addition, the law now allows energy performance contracts to include water conservation retrofits, enabling state and local government facilities to obtain additional savings on their utility bills and make improvements to their buildings.

Many state agencies and private businesses face increasing energy costs and the need to replace obsolete equipment, but lack the funds to make building improvements. Energy performance contracting has several distinguishing features which address this need:

- 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 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, by law, the energy savings produced by the project must be 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.

- The risk of energy savings performance is transferred to the Energy Service Company (ESCO) or contractor, because payments are contingent on actual savings achieved and the ESCO guarantees a certain amount of annual savings, paying the facility owner the difference if the savings are not achieved (DBEDT, 1998).

Results of Several Hawaii Performance Contracting Projects					
Organization	Building Area (Ft.^{2})	Annual Utility Bills ($)	Est. Annual Energy Savings (kWh)	Est. Annual Savings ($)	Annual Emissions Reduction (Tons CO_2)
State Facilities					
University of Hawaii at Hilo	726,532	1,400,000	3,728,000	450,000	3,765
Na Makani Energy Initiative			335,300	57,000	339
Hawaii Healthcare Systems			13,300,000	3,468,000	13,433
County Facilities					
Hawaii County	792,500	2,100,000	1,639,000	255,000	1,655
Kauai County	211,462	250,000	264,000	68,000	169
City & County of Honolulu	100,000	891,000	4,094,000	431,000	4,217
TOTAL	**2,557,026**	**6,041,000**	**40,723,600**	**8,704,000**	**41,115**

Table 14. Hawai'i Performance Contracting Projects (DBEDT Energy Data, 2003).

Table 14 shows the results of several Hawai'i performance contracting projects completed in the 1990s.

5. National Energy Policy.

The National Energy Policy, which was developed by the Bush Administration at the beginning of its first term, includes several recommendations regarding energy efficiency. We have summarized in Table 15 a few of the recommendations from the Department of Energy 2005 Status Report on the Implementation of National Energy Policy Recommendations (DOE, 2005).

Recommendations	Status
That the President direct the Secretary of Energy to promote greater energy efficiency by: • Expanding the Energy Star program beyond office buildings to include schools, retail buildings, health care facilities, and homes. • Extending the Energy Star labeling program to additional products, appliances, and services. • Strengthening Department of Energy public education programs relating to energy efficiency.	The Energy Star program has been expanded to include home ventilation fans, small commercial HVAC units, ceiling fans, reach-in commercial refrigerators, portable phones, home insulation and air leak sealing, commercial cooking equipment, and vending machines. Energy Star specifications have been upgraded for residential windows, compact fluorescent bulbs, residential light fixtures, central air conditioners, televisions, and VCRs and have also been extended to new categories of commercial buildings including hospitals, supermarkets, hotels, financial centers, bank branches, courthouses, warehouses, and residence halls. The DOE has launched several public awareness campaigns to help consumers and businesses save energy, including the DOE Energy Savers campaign, to educate consumers and businesses on smart energy use (DOE, 2005).

That the President direct the Secretary of Energy to: • establish a national priority of improving energy efficiency.	The DOE has developed a web-based energy intensity indicator that can be used to track the energy intensity of the U.S. measured by the amount of energy required for each dollar of economic productivity (DOE, 2005).
That the President direct the EPA Administrator to: • develop and implement a strategy to increase public awareness of the sizable savings that energy efficiency offers to homeowners across the country.	The USEPA launched several public awareness campaigns to help consumers and businesses save energy. EPA's 2003 "Change a Light, Change the World" campaign challenges Americans to switch to lighting products that save energy. For 2004, EPA started the "Cool Change Campaign" to encourage homeowners to learn how to increase their comfort at home during the summer months and save energy (DOE, 2005).

Table 15. Department of Energy 2005 recommendations and recommendation status (DOE, 2005).

6. Federal Policy Initiatives Directed by the Energy Policy Act of 2005

There are a number of federal policy initiatives in the Act to enhance energy efficiency. These include the following:

- **Energy Efficiency Goals for Federal Facilities.** The Act updates savings goals for federal facilities and authorizes a variety of new and continued activities to achieve these goals. Authorization for the use of Energy Savings Performance Contracts by federal entities is extended for 10 years.

- **High Performance Public Buildings.** The Act authorizes a grant program to states to assist local governments in improving the efficiency of their buildings.

- **Combined Heat and Power (CHP).** States are directed to consider adopting model interconnection standards for CHP systems.

- **Real Time Pricing.** A provision of the Act directs state utility commissions to consider establishing real-time pricing programs in their states.

- **Daylight Savings Time.** The provision of the Act related to the extension of daylight savings time does not apply to Hawai'i. However, by extending daylight savings time by one month (one week in the spring, three weeks in the fall) energy use on the mainland might be reduced.

D. Tax and Other Government Financial Incentives

The City and County of Honolulu, State of Hawai'i, and the federal government offer income tax credits as incentives for installation of solar water heaters. In addition, three of Hawai'i's four counties have programs to encourage energy efficiency measures and/or purchase of solar water heaters. Some of the income tax credits are summarized in Table 16.

State of Hawai'i Tax Credits
Residential Sector Energy Efficiency: Income tax credit of 35 percent up to $2,250 of the cost of a solar water heater and up to $5,000 for photovoltaic systems on single family homes, whichever is less. For solar installations in multi-unit residential buildings, the credit is 35 percent or $350, whichever is less, for each unit. There is a credit of up to $1,500 for wind systems for single family residences.
Commercial/Industrial Energy Efficiency: Income tax credit of 35 percent up to $250,000 of the cost of solar water heaters and up to $500,000 for photovoltaic and wind systems, whichever is less, for hotels, commercial, and industrial buildings.

Table 16. Some income tax credits available to Hawai'i residents.

One success story regarding these types of initiatives and incentives is the loan program instituted by Maui Electric Company (MECO) and the County of Maui. In September 2002, Maui Electric Company (MECO) and the County of Maui together launched the Maui Solar Roofs Initiative to increase the use of renewable energy in Maui County. The county designated $450,000 for a revolving fund for interest-free loans for the installation of solar water heating. MECO administers the loan program and offers a $1000 rebate for installations through its approved solar contractors as part of its DSM program. Over 350 systems have been installed under the program as of 2006. Half of the funds have been designated for households with incomes at or below 100 percent of the median.

The federal government also provides opportunities and incentives, with one example being the residential solar and fuel cell tax credits. The Energy Policy Act of 2005 established a 30 percent tax credit up to $2,000 for the purchase and installation of residential solar electric (photovoltaic) and solar water heating systems. An individual can take both a 30 percent credit up to the $2,000 cap for a photovoltaics system and a 30 percent credit up to a separate $2,000 cap for a solar water heating system. A 30 percent tax credit up to $500 per 0.5 kW is also available for fuels cells. The tax credit does not apply to solar water heaters for swimming pools or hot tubs. The credit is calculated based on the individual′s expenditures excluding any other government or utility incentives received. To be eligible for the credit, a system in an existing home must be "placed in service" or activated between January 1, 2006, and December 31, 2007.

E. Utility Demand-Side Management (DSM) Programs to Enhance Efficient Use of Electricity

DSM seeks to reduce the amount of electricity used by utility customers through conservation and efficiency efforts. In addition, load management programs seek to change the time of day of peak energy use to reduce the peak demand. By reducing peak demand, it may be possible to postpone the need for future power plants. Customers that use DSM measures enjoy reduced utility bills. Also to the extent that DSM programs are able to defer the addition of new power plants, all customers benefit from lower overall rates.

While all of Hawai'i's electric utilities have DSM programs, we will discuss the HECO DSM programs, which are the most comprehensive and serve the largest number of Hawai'i's electricity customers. The other Hawai'i electric utilities have very similar DSM programs.

1. HECO's Current Residential Demand-Side Management Programs

HECO currently has two residential demand-side management programs, both focused on solar water heating.

Residential Efficient Water Heating Program. The Residential Efficient Water Heating Program (REWH) is intended to reduce electricity use for water heating, which makes up about 14 percent of the typical household's electricity demand.

HECO offers rebates to encourage installation of solar water heaters, heat pump water heaters, and high efficiency electric water heaters. There are no tax credits for heat pumps or high efficiency electric water heaters. The three HECO utilities have subsidized the installation of 20,000 solar water heaters since the program began in 1996. The rebate on a solar water heater is $750, $175 for a heat pump water heater, and $40 to $70 for a high efficiency electric water heater (HECO, 2005b). As described above, the customer purchasing a solar water heater can also earn a state income tax credit of 35 percent of the cost of the system or $1,750, whichever is less. This effectively reduces the cost to the customer to about 50 percent of a solar water heating system's cost. The customer pays $2,500 of the $5,000 total cost. About 5,270 customers participate in the program annually. Each solar water heater saves about 2,040 kWh/year and reduces peak demand by 0.461 kW.

Residential New Construction Program. Another residential DSM program is the Residential New Construction Program. In this case, builders are offered incentives to install solar water heaters, heat pump water heaters, or high efficiency electric water heaters in new homes. There are about 4,015 participants per year and each solar water heater saves 1,924 kWh and reduces demand by 0.453 kW (HECO, 2005b).

2. HECO's Proposed New Residential DSM Programs

In its draft IRP, HECO proposes a number of enhanced and new residential DSM programs.

Residential Efficient Water Heating (REHW). A new REHW program will continue to promote solar water heaters and high efficiency electric water heaters to customers living in existing residential dwellings. In addition to cash rebates, HECO will also provide customers with educational materials that offer ways customers can reduce their water heating energy consumption. Target audiences are in the single-family, multi-family, and rental markets.

Residential New Construction Program (RNC). The RNC also promotes solar water heaters and high efficiency measures plus packages of other energy efficiency measures, which included the following:

solar water heaters
water heater tank and timers
high efficiency water heaters
high efficiency air conditioning
high efficiency room air conditioning
Energy Star windows
natural ventilation
compact fluorescent lamps
ceiling fans
Energy Star appliances
wall insulation
ceiling insulation or radiant barriers
skylights

HECO will partner with the Building Industry Association of Hawai'i's "BuiltGreen Initiative" to design the components of, and the requirements for, the energy efficiency packages. Cash rebates and financing options will be offered to residential customers who purchase qualified equipment and/or incentives would be offered to dealers who sell qualified equipment. The program will also provide customers with educational materials to discuss ways they can reduce their energy consumption.

Energy Solutions for the Home (ESH). The ESH program is designed to provide an array of efficiency options for several residential end-uses. The program will offer cash rebates to residential customers who purchase high efficiency electric equipment. They will also be provided educational materials on reducing energy consumption. The program is intended to work in parallel with the national EnergyStar program to leverage its benefits. ESH will focus on the following end-uses: space cooling, cooling equipment servicing, lighting, and appliances (specifically EnergyStar appliances).

Residential Low Income (RLI). The RLI program will enable low-income customers to receive high efficiency equipment for little or no cost. The efficiency equipment will be limited to compact fluorescent lamps and low-cost water heating conservation measures such as faucet aerators and low flow shower heads. A tune-up of any air conditioning equipment present will also be available. The customers will also be provided with educational materials about energy efficiency.

Residential Direct Load Control Program (RDLC). The RDLC program would provide incentives to customers to participate by allowing HECO direct control over their electric water heaters and air conditioning equipment during system peak hours through the use of load control devices attached to the customer equipment. Water heating and air-conditioning load control will be implemented by attaching a switch to the appliance that can be activated or deactivated through a pager signal dispatched by HECO during a system emergency. The controls could also be automatically activated by an under frequency relay in times of system emergency. Air conditioning would be deactivated in 15 minute intervals to reduce customer discomfort.

Residential Customer Energy Awareness Program (RCEA). The RCEA program will seek to determine whether or not an aggressive customer communications program can change the level of residential customer awareness of energy options and encourage adoption of energy-efficient appliances (HECO, 2005b).

3. HECO's Current Commercial and Industrial Demand-Side Management Programs

HECO currently has four commercial and industrial DSM programs: the Commercial and Industrial Energy Efficiency Program (CIEE), the Commercial and Industrial New Construction Program (CINC), the Commercial and Industrial Customized Rebate Program (CICR), and the New Commercial and Industrial Direct Load Control Program (CIDLC).

Commercial and Industrial Energy Efficiency Program (CIEE). The CIEE program provides a full range of energy efficiency options from air conditioning to lighting to low-interest loans. The program offers cash rebates to nonresidential customers who purchase high efficiency electric equipment. It also provides vendor incentives to dealers who sell high efficiency electric equipment. Specific energy efficient measures being promoted under this program include:

Packaged rooftop HVAC units	CFL lamps
TB lighting	T5 lighting
LED exit lights	Induction lighting
Premium efficiency motors	Window tinting
High efficiency booster pumps	

Commercial and Industrial New Construction Program (CINC). The CINC program provides customers with design assistance and custom rebates for the construction of energy-efficient buildings and facilities. The program covers both new buildings and facilities and those undergoing major renovation. A major renovation is defined as buildings where multiple major systems are undergoing significant updates. The program emphasizes the same measures of the CIEE program with the addition of customization of the projects.

Commercial and Industrial Customized Rebate Program (CICR). The CICR program allows for site-specific measures that do not lend themselves to prescriptive incentive program design. HECO works with these customers to identify energy efficiency opportunities in conventional end-uses and their specific processes, including emerging technologies. They will seek to identify the potential savings from the proposed installation of the energy-saving equipment and develop a customized rebate program. The program also addresses building commissioning and equipment maintenance.

New Commercial and Industrial Direct Load Control Program (CIDLC). The CIDLC will offer ongoing incentives to participating commercial and industrial customers in return for HECO being able to drop some or all of their electrical service during peak hours or when the system is approaching peak load. The customer load may also be terminated if the system frequency drops to a preset under frequency level. Incentives will be provided in the form of monthly bill credits (HECO, 2005b).

4. Historical and Projected Results of the HECO DSM Programs

The existing HECO DSM programs have been in effect since 1996. Table 17 shows the historical results for net demand and for net energy savings from 1996 to 2002.
Table 18 shows projected residential DSM program results based on the draft HECO

Historical HECO DSM Program Results and Expenditures			
Program	Net Demand Savings (MW)	Net Energy Savings (GWh)	Total Expenditures
Residential Water Heating (REWH)	8.5	37.67	$18,715,013
Residential New Construction (RNC	3.8	11.59	$ 7,973,842
Residential Subtotal	12.3	49.26	$26,688,855
C&I Prescriptive Rebates (CIEE)	8.9	62.79	$10,755,663
C&I New Construction (CINC)	4.1	25.66	$ 5,214,101
C&I Custom Rebates (CICR)	4.7	34.5	$ 6,267,639
C&I Subtotal	17.7	122.95	$22,237,403
Total	30.0	172.21	$48,926,258

Table 17. Historical HECO DSM Programs (HECO, 2005b).

IRP plan. Table 19 shows the projected results of the HECO commercial/industrial DSM programs.

Projected Impact of HECO Residential DSM Programs					
	Program	2006	2010	2015	2020
REWH	Peak Demand Reduction (MW)	1.0	4.8	9.7	14.5
	Energy Savings (GWh)	3.70	18.51	37.01	55.51
RNC	Peak Demand Reduction (MW)	1.1	5.5	8.2	11.0
	Energy Savings (GWh)	2.23	11.16	17.14	23.12
ESH	Peak Demand Reduction (MW)	2.4	12.1	24.1	36.2
	Energy Savings (GWh)	13.36	66.79	133.59	200.49
RLI	Peak Demand Reduction (MW)	0.7	3.6	7.2	7.2
	Energy Savings (GWh)	2.65	13.24	26.48	39.72
RDLC	Peak Demand Reduction (MW)	5	8.5	8.5	8.5
	Energy Savings (GWh)	0	0	0	0
RCEA	Peak Demand Reduction (MW)	0	0	0	0
	Energy Savings (GWh)	0	0	0	0
Total	Peak Demand Reduction (MW)	10.20	34.50	57.70	77.40
Total	Energy Savings (GWh)	21.94	109.70	214.22	318.83

Table 18. Projected Impact of HECO Residential DSM Programs (HECO, 2005b).

Projected Impact of Proposed Commercial and Industrial DSM Programs					
	Program	2006	2010	2015	2020
CIEE	Peak Demand Reduction (MW)	1.9	9.4	18.9	28.3
	Energy Savings (GWh)	13.01	65.06	130.02	195.16
CICR	Peak Demand Reduction (MW)	1.7	8.7	17.5	26.2
	Energy Savings (GWh)	12.81	63.04	126.07	189.11
CINC	Peak Demand Reduction (MW)	0.5	2.8	5.2	7.8
	Energy Savings (GWh)	3.56	17.20	35.59	53.39
CIDLC	Peak Demand Reduction (MW)	5.9	13.5	13.5	13.5
	Energy Savings (GWh)	-	-	-	-
Total	**Peak Demand Reduction (MW)**	**4.1**	**20.9**	**41.6**	**62.3**
Total	**Energy Savings (GWh)**	**33.5**	**166.2**	**333.3**	**500.0**

Table 19. Projected Impacts of HECO Commercial and Industrial DSM Programs (HECO, 2005b).

F. Programs Providing Information and Tools

Many people would like to be more energy efficient for both economic and environmental reasons, but lack the information needed to make appropriate decisions. The State of Hawaiʻi has instituted efforts to provide this information to Hawaiʻi residents. The following are efforts to provide useful information to a variety of stakeholders.

1. Hawaiʻi BuiltGreen™ Program

The Hawaiʻi BuiltGreen Program is a statewide program that provides information, seminars, exhibits, and the example of a real home to help builders and homeowners design and build energy- and resource-efficient homes in Hawaiʻi. The program was originally developed in 2000 by DBEDT, the Building Industry Association of Hawaiʻi (BIA), Hawaiian Electric Company, the Honolulu Chapter of American Institute of Architects, and the

University of Hawaiʻi at Mānoa School of Architecture. It is now promoted by DBEDT, BIA, utility companies, and other community organizations. A "BuiltGreen" home provides its occupants more comfort with less cost to operate and less waste of energy and resources. Three "Big Bang" techniques to achieve the comfort, savings, and efficiency include utility-approved solar water heater, insulation and/or radiant barrier in roof and walls, and natural ventilation. See http://www.bia-hawaii.com.

2. Guides for Energy Efficiency in Hawaiʻi Homes

A series of publications, produced by DBEDT, describe voluntary measures that architects, builders, and property owners can take to make their buildings more comfortable and energy efficient. These include the Hawaiʻi Homeowner's Guide to Energy, Comfort & Value, (a booklet, available at http://www.hawaii.gov/dbedt/info/energy/publications/hhog.pdf).

3. The Field Guide for Energy Performance, Comfort, and Value in Hawaiʻi Homes

The field guide was produced by DBEDT and the American Institute of Architects, Hawaiʻi Chapter. The Field Guide provides detailed illustrations and other information about how to design and build an energy-efficient, comfortable, and economical home in Hawaiʻi. See http://www.hawaii.gov/dbedt/info/energy/efficiency/fieldguide/.

4. Hawaiʻi Commercial Building Guidelines for Energy Efficiency

The *Hawaiʻi Commercial Building Guidelines for Energy Efficiency* were developed by the Architectural Energy Corporation for DBEDT to assist architects, engineers, lighting designers, contractors, building owners, and others in making decisions about the design of their buildings and systems for energy efficiency. The objective is energy-efficient buildings that are also healthy and pleasing places to spend time in. These *Guidelines* address new construction as well as major renovation of commercial buildings. The Guidelines take a whole building approach and discuss the following:

- Solar control strategy.
- Day lighting and visual comfort strategy.
- Thermal comfort strategy.
- Special indoor environment requirements.
- Air quality strategy.

The complete document is available from the consultant's web site at: http://www.archenergy.com/library/general/hawaiigl/.

5. Energy Analysis Tools

The USDOE offers a "Building Toolbox" as a comprehensive guide to creating more efficient, affordable buildings. The toolbox provides many guidelines, tools, success stories, and links to guide builders or renovators through the process of designing, constructing, or renovating high-performance buildings. See http://www.eere.energy.gov/buildings/info/toolboxdirectory.html for links to these tools. Tools are provided to assist in the following areas:

- Planning and financing projects with energy efficiency and sustainability as objectives. Discusses the whole building design approach, setting project goals, reviewing applicable codes and standards, planning for building commissioning, and financing options for high-performance buildings.
- Designing, constructing, and renovating high-performance buildings using the whole building approach and design tools. Covers building citing considerations, integrated design solutions, and additional construction and renovation opportunities for saving energy and protecting the environment.
- Choosing building components that use the latest energy-efficient technologies and practices.
- Operating and maintaining buildings to get the most from money spent on energy, including many low-cost and no-cost ways to save.

6. Hawaiʻi High-Performance Schools Guidelines

Under a grant from USDOE, DBEDT produced a series of documents including guidelines, case studies, examples, diagrams, calculation tools, and building commission information for use by State of Hawaiʻi Department of Education building managers. These materials provide information on how schools can incorporate good building design and efficient cooling and lighting techniques to enhance the learning environment and reduce energy bills. These materials are available at: http://hawaii.gov/dbedt/info/energy/publications/schools/.

7. Energy Efficiency Information on State of Hawaiʻi Department of Business, Economic Development, and Tourism Strategic Industries Division (formerly Energy, Resources, and Technology Division) Web Site

The web site (http://www.hawaii.gov/dbedt/info/energy/efficiency/) offers a broad variety of information about energy in Hawaiʻi, including most recent studies prepared for the state. The following examples are taken from the web site and are aimed at residential customers offering useful tips to save money on energy that will also improve Hawaiʻi's sustainability. There are many ways to save money on your energy bills by using energy wisely. Some examples are:

a. Air Conditioning

The most efficient air conditioner in Hawaiʻi is the flow of trade winds through a house. The next most efficient cooler is a ceiling or standing fan. If you must use an air conditioning unit, keep the hours of usage down as low as possible. When purchasing a new unit, select a model with a high "EER" (energy efficiency ratio). High numbers are 11, 12, and 13.

b. Architectural Design

Ventilation, shading, landscaping, and ceiling insulation can help keep your home cooler, so that ideally, you won't need air conditioning. Energy-efficient design is described in detail in the Field Guide for Energy Performance, Comfort, and Value in Hawaiʻi Homes.

c. Cooking

Microwaves are great energy-savers, while ovens use a tremendous amount of energy. Use microwaves whenever possible. When cooking on the range, keep a tight lid on pans. You can turn off electric ranges a bit before the food is cooked, as the "residual heat" in the burner will continue the cooking process for quite a while.

d. Laundry

When you do laundry, you use energy in three ways: (1) to heat the water (if you use the "hot" or "warm" setting), (2) to run the washing machine, and (3) to dry the clothes.

The simplest way to reduce your energy use is to wash with cold water (in Hawaiʻi, "cold" is not really cold, it's usually about room temperature, in the 70s). And use the clothesline to dry your clothes instead of the dryer. And finally, if you're in the market for a new, more efficient washer, do not forget to count the savings in water and energy when you compare costs. "Horizontal axis" washing machines, popular in Europe for many years, are now increasingly available in the U.S. They save on electricity, water, and detergent.

e. Lighting

Something as simple as selecting the right light bulb can reduce energy bills and reduce the amount of heat produced by the light. Certain types of light bulbs, such as compact fluorescents, are up to four times more energy-efficient as standard incandescent bulbs. Energy efficiency of different types of light bulbs is very different, and incandescent bulbs, although the cheapest to buy at the store, can waste as much as $11 per year in electricity compared to other light bulbs.

Why do standard incandescent bulbs use so much more energy? Well, for one thing, they are producing quite a bit of heat along with the light. Fluorescent bulbs, on the other hand, are much cooler. Operating costs for the different types of lights are very different and the most expensive is the incandescent. Figure 15 from the DBEDT energy web site compares the operating costs of a variety of lighting types.

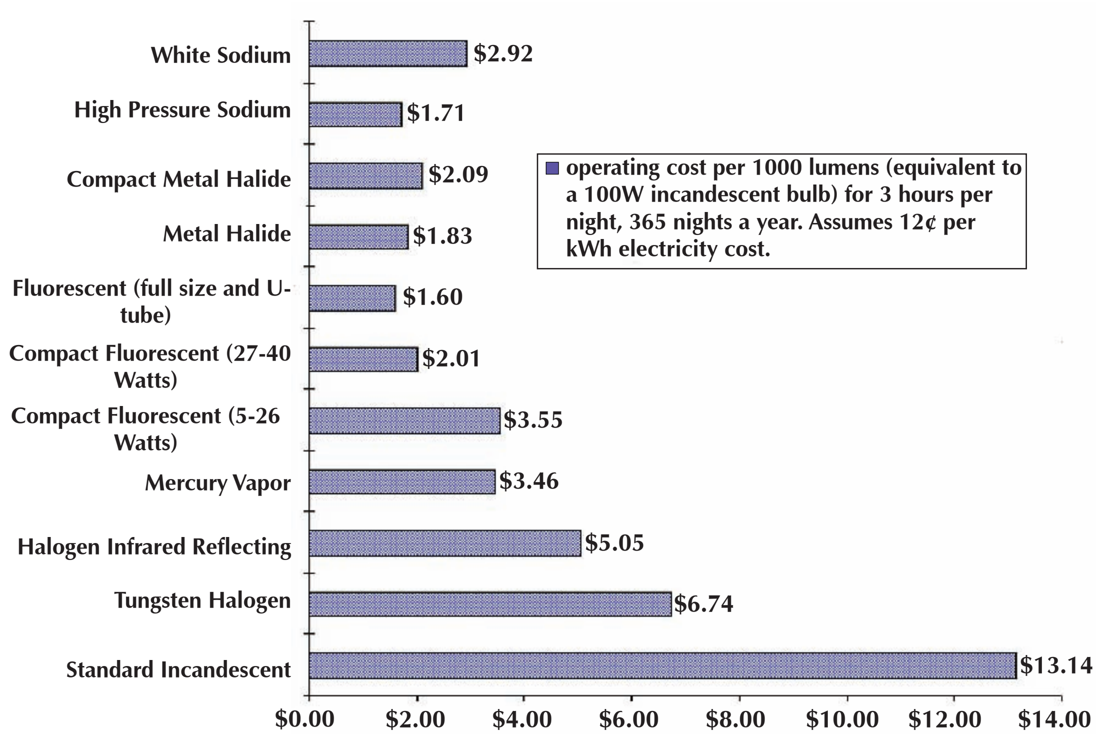

Figure 15. Operating Costs of Various Lighting Types.

f. Performance Contracting

Commercial, industrial, and government buildings can often realize reduced energy bills through performance contracting (http://hawaii.gov/dbedt/info/energy/efficiency/state/performance/), or by developing an agreement with an energy service company that will guarantee improved energy efficiency and it will not cost you anything. It is essentially a shared savings plan, and is currently saving the state hundreds of thousands of dollars per year.

g. Refrigerators

New refrigerators use as little as half as much electricity as some old refrigerators. They can reduce your electricity bill by as much as $120 per year. That is a great reason to get a new fridge!

h. Water Heating

Water heating accounts for a large portion of residential energy use. Some simple steps (such as turning down the thermostat, insulating older models, and installing a timer) can reduce water heating costs by as much as $480 yearly. (That is a savings of $40 per month for a family of four.) Solar water heaters and heat pumps are very energy-efficient and there are state tax credits and utility rebates worth hundreds of dollars! For more information on these programs, see the solar web page at http://www.hawaii.gov/dbedt/info/energy/renewable/solar.

8. U.S. Department of Energy's Federal Energy Management Program (FEMP)

According to the FEMP web site (http://www.eere.energy.gov/femp/), FEMP "works to reduce the cost and environmental impact of the Federal government by advancing energy efficiency and water conservation, promoting the use of distributed and renewable energy, and improving utility management decisions at Federal sites." Since about 16 percent of O'ahu's electricity is used by military installations and additional amounts are used by federal civilian facilities, the FEMP program is important to Hawai'i's energy sustainability.

As the largest single energy consumer in Hawai'i and the United States, the federal government recognizes that it has both an opportunity and a clear responsibility to lead by example with smart energy management. In addition, the Energy Policy Act of 1992, recent executive orders, and presidential directives require federal agencies to meet a number of energy and water management goals, among other requirements. Federal agencies are called upon to reduce their energy use by 35 percent by 2010 in comparison to 1985 levels. FEMP assists federal agencies in achieving these goals.

FEMP provides technical assistance to federal energy managers in the following areas:

- Incorporating energy efficiency in new construction.
- Building retrofits to improve efficiency.
- Energy efficient equipment procurements.
- Operations and maintenance (O&M) training for efficiency.
- Utility management.

FEMP's activities save tax dollars through energy cost savings, renew and rejuvenate federal buildings and related infrastructure at minimal cost to agencies, protect air quality and conserve water, contribute to the nation's energy and economic security, and increase market demand for advanced energy technologies.

FEMP provides advice on project financing using energy savings as contracts, utility energy service contracts, taking advantage of rebates, and using public benefit funds where they are available. Through these means, agencies can take advantage of private sector capital to fund energy- and water-saving equipment and renewable energy systems at federal facilities.

FEMP also provides technical assistance to federal energy managers for new construction and facility improvement projects. These projects can incorporate energy efficiency, renewable energy, distributed energy technologies, sustainable design practices, state-of-the art lighting, and water-saving technologies. Technical assistance available includes:

- Energy and water audits for buildings and industrial facilities.
- Peak load management.
- Whole-building design and sustainability.
- Renewable energy technologies.
- Distributed energy resources.
- Combined heat and power technologies.
- Laboratory design.

9. Federal Information Programs Authorized by the Energy Policy Act of 2005

The act authorizes a major public awareness campaign on how to save energy and the benefits of doing so. The Act directs the Federal Trade Commission to review and revise the Energy Guide appliance labeling program to make it more effective. The program is designed to provide information to consumers on the relative energy efficiency of electrical products. Another provision directs the USDOE to conduct an education campaign on the energy efficiency benefits of properly conducted air conditioning maintenance (ACEEE3).

G. Appliance and Equipment Standards

1. Energy Star Program

The ENERGY STAR program is a combination of an appliance and equipment standard and an information program. It is a "government/industry partnership that offers businesses and consumers energy-efficient solutions, making it easy to save money while protecting the environment for future generations" (ENSTAR).

The US Environmental Protection Agency (EPA) introduced ENERGY STAR in 1992 as a voluntary labeling program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. The first labeled products were computers and monitors. EPA expanded the label to additional office equipment products and residential heating and cooling equipment by 1995. In 1996, EPA partnered with the US Department of Energy and now the ENERGY STAR label is on major appliances, office equipment, lighting, and home electronics. EPA has also extended the label to cover new homes and commercial and industrial buildings. ENERGY STAR delivers the technical information and tools that organizations and consumers need to choose energy-efficient solutions and best management practices. According to their web site, ENERGY STAR has saved businesses, organizations, and consumers about $16 billion in 2004 alone.

2. Federal Equipment Efficiency Standards

The Energy Policy Act of 2005 sets equipment efficiency standards on 16 products—exit signs, traffic lights, building transformers, torchiere lighting fixtures, compact fluorescent lamps, commercial unit heaters, residential dehumidifiers, commercial refrigerators and freezers, large commercial air conditioners, commercial ice makers, commercial clothes washers, pedestrian signals, mercury vapor lamp ballasts, fluorescent lamp ballasts, pre-rinse spray valves (used in restaurants), and residential ceiling fan light kits. The law calls for the USDOE to set efficiency standards via rulemaking on three products—external power supplies, battery chargers, and refrigerated beverage vending machines. It also requires USDOE to regularly report to Congress when efficiency standard rulemakers are behind schedule, so steps can be taken to get back on schedule.

3. Energy Efficiency Resource Standards

The bill authorizes a pilot program with individual states and calls for a study with the National Association of Regulatory Utility Commissioners on state and regional policies to promote energy efficiency by setting energy efficiency resource standards.

H. Voluntary Programs – The Rebuild Hawaiʻi Consortium

The Rebuild Hawaiʻi Consortium is a statewide forum established in 1998 to encourage Rebuild America partnerships of utilities, community and private business groups in Hawaiʻi to share information on energy and resource development. By discussing energy efficiency, economic development, re-investing energy savings in the community, media and outreach, and a host of other Rebuild America-related topics, the Consortium finds connections that help leverage the many resources of the members to affect better, bigger results in energy efficiency projects. For more information, see the Rebuild Hawaiʻi web site at: http://www.state.hi.us/dbedt/ert/rebuild/.

I. Additional Energy Efficiency Programs for Consideration

We have seen that Hawaiʻi employs a wide range of energy efficiency programs, which together have contributed to Hawaiʻi's energy sustainability. The listing in Appendix A15 of (1) rules and regulations and of (2) financial incentives or energy use efficiency is from the Database of State Incentives for Renewable Energy (DSIRE). It can be found at http://www.dsireusa.org/. DSIRE is an ongoing project of the Interstate Renewable Energy Council (IREC) funded by the USDOE and managed by the North Carolina Solar Center.

The users of this case study may want to consult the DSIRE web site for details on these provisions and to compare those in use in Hawaiʻi with those of other states. Some measures not implemented in Hawaiʻi may be useful, in particular Public Benefit Funds for DSM programs and renewable energy (Appendix 21). A Public Benefit Fund may increase deployment of such systems since more money collected could be applied to projects if shareholder incentives and lost margins were not paid to the utility.

J. Future Technologies to Enhance Efficiency and Sustainability

Recent information on developing future technologies to enhance energy efficiency and sustainability is apparently not available at this time. However the table in Appendix A16 was taken from the late 1998 study – Emerging Energy-Savings Technologies and Practices or the Building Sector – which was sponsored by Association of State Energy Research and Technology Transfer Institutions. It provides a listing of the type of technologies of interest.

K. Conclusions

Of the three highest sectors of primary energy use in Hawaiʻi – air transportation (30 percent), ground transportation (19 percent), and electricity (39 percent) – electricity is the biggest. It is in the ground transportation and electricity sectors that Hawaiʻi is best able to achieve sustainability. In the electricity sector, gains can be made through improving end-use efficiencies. In Hawaiʻi, the electricity sector end-uses are primarily buildings (both residential and business) and a limited number of industrial operations. However, there are many barriers to increasing energy efficiency. The residential sector is the largest end-use electricity sector. With its large and diverse customer base, it presents a challenge to efficiency measures designed to reduce energy demand. Government policies, DSM programs, tax incentives, consumer education, building codes, and other measures aimed at modifying customer use of energy can be very successful. For example, DSM measures to encourage solar water heater use have enjoyed considerable success, with approximately 80,000 solar water heaters operating statewide. Along with improving electricity end-use efficiency, greater use of renewable energy would assist in increasing the sustainability of Hawaiʻi's energy system. The next chapter will look at renewable energy for Hawaiʻi and address how renewables should play a greater role in Hawaiʻi's future.

VI. Renewable Energy for Hawaiʻi

A. *Introduction*

It is widely recognized in Hawaiʻi that there are significant untapped renewable energy resources. These include wind-to-power generators, sunshine for solar water heaters and solar thermal or photovoltaic electricity generation, streams capable of providing run-of-the-river hydroelectricity, volcanic areas producing superheated underground steam usable for geothermal power, waves and tides capable of producing wave and tidal energy, municipal solid wastes and wastewater treatment byproducts capable of fueling generators, excellent growing conditions to produce biomass for generation or conversion into liquid fuels, and a significant difference between ocean surface temperatures and deep water capable of being used for ocean thermal energy conversion or for seawater air conditioning.

In 1881, King Kalākaua met with Thomas Edison in New York to learn about electricity. By 1886, the King's royal palace, Iolani Palace, became the first royal palace in the world to be lit by electricity. Two years later, in 1888, a hydroelectric plant on Nuʻuanu Stream produced electricity for street lights in Honolulu.

In 1891, HECO was formed to produce electricity for sale on Oʻahu using coal-fired generators, and in 1905, the company switched from coal to oil fuel. Around this same time, most of Hawaiʻi's sugar plantations used excess steam from boilers burning sugar cane waste (called bagasse) to generate electricity for their own use and for sale. On some islands, the sugar plantations were the original electric utilities. As late as 1962, the sugar plantations produced 18 percent of all electricity in Hawaiʻi using bagasse and plantation-owned hydroelectric plants.

As electricity demand grew and sugar plantations closed for economic reasons, the percentage of electricity from renewable energy also declined. The Arab oil embargo of 1973 stimulated new efforts to increase renewable energy use for energy security, reduce oil use and exposure to volatile oil markets, and to increase self-sufficiency and sustainability. As can be seen in Figure 16, despite these efforts there has been until recently a continuing decline in the percentage of renewable energy relative to rapidly growing electricity sales.

Over the same period, however, the variety of renewable energy technologies has increased. Hawaiʻi's renewable portfolio has expanded from sugar bagasse (biomass) and hydroelectricity to include wind, solar water heating, geothermal, photovoltaics, and landfill methane (from 1990 to 2002). Research and development were undertaken in those areas that led to deployments of operational systems. Systems successfully tested include an Ocean Thermal Energy Conversion system and a biomass gasifier, but these have not yet been deployed. Recently experiments with wave energy were initiated at the Kāneʻohe Marine Corps Base in Hawaiʻi. In addition, the state has diversified its fuel mix by adding coal, which continues to be used at Hawaiian Commercial and Sugar on Maui, as a supplemental fuel to the sugar industry in the mid-1980s. In 1992, a major coal plant began operation on Oʻahu. As of mid-2005, it appears that a combination of state policies and incentives, federal incentives, economics, and renewed energy security concerns have put Hawaiʻi on the threshold of a significant increase in renewable energy use.

In this chapter we explore some aspects of renewable energy use in Hawai'i. We will briefly examine the current status of renewable energy in Hawai'i and challenges of the future, summarize Hawai'i's renewable energy resources, discuss what the state of Hawai'i, the federal government and the electric utilities have done to encourage renewable energy use, as well as summarize what other states are doing to foster renewable energy and look at future renewable energy technologies and their prospects.

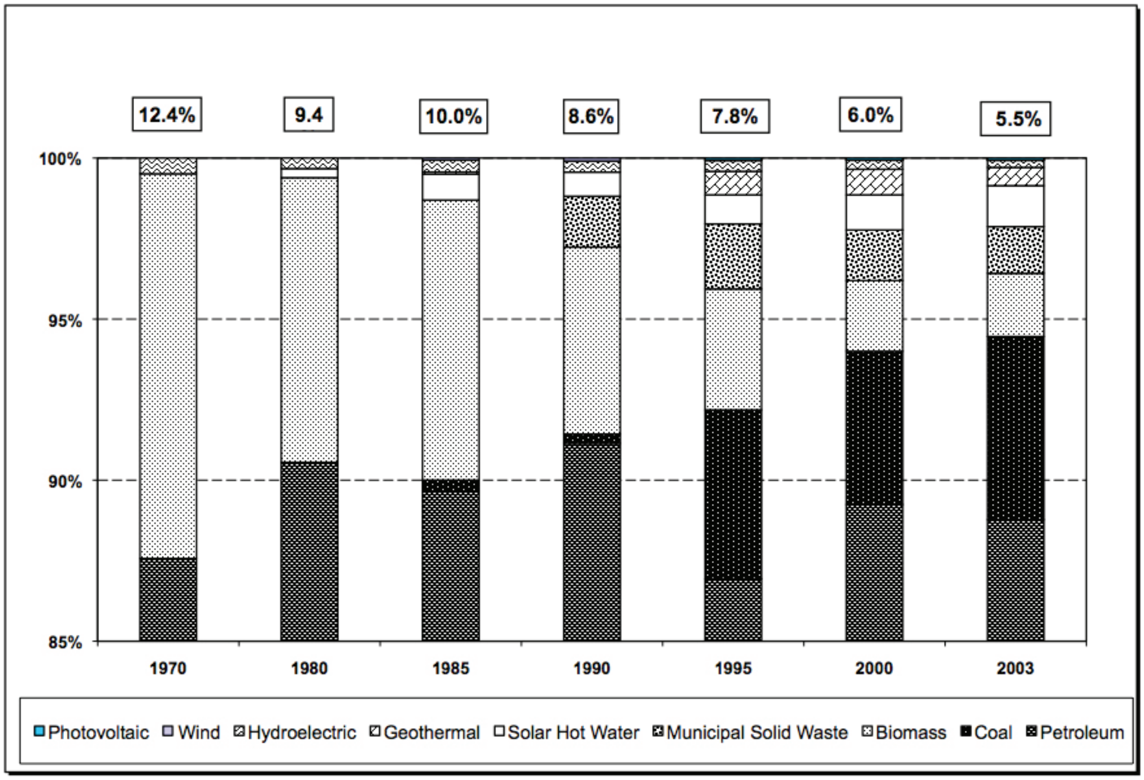

Figure 16. Renewable Energy as a Share of Primary Energy Consumption in Hawai'i (DBEDT Energy Data, 2003).

B. Renewable Energy Use in Hawai'i: Current Status and Challenges for the Future

Virtually all renewable energy use is in the electricity sector. The exceptions are some solar drying of agricultural products and some generation or process heat production for agricultural uses that do not sell to the utility. Although the state generally classifies solar water heating as a contribution of energy to the electricity sector, it actually offsets electricity that would otherwise be used for water heating by directly heating the water.

1. The Status of Renewable Energy Generation in Hawai'i, 2004

In 2004, the Hawai'i electric utilities produced almost 7.8 percent of their sales from renewable energy. Appendix A17 shows the renewable energy systems used, the energy sources, the amount of electricity generated for utility use, the percent of each utility's sales by source, and the percent of statewide sales by source. The two largest means of producing renewable energy by the utilities are HECO's H-POWER plant (located on O'ahu) and HELCO's Puna geothermal plant (located on the Big Island).

While almost 25 percent of HELCO's sales were provided by renewable energy, only about 1 percent of the renewable energy was produced by company-owned wind and hydropower. The remainder was purchased from independent power producers. HECO, serving the largest electricity system on O'ahu, only had about 5.4 percent of its sales provided by renewable energy, but this amount was 3.9 percent of statewide sales. Appendix A18 shows the renewable energy generation capacity in Hawai'i in 2005. Note that about two-thirds of this capacity is firm, which means it is available virtually 24 hours a day, seven days a week, except for periodic maintenance.

Figure 17 shows the relative contribution of the renewable energy resources used in 2004 by type of resource. Municipal waste, which includes the solid waste burned by the H-POWER plant, waste tires and waste oil burned in the AES coal plant, and waste oil burned in steam units at KIUC's Port Allen plant, provided nearly half of the state's renewable energy. Geothermal, at 26.8 percent, was the second. Solar water heating offset kWh equivalent to 10.5 percent of the total, followed by the sugar industry's use of bagasse and hydro systems to produce 9.8 percent, and hydroelecric producing 4.7 percent. Wind energy and solar photovoltaics together produced only 1.2 percent.

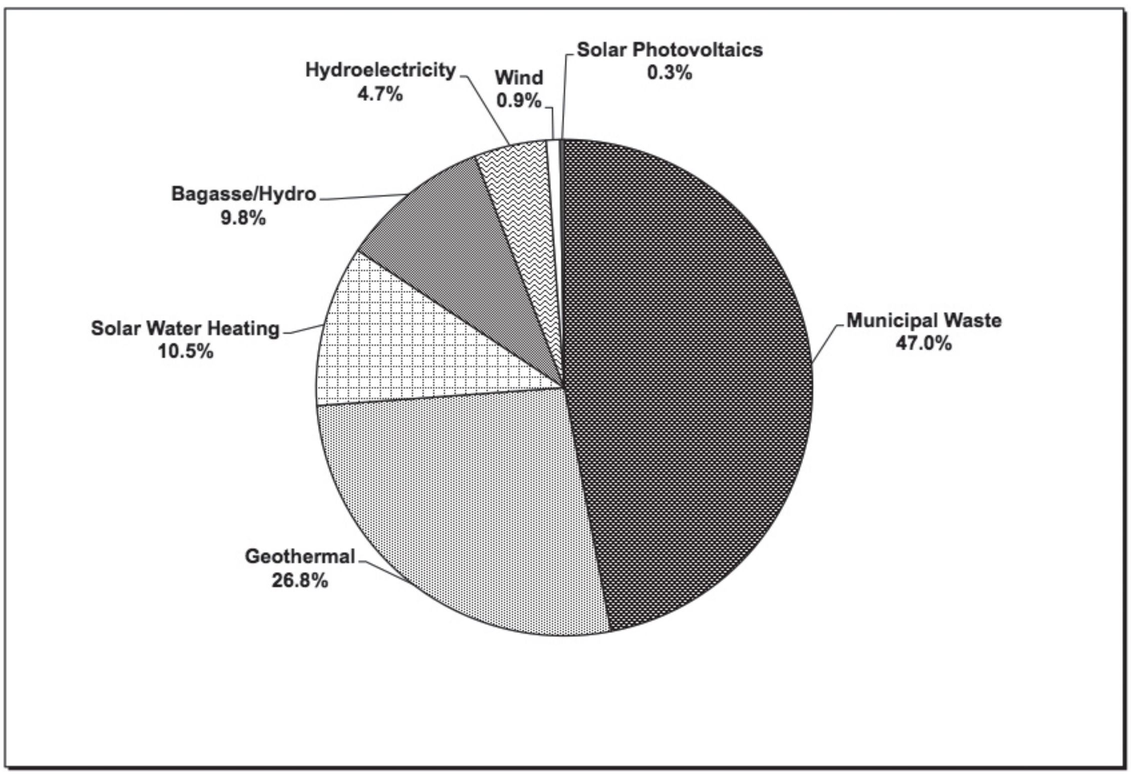

Figure 17. Percentage Contribution of Renewable Energy Resources to Statewide Renewable Energy Use, 2004 (DBEDT Energy Data, 2004).

2. Challenges for Future Renewable Energy

Some of the recent spikes in the price of oil (more than $150 per barrel of light sweet crude in mid 2008) would seem to suggest a promising future for renewable energy in Hawai'i. Future oil prices will likely remain high, despite the recent downturn, and the cost of renewable energy will continue to decline. However, there are some technical challenges that need to be met on the road to a more sustainable future.

As noted elsewhere, Hawai‘i’s electricity systems are not interconnected. This reduces the value of intermittent renewable energy technologies. They must be backed up by either fossil fuel generation or some type of energy storage at additional cost. Furthermore, most intermittent technologies do not produce a steady flow of electrons, which presents challenges to power quality, especially on small systems. Hawai‘i’s utilities are working on solving the technical challenges as discussed below.

An additional challenge is the pattern of electricity use in Hawai‘i. The peak demand is generally in the evenings between 6 and 8 p.m., which reduces the value of photovoltaic power no longer available at that time. In contrast, on the mainland, peak demand is generally in the mid-afternoon, coincident with peak photovoltaic production. Nighttime energy demand on most of the islands is very low. On the Big Island, it is typically less than half of the peak demand. This can result in the curtailment of available renewable energy and certain steam units must be run constantly.

Let us now take a look at some of Hawai‘i’s renewable energy resources in more detail.

3. Hawai‘i’s Renewable Energy Resources

As noted above, Hawai‘i has a large variety of renewable energy resources. This section briefly describes each type, based on information from the DBEDT web site.

a. Municipal Waste

As we saw above, electricity from refuse-derived fuel, better known as garbage, was used by the H-POWER plant on O‘ahu to produce the largest amount of renewable energy in 2004. The plant has a capacity of 63 MW, of which 46 MW is used for sale to HECO.

Since it began operations in May 1990, the plant has processed about 600,000 tons of waste per year, generating electricity which would otherwise have required about 600,000 barrels of oil per year. Materials which do not burn are recycled.

Although the plant is an important source of renewable energy, its primary purpose is to reduce the volume of waste going to landfills. The remaining ash from burning the MSW is about 10 percent of the volume of what otherwise would have gone to the landfill. The other islands face similar challenges of finding sufficient space for landfills. At various times, each island has looked at the possibility of similar garbage-to-energy systems, but they have not yet moved forward.

Used tires are also a significant disposal problem. On O‘ahu, the AES coal plant has obtained a permit to grind up used tires and burn them in its atmospheric fluidized bed coal system to produce electricity. They also burn waste oil, helping to solve another waste disposal problem. The HC&S sugar mill on Maui burns waste oil as well, and KIUC began using it in one of their steam units at Port Allen in 2004. Until 2004, when its contract to provide power to HELCO expired, the Hilo Coast Power Company also burned some waste oil in its coal fired boilers. Used cooking oil is the raw material for producing biodiesel on Maui and O‘ahu. This also makes use of material that would otherwise be difficult to dispose of.

b. Electricity from Landfill Gas and Wastewater Treatment Gas

From 1990 to 2002, methane was collected from the Kapa'a landfill on O'ahu and used as fuel to power a 3.2 MW combustion turbine, which generated electricity sold to HECO. The heat from the turbine's exhaust was used to dry sand and gravel at an adjacent quarry. The gas turbine suffered a catastrophic failure in 2002 and the operators decided not to repair it. The City and County of Honolulu has studied the possibility of resuming electricity production from the landfill, but have not taken action yet. In addition, feasibility studies indicate that methane produced at the Kailua wastewater treatment facility could be used to generate electricity, reducing operating costs. Another advantage of burning methane as a fuel is that the resulting carbon dioxide has less than 1/21 of the radiative forcing compared to methane that escapes into the atmosphere. Each of the three major neighbor islands has similar resources for landfill methane electricity and some wastewater treatment gas use.

c. Biomass from Sugar on Maui and Kaua'i

Since the beginning of the 20th century, sugar factories in Hawai'i have burned bagasse to provide steam for sugar processing and the generation of electricity. Electricity not needed for factory operations is sold to local utility companies. In addition, ethanol made from sugarcane molasses has been produced in Hawai'i and mixed with gasoline to produce fuel for automobiles.

While sugar plantations used to be ubiquitous in Hawai'i, the only ones remaining in operation are on Kaua'i (Gay and Robinson) and Maui (HC&S) due to Hawai'i's shift from an agriculture economy to a service-military economy. These operations have a capacity to produce a combined total of about 46 MW of power from biomass. Most of this is used internally by the factories for sugar processing. HC&S has a contract to provide MECO with a steady 16 MW of power. During times when the hydro sources are slow and not much bagasse is available, HC&S supplements renewable bagasse with coal, heavy fuel oil, diesel fuel, and waste oil to meet the contracted output.

d. Biodiesel from Used Cooking Oil, Maui and O'ahu

Used cooking oil is converted into biodiesel at Pacific Biodiesel facilities on Maui and O'ahu. As of 2004, the facility on Maui produced 150,000 gallons per year, and the output of the O'ahu plant is 400,000 gallons per year. Biodiesel may be blended with regular diesel and used in existing diesel engines in trucks, buses, boats, and stationary generators.

e. Geothermal Energy in Hawai'i

In 1881, King David Kalākaua discussed with Thomas Edison the possibility of using power from Hawai'i's volcanoes to produce electricity to light Hawai'i's capital, and transmitting this power by submarine cable to the other islands. Geothermal exploration in Hawai'i began in the 1960s. The first geothermal well in Hawai'i that produced steam was drilled in 1976. This well, named HGP-A, is 6,140 feet deep, and is one of the hottest wells in the world. The 3 MW generating plant which used steam from the well began producing electricity in 1982 and continued in operation until 1989.

Noi'i O Puna, the Puna Research Center located next to the HGP-A well, provided a test site for direct-use demonstration projects using geothermal heat and other byproducts. They included such varied projects as dyeing fabrics, using geothermal hot water for aquaculture, and drying fruits and lumber. Projects were terminated when the HGP-A plant was closed.

Puna Geothermal Venture. Under a Power Purchase Agreement with Hawaiʻi Electric Light Company, PGV delivers an average of 25-30 MW of firm energy on a continuous basis, supplying approximately 20 percent of the total electricity needs of the Big Island. The company uses modern reinjection technology to dispose of spent gases and fluids from the generating process.

Hawaiʻi Deep Water Cable Project. From 1982 through early 1990, a research and development project was underway to develop an underwater cable to connect the island of Hawaiʻi with Oʻahu. The concept was to build a 500 MW geothermal power plant on Hawaiʻi and to export the power to Oʻahu. The project showed that the cable system was technically feasible, but too costly. At about the same time, some Big Island residents took action to oppose the project, which led to a lawsuit and a settlement in which the governor agreed that the state's policy would support geothermal energy production on the Big Island exclusively for use on that island.

f. Hydropower

Hawaiʻi has several run-of-the-river hydropower plants on Hawaiʻi, Kauaʻi, and Maui. Although they are small in comparison to many mainland facilities, they have furnished power to sugar mills and the three island utility companies for many years. The 12 MW Wailuku River Hydroelectric Power Company plant is the largest in the state and began producing electricity in May 1993. More hydropower plants on Hawaiʻi, Kauaʻi, and Maui have been proposed.

g. Ocean Energy

Ocean energy is found in three forms: ocean thermal energy conversion (OTEC), wave energy, and tidal energy. Hawaiʻi has tremendous potential in at least two (wave and OTEC) of the three areas. The potential issue with tidal energy generation in Hawaiʻi is the relative lack of tidal range between high and low tides, one to two feet at the most. Wave energy uses energy from waves to drive a working fluid through a generator. Wave or tidal power plants can be based on land or in water. There is a wave energy plant at Kāneʻohe Marine Corps Base on the island of Oʻahu, built to examine the use of wave energy. OTEC, which uses the difference in temperature between water from the surface of the ocean and from several thousand feet down, has been examined at the Natural Energy Laboratory of Hawaiʻi Authority (NELHA) in Kailua-Kona on the Big Island of Hawaiʻi. OTEC was successfully demonstrated in Hawaiʻi, but was not judged economical enough to build a utility scale plant. Technologies for wave and tidal energy generation, however, are being used successfully in other parts of the world and continue to evolve. There are two reports available that describe Hawaiʻi's resource and assess feasibility of wave energy projects to which the reader is referred for more information (DBEDT, 1992; DBEDT, 2002).

h. Solar Thermal Energy, Desalination, Drying

The primary use of solar thermal energy in Hawaiʻi is for solar water heating. An estimated 80,000 single family homes, multi-unit dwellings, and institutional facilities in Hawaiʻi are served by solar water heaters, the highest per capita solar water heating use in the nation. Other uses of solar energy include solar powered desalination, solar drying, and photovoltaics.

Solar-powered desalination was demonstrated by a small-scale project conducted at the Natural Energy Laboratory of Hawaiʻi Authority at Keahole, on the island of Hawaiʻi. A sloped transparent glass or plastic roof was installed over a reservoir containing salty or brackish water. When the sun shines through the glass, the water is heated, causing it to evaporate and leave the salt behind. When the water vapor touches the cover, it condenses on the inside of the glass and the fresh water droplets roll down the inside of the glass into a collection trough. The Honolulu Board of Water Supply is currently in the process of testing and building a full-scale seawater desalination plant, capable of producing 5 million gallons per day of potable water.

Heat from the sun can also be used to dry a variety of materials - fruit, vegetables, fish, beef jerky, coffee beans, cocoa beans, macadamia nuts, decorative items, herbs, clothing, paper, and so forth. The ancient Hawaiians used the sun to dry food, herbs, and clothing (tapa cloth).

i. Photovoltaics

Photovoltaic (PV) cells produce electricity from sunlight. It is estimated that more than 500 private homes and farms in Hawaiʻi are using PV systems for some or all of their electrical needs. In addition, a number of remote communication systems and scientific monitoring equipment are powered by PV. Although relatively expensive, net metering programs, described below, help reduce costs. Appendix A19 lists some of the major projects involving photovoltaics.

The following are brief descriptions of the two most significant solar PV projects planned or existing in Hawaiʻi.

- **Photovoltaics to Power Army Homes.** According to an article in the Honolulu Advertiser (Aug. 3, 2005), PV systems totaling 7 MW were to be installed on nearly 3,000 new Army homes built on Oʻahu at Schofield Barracks. The homes also have solar water heaters, cool windows, roof vents, and low-flow faucets, showers and toilets.

- **Mauna Lani Resort.** The Mauna Lani Resort is located on the Kohala Coast of Hawaiʻi. Facing electricity rates that are among the highest in the United States, management sought ways to reduce operating costs and the risk of future fuel price volatility as well as contribute to Hawaiʻi's sustainability and environmental preservation.

Since the mid-1990s, the resort has implemented a broad range of energy efficiency and renewable energy projects. The first solar electric system was installed on the hotel roof in May 1998. By June 2003, the Mauna Lani had installed seven photovoltaic systems totaling over 674 kW, making it the largest solar-powered resort in the world.

The PV projects at the resort include: three rooftop systems on the hotel, a rooftop system on the golf facilities building, 162 solar-powered golf carts, a ground-mounted tracking system and the world's only solar-powered Watsu massage spa. In addition to the PV systems, there was a comprehensive energy efficiency retrofit of the hotel building, a central plant retrofit, facility-wide lighting retrofit, and solar thermal pool heating added.

j. Wind Energy in Hawai'i

In the early 1980s, there was considerable emphasis on wind energy in Hawai'i. HECO formed a non-regulated subsidiary to construct a wind farm at Kahuku on O'ahu's North Shore. In addition, the Department of Energy funded the world's largest wind turbine at the time, the Boeing Mod-5 capable of producing 5 MW. Unfortunately, due to the limitations of wind turbine technology at the time and the harsh conditions of the site, the wind farm proved uneconomical and was shut down in 1996.

Existing Wind Farms. Other wind farms were built on the Big Island, which initially had greater capacity than today. The wind turbines that remain operational are remnants of a larger fleet. As noted above, Apollo Energy operates a wind farm at South Point, and HELCO operates one at Lalamilo Wells.

Much of the data below was gathered from HECO's website: www.heco.com.

- **Hāwī Renewable Development (HRD)** and HELCO signed a power purchase agreement (PPA) on December 30, 2003 for as-available energy from a 10.5 MW wind farm at Hāwī. The agreement was approved by the PUC on May 14, 2004. The wind farm began producing power in 2006.

- **Apollo Energy Corporation** was contracted to re-power its existing 7 MW Kamaoa Wind Farm located at South Point, Hawai'i. Under the plans, the repowered wind farm will use 14 GE 1.5 MW wind turbines to produce 20.5 MW. After several years of negotiations over technical issues, on October 13, 2004, HELCO and Apollo signed a PPA for as-available energy, which was approved by the PUC on March 10, 2005. Commercial operation began in late 2005 but was shut down in August 2006 due to disrepair of the wind turbines. The Kamaoa Wind Farm is to be replaced by the Pakini Nui project, projected completion by April 2007, which will supply up to 21 MW of power to the Big Island electricity grid.

- **Kaheawa Wind Power, LLC (KWP)** built a 30 MW wind farm at Kaheawa Pastures on Maui using 20 GE 1.5 MW turbines. A PPA was executed by KWP and MECO and approved by the PUC on March 18, 2005. The farm began producing power in June, 2006.

- **Potential Wind Project at Kahe on O'ahu.** HECO recently completed over a year of on-site monitoring of the strength, direction and turbulence of wind on the ridges above HECO's Kahe Power Plant near Nānākuli. The monitoring confirmed what computer-generated, high-resolution wind resource maps previously showed; this area has one of O'ahu's strongest wind resources. However, due to public pressure, on September 27, 2005, Honolulu Mayor Mufi Hannemann stated that the city would not grant two critical permits needed for the project to progress. HECO has now shifted efforts to investigating the possibility of a wind project in Kahuku, where an earlier wind farm once existed.

C. Renewable Energy and State of Hawai'i Energy Objectives and Policies

As discussed above, Section 226-18, HRS sets the state of Hawai'i energy policies. The elements directly related to renewable energy are listed below:

Section 226-18 Objectives and policies for facility systems energy:

(a) Planning for the State's facility systems with regard to energy shall be directed toward the achievement of the following objectives, giving due consideration to all.

(1) Increased energy self-sufficiency where the ratio of indigenous to imported energy use is increased.

(b) To further achieve the energy objectives, it shall be the policy of this State to:

(1) Support research and development as well as promote the use of renewable energy sources.

Based upon these policies, the state of Hawai'i has taken a number of actions. These include: (1) setting additional objectives and policies favoring renewable energy through legislation, (2) providing an analytical basis for renewable energy policy support and to assist potential developers, and (3) attempting to stimulate the market for renewable energy. These activities will be discussed in the next three sections.

D. State of Hawai'i Legislation Setting Additional Objectives and Policies Favoring Renewable Energy

The Hawai'i State Legislature has consistently supported renewable energy. Legislation that will help deploy renewable energy and enhance the sustainability of Hawai'i's energy system is briefly summarized below. For additional details, please consult the Hawai'i State Legislature website at http://www.capitol.hawaii.gov. For Acts referenced below, see the Archive pages. To review the Hawai'i Revised Statutes (HRS), see the bottom of the Bill Status & Docs page.

1. Renewable Energy Portfolio Standard (RPS)

In her campaign and State of the State address in 2004, Governor Linda Lingle called for 20 percent renewable energy by the year 2020. Act 95, Session Laws of Hawai'i (SLH) 2004 was a compromise bill that sought to put her vision into action. It is the strongest policy in support of renewable energy that the State has established. The act created Section 269-92 HRS, which specified that each electric utility company that sells electricity for consumption in the State shall establish a renewable portfolio standard of:

(1) Seven per cent of its net electricity sales by December 31, 2003
(2) Eight per cent of its net electricity sales by December 31, 2005
(3) Ten per cent of its net electricity sales by December 31, 2010
(4) Fifteen per cent of its net electricity sales by December 31, 2015
(5) Twenty per cent of its net electricity sales by December 31, 2020

Renewable energy was broadly defined in Section 269-91, HRS, as

> . . . electrical energy produced by wind, solar energy, hydropower, landfill gas, waste to energy, geothermal resources, ocean thermal energy conversion, wave energy, biomass, including municipal solid waste, biofuels, or fuels derived from organic sources, hydrogen fuels derived from renewable energy, or fuel cells where the fuel is derived from renewable sources. Where biofuels, hydrogen, or fuel cell fuels are produced by a combination of renewable and nonrenewable means, the proportion attributable to the renewable means shall be credited as renewable energy. Where fossil and renewable fuels are co-fired in the same generating unit, the unit shall be considered to produce renewable electricity in direct proportion to the percentage of the total heat value represented by the heat value of the renewable

fuels. "Renewable energy" also means electrical energy savings brought about by the use of solar and heat pump water heating, seawater air-conditioning district cooling systems, solar air-conditioning and ice storage, quantifiable energy conservation measures, use of rejected heat from co-generation and combined heat and power systems excluding fossil-fueled qualifying facilities that sell electricity to electric utility companies, and central station power projects.

This broad definition was the result of a compromise to reduce utility concerns about possible difficulties in complying. Although there are no penalties for noncompliance at the present time, the Public Utilities Commission was charged with making rules and establishing rates, a process which is currently underway. Details about the collaboration, including workshop presentations and filings, can be found at: http://www.hawaii.gov/budget/puc/energy/#act95.

Compliance with the law should increase the use of renewable energy. In 2004, the three Hawaiian Electric utilities which were allowed to aggregate their use of renewable resources had the equivalent of 11.4 percent of sales (HECO, 2005a) and KIUC had 13.2 percent of sales (KIUC, 2005) from renewable energy and efficiency measures as defined by the law. The utilities are including renewable energy resources to meet the requirements of the law in their integrated resource plans.

Changes to the Hawaiʻi RPS law during the 2006 Legislative session are discussed further in Chapter VIII.

2. Net Energy Metering

Net energy metering is a way to encourage the use of eligible renewable energy electricity generators by residential and commercial customers. The owner or leaser of an eligible renewable energy generator can enter into an agreement with the utility to connect the generator to the utility grid to feed surplus electricity into the grid. Any kWh put into the grid will be subtracted from the kWh of electricity the customer uses. If the customer should provide the utility with more electricity than the utility provides the customer, the excess power is "granted" to the utility. Net metering and the simplified interconnection agreement with the utility make it easier and more cost-effective for Hawaiʻi residents, government agencies, and business owners to install small, on-site renewable energy systems.

For additional information about HECO's net metering requirements, see their website: www.heco.com. All four Hawaiʻi electric utilities offer net metering. Hawaiʻi was the 34th state to enact net metering. A list of other states is available from the "Database of State Incentives for Renewable Energy" at : http://www.dsireusa.org.

3. Hawaiʻi Public Utilities Commission Renewable Resource Docket

Senate Concurrent Resolution No. 40, adopted in 1994, requested the Public Utilities Commission to initiate an informational docket to facilitate the development and use of renewable resources in the state. The Commission opened a collaborative Docket 94-0226 to examine what other states were doing to encourage renewable energy, to compare them with Hawaiʻi's current policies, to identify barriers, and to formulate strategies to remove the barriers and implement renewable energy in Hawaiʻi.

In 1996, 21 parties participated in the process which produced a two-part report titled "Strategies to Facilitate the Development and Use of Renewable Energy Resources in Hawai'i." The first part was a study by the National Renewable Energy Laboratory, offering options for Hawai'i. The second part summarized the efforts to formulate strategies to enhance the use of renewable energy.

The barriers identified in the collaborative document included the following:

- Insufficient avoided cost prices for developer financing.
- Operational limitations on the amount of renewable energy usable at various times.
- Complex and lengthy permitting processes and difficulties in finding available sites.
- Form of payment offered to developers does not facilitate financing.
- Lack of new renewables in Integrated Resource Plans.
- Protracted nature of power purchase agreement negotiations.
- Lack of direct consumer access to renewable power.
- Potential negative environmental and social impacts.
- Certain renewable and storage technologies are insufficiently mature to be economically viable.
- Fragmented and overlapping efforts by the state in renewable energy research, development, demonstration, and commercialization.

In most cases, little progress has been made in removing these barriers, which were reported to the Legislature in 1996. Neither the Commission nor the Legislature has opted to take comprehensive action to deal with these issues. The report is available at: http://hawaii.gov/dbedt/info/energy/publications/index_html/.

E. State of Hawai'i Projects to Provide an Analytical Basis for Renewable Energy Policy and to Assist Potential Developers

The analytical basis for renewable energy has been provided through energy planning efforts and technical renewable energy resource assessments.

1. Energy Planning

Examination of the options for renewable energy has been integral to the state's energy planning process since the mid-1970s. There have been several documents which recommended increasing the use of renewable energy: *the Hawai'i Renewable Energy Assessment (1975), the Hawai'i Integrated Energy Assessment (1981), the Hawai'i Integrated Energy Plan (1991), the Hawai'i Energy Strategy (1995)* and *the Hawai'i Energy Strategy 2000.*

The most recent of these documents, *Hawai'i Energy Strategy 2000* (DBEDT, 2000), devoted a chapter to "Increasing Renewable Energy Use in Hawai'i". It cited the advantages of renewable energy, the current renewable energy use in Hawai'i, and discussed near-term prospects for additional renewable energy. There were also recommendations for renewable energy portfolios for each of Hawai'i's utilities (see section J. *Recommendations to Enhance and Increase Renewable Energy in Hawai'i* below for more specifics).

2. Renewable Energy Resource Assessments

The state has funded several assessments which were intended to be used by potential renewable energy developers to screen potential sites for a variety of renewable energy technologies. These assessments identified specific locations for which the renewable energy resource, land use zoning, and land ownership were appropriate for renewable energy deployments.

The most detailed of these assessments was the *1995 Renewable Energy Resource Assessment and Development Program* (DBEDT, 1995) completed as part of the Hawaiʻi Energy Strategy program. The assessment was done by RLA Associates, which is now known as Global Energy Concepts. The report included a "Renewable Energy Resource Assessment Plan", "Renewable Energy Resource Supply Curves", and a "Renewable Energy Integration Plan."

An Update of Selected Cost and Performance Estimates was produced in 2000, in support of efforts to pass a RPS, which was ultimately passed as a goal. *Select Hawaiʻi Renewable Energy Project Cost and Performance Estimates* (GEC, 2004) was completed in mid-2004 in support of the second and successful attempt to pass the RPS described above.

3. High Resolution Wind Maps

These maps were recently completed and provide a supplement to the assessments described above. New map-making technology, based on dynamic numerical simulation models, and increased computational capabilities have produced maps that are more accurate and more detailed than those available previously. The new maps reveal new potential wind sites with rich wind regimes. Their availability may accelerate the initial stages of wind project development. Nevertheless, it is standard practice to confirm such assessments by collecting wind speed data over a year at a proposed wind site as a basis for obtaining project financing.

HECO, MECO, DBEDT and the National Renewable Energy Laboratory jointly funded the project to develop wind maps of Oʻahu, Hawaiʻi (Big Island), Maui, Molokaʻi, Lānaʻi, and Kauaʻi. These maps have a grid resolution of 200 meters and provide wind speeds at 30, 50, 70, and 100 meters as well as wind power densities at 50 meters. The maps include basic overlays of significant features such as cities, parks, roads, and power lines.

The maps identified a new potential wind site on Oʻahu on a ridge above the Kahe power plant. HECO has verified the wind resource with over a year's worth of wind measurements and is now seeking public support for the project. The project is part of HECO's preferred plan in its current draft, which will not be granted necessary permits by the City & Country of Honolulu due to community pressure. The high-resolution wind resource maps for Oʻahu, Big Island of Hawaiʻi, Maui, Molokaʻi, and Lānaʻi are available on the HECO web site (http://www.heco.org).

4. State of Hawaiʻi-Sponsored Studies on Renewable Energy

The State Energy Office managed production of numerous studies and analyses to determine how best to deploy renewable energy or to examine other related technical aspects. These studies were usually financially supported by the USDOE either through funds provided annually for the State Energy Program or through competitively awarded Special Project grants. A listing is provided at: http://www.hawaii.gov/dbedt/info/energy/publications/.

F. *State of Hawai'i Efforts to Stimulate the Market for Renewable Energy*

Historically, state efforts to support renewable energy began with research, development, and development (RD&D) activities supported by the state of Hawai'i and federal government. These are followed by various financial incentives to help renewable energy developers with their projects.

1. RD&D Activities

The RD&D activities included support for some of Hawai'i's initial wind energy deployments. These include the 3.2 MW Boeing Mod-5 wind turbine at Kahuku on O'ahu, successful construction and test of an Ocean Thermal Energy Conversion prototype at Keahole on the Big Island of Hawai'i, geothermal test drilling and assessments, research on a wind-diesel hybrid system on Moloka'i, early deployments of PV and work on a biomass gasifier at Pu'unene on Maui. Efforts are now being made to develop a renewable energy-based hydrogen infrastructure for future fuel cell applications.

The Biomass Gasifier. The pre-commercial biomass gasification research facility on Maui successfully demonstrated the technical feasibility of producing fuel gas (biogas) from sugar cane bagasse. The biogas could be utilized in gas turbines for generating electricity and for producing methanol fuel for transportation purposes. The research demonstrated that biogas can fuel an advanced turbine system to produce electricity with a possible 50 percent increase in efficiency. In addition, the technologies developed could enable the widespread use of a cleaner, self-sustaining energy resource. Hawai'i's assets (e.g., a highly developed bio-energy infrastructure, resident technical capability in research and engineering, and a year-round growing season) offer unique advantages for developing these state-of-the-art systems. However, the USDOE did not elect to provide additional funding for commercialization of the facility (DBEDT, 2000).

Hydrogen RD&D. Recently, the focus has shifted to hydrogen infrastructure development. A key element is to find ways to produce electricity from the electrolysis of hydrogen from renewable sources. In that way, hydrogen could become a transportation fuel and would also be a way to store electricity generated by renewable resources that might otherwise be curtailed due to low load conditions. See the State of Hawai'i's hydrogen roadmap, titled "Nurturing a Clean Energy Future in Hawai'i: Assessing the Feasibility of the Large-Scale Utilization of Hydrogen and Fuel Cells in Hawai'i" at: http://www.hawaii.gov/dbedt/info/energy/publications/hydrogen02.pdf (HNEI, 2002).

Hydrogen's potential as a long-term sustainable energy solution was discussed in detail in the roadmap, which included the following:

- Hydrogen could become an inexhaustible supply of fuel.
- Hydrogen would be sustainable if produced by renewable energy resources.
- Hydrogen fuel cells are much more efficient than combustion processes for producing electricity.
- Hydrogen production could use electricity from intermittent and distributed renewable resources at times when they are not needed to meet electric utility demand.
- Hydrogen does not pollute when burned and is nontoxic since it emits only water.
- When generated using renewable energy, hydrogen production produces minimal environmental impact.

- Hydrogen fuel cells can provide a highly efficient and reliable source of energy "on demand" for low-noise, emissions-free transportation, as well as a modular means for providing distributed energy for the utility sector.

2. State of Hawaiʻi Financial Incentives

The Hawaiʻi Energy Tax Credits allow individuals or corporations to claim a state income tax credit of 20 percent of the cost of equipment and installation of a wind system and 35 percent of the cost of equipment and installation of a solar thermal or PV system. Originally enacted in 1999, the tax credits were revised in 2003 and extended to the end of 2007. SB 3162, enacted in June of 2004, allows a credit that exceeds the taxpayer's income tax liability to be carried forward to subsequent years until exhausted. The 2006 Legislature removed the termination date of the tax credit. The tax credits were previously discussed in the context of energy efficiency as solar water heating is part of utility DSM programs. The following is a summary of the credits:

Credits for solar thermal and PV energy systems:

- Single family residential property is eligible for a credit of 35 percent of the actual cost or $2,250 for solar thermal systems, and $5,000 for PV systems, whichever is less.
- Multi-family residential property is eligible for a credit of 35 percent of the actual cost or $350 per unit, whichever is less.
- Commercial property is eligible for a credit of 35 percent of the actual cost or $500,000 for photovoltaic and $250,000 for solar thermal, whichever is less.

Credits for wind powered energy system:

- Single family residential property is eligible for a credit of 20 percent of the actual cost or $1,500, whichever is less.
- Multi-family residential property is eligible for a credit of 20 percent of the actual cost or $200 per unit, whichever is less.
- Commercial property is eligible for a credit of 20 percent of the actual cost or $500,000, whichever is less.

3. Industry Recruitment Tax Breaks for Qualified Research

Hawaiʻi is the only state in the nation to offer a 100 percent tax credit for an equity investment in a qualified high tech business (QHTB). The credit is intended to encourage investment in high technology companies. A "qualified high technology business" is defined as "a business that conducts more than 50 percent of its activities in qualified research." "Qualified research" includes "non-fossil fuel energy-related technology," which is energy produced by wind, solar energy, hydropower, geothermal resources, ocean thermal energy conversion, wave energy, hydrogen, fuel cells, landfill gas, waste to energy, biomass including municipal solid waste, and biofuels. Details on the tax credit can be found at http://www.state.hi.us/tax/announce/2003ann01.htm.

4. State "Enterprise Zone" Incentives

Wind energy sites and agriculture enterprises producing energy crops or biofuels that are located in Enterprise Zones may be eligible for incentives that range from waiving of county fees to exemption from state general excise taxes. The program applies to agricultural production or processing, manufacturing, wind energy production, and nine other general areas.

5. Contractor Licensing

To increase the availability of installers, Hawaiʻi offers specialty licenses for solar contractors through the Department of Commerce and Consumer Affairs: Solar Power Systems Contractor (C-60), Solar Energy Systems Contractor (C-61), Solar Hot Water Systems Contractor (C-61a), and Solar Heating and Cooling Systems Contractor (C-61b). These licenses require business and trade exams plus four years of experience. Note that an Electrical Contractor (C-13) license is required to install PV systems and it includes the work of the C-60 solar power systems contractor. Plumbing contractors (C-37) are also allowed to install solar hot water heating systems. See the following for additional information: http://www.hawaii.gov/dcca/areas/pvl.

6. Interconnection

Hawaiʻi has established interconnection rules for small renewables and, more recently, separate rules for all other distributed generation. Simplified interconnection and net metering are available for solar, wind, biomass, and hydroelectric systems up to 50 kW (increased from 10 kW by Act 104 in June of 2005). The state's largest electric utility, Hawaiʻi Electric (HECO), which also owns Hawaiʻi Electric Light Company (HELCO) and Maui Electric Company (MECO), has a set of simple how-to guidelines and contact information for interconnecting such systems. HECO also has a simple, two-page net metering agreement.

7. Solar Access Law

The Legislature established the right of homeowners to install solar systems in Section 196-7, HRS, which prohibits the creation of any covenant or restriction contained in any document restricting the installation or use of a solar energy system on a residential dwelling or townhouse. As of September 1, 2005, these rules were strengthened by HB 1017, which directed homeowners associations to adopt rules that provide for the placement of solar energy systems. In addition, amendments to Section 514A-89, HRS, dealing with additions and alterations made to condominiums were made to recognize solar energy systems accordingly.

G. Federal Programs Supporting Renewable Energy. (The following is based upon a Summary of Provisions of the Energy Bill by the Congressional Quarterly.)

There are many federal programs, policies, incentives, provisions, etc. that are geared toward supporting renewable energy development. We will summarize these federal efforts in Appendix A20 as they are pertinent to the general, but not specific, discussion of renewables in Hawaiʻi.

H. Electric Utility Programs Supporting Renewable Energy

The electric utilities have made claims of support for renewable energy for many years. In the mid-1980s, Hawaiian Electric Company formed a subsidiary which ultimately built a wind farm at Kahuku in northeast O'ahu. Unfortunately the first-generation wind turbines were not very durable, especially in the turbulent areas where the wind farm was located and constant salt spray from the ocean added to their maintenance problems. The wind farm was sold to a wind developer in 1991, who was only able to keep the turbines operational until 1996. KIUC operates some hydro units.

Utilities are committed to complying with renewable portfolio standard, and are including renewable resources in the integrated resource plans, but, as of yet, have made no moves towards significant deployment of utility-owned renewable energy. They are engaged in many projects, however, which ultimately may foster additional renewable energy. These are discussed below starting with a review of renewable energy related DSM programs.

1. Utility DSM Programs Supporting Renewable Energy

As part of utility DSM programs discussed in the previous chapter related to energy efficiency, customers are provided incentives or rebates for installation of renewable energy and energy efficiency measures. Those relating to renewable energy are summarized below.

a. HECO, MECO, HELCO - Energy $olutions Solar Water Heater Rebate

As part of their Energy $olutions programs, Hawaiian Electric Company, Inc. (HECO), and its subsidiaries, Maui Electric Company, Ltd. (MECO), and Hawai'i Electric Light Company, Inc. (HELCO), provide one-time rebates to qualifying customers who install solar water heaters. The program began in June 1996 and a rebate for the 20,000th system installed through the program was paid in February of 2003.

The Residential Energy $olutions solar water heater rebate amounts are as follows:

HECO - $750 Retrofit, $750 New Construction
MECO - $1,000 Retrofit, $1,000 New Construction
HELCO - $1,000 Retrofit, $1,000 New Construction

Since initiated in 1996, the campaign has been successful in persuading thousands of utility customers to use solar water heaters.

b. Kaua'i Island Utility Cooperative (KIUC) - Solar Water Heating Program

Kaua'i Island Utility Cooperative's Commercial Energy Wise Program began in 1998. Participants receive an energy use analysis and screening for the installation of cost-effective energy saving devices, which includes solar water heating systems. Commercial customers are eligible for a 50 percent rebate for such devices. Residential customers are eligible for a flat $800 rebate for each solar system installed. During 2004, 54 residential systems were installed through the rebate program.

2. Utility Activities to Support Renewable Energy

The following activities are discussed on the HECO web site.

a. Renewable Hawai'i, Inc.

HECO formed an unregulated renewable energy subsidiary, Renewable Hawai'i, Inc., to invest in commercially and economically viable renewable energy generation projects for Hawaiʻi. Renewable Hawaiʻi has issued a number of requests for proposals in an effort to identify projects for investment. To date, no projects have been built. See the website at http://www.renewablehawaii.com for more information.

b. Hawaiʻi Fuel Cell Test Facility

HECO's Ward Avenue complex is the site of the new Hawaiʻi Fuel Cell Test Facility to support the hydrogen fuel cell research efforts of the University of Hawaiʻi Natural Energy Institute (HNEI, 2002). In 2003, HECO provided a warehouse in which HECO, HNEI, the Office of Naval Research, and UTC Fuel Cells have installed a facility to test fuel cell designs, materials, fuels and components, evaluating endurance, reliability and efficiency.

c. Electric Power Research Institute (EPRI) Offshore Wave Energy Project

HECO participated in a multi-phase, multi-state collaborative project headed by EPRI that examined the feasibility of offshore wave power. The project, completed in 2004, provided a conceptual design (including performance and cost estimates) for an offshore wave power system and assessed environmental and permitting issues.

d. Assessment of Biofuels for Use in Utility Generators

HECO is considering the use of biofuels (e.g., biodiesel, ethanol, etc.) in electric power generating units. To evaluate the technical feasibility, HECO is conducting an assessment of biofuel properties, supply, availability, pricing, and generating unit performance and emissions. Phases 1 and 2 of the project have been completed, and HECO is currently working on Phase 3, which involves infrastructure and operational issues.

e. Wind Farm Electronic Shock Absorber

As noted above, fluctuations in system voltage and frequency caused by the rapidly changing energy output of a wind farm create power quality issues. In extreme cases, these fluctuations may require disconnection of the wind farm from the transmission system or compensation by load-following fossil fuel generation units. To address this problem, the HECO utilities are working with a private company to develop and demonstrate an electronic shock absorber facility. The purpose is to isolate the utility transmission system from wind farm energy fluctuations. In January 2006, HECO and S&C Electric Co. installed the PureWave Electronic Shock Absorber at Lalamilo Wind Farm on the Big Island. The installation will test the shock absorber's potential for increasing and stabilizing the amount of wind power produced.

f. Intermittent Generation Assessment Protocol

Wind gusts and turbulence can cause rapidly changing energy output from a wind farm. On a weakly supported transmission line or an isolated island grid system this can create fluctuations in both frequency and voltage. To improve existing planning and evaluation tools, HECO worked with a consultant to address the impact of intermittent renewable energy generation on small, isolated electric utility systems. The study was completed in 2005.

g. Natural Energy Laboratory of Hawaiʻi Authority Gateway Project

HELCO partnered with the Natural Energy Laboratory of Hawaiʻi Authority (NELHA), DBEDT, the University of Hawaiʻi's Natural Energy Institute, and Sentech in a project to construct distributed energy systems at the Gateway Center located at the entrance to NELHA′s Hawai‘i Ocean Science and Technology (HOST) Park. This project aims to demonstrate renewable distributed energy resources and technology. HELCO installed two 20 kW photovoltaic systems at the Gateway Center in August 2004.

h. Hydroelectric Resource Assessment

HECO and DBEDT jointly funded a study to assess the hydroelectric resource potential of water systems and existing water reservoirs operated by the County of Hawai‘i Department of Water Supply, State of Hawai‘i Department of Agriculture, and private landowners. In the study, which was completed in 2004, the feasibility of in-line hydroelectric power production and pumped storage hydroelectric applications was examined

i. In-Line Hydroelectric Generator Project

HELCO has committed funding to assist the County of Hawai‘i Department of Water Supply with an in-line hydroelectric generator project. Several feasible sites were identified and both parties are assessing next steps, including identifying the number and location(s) of the installations.

j. Bulk Energy Storage System Evaluation

DBEDT and HELCO used funding competitively awarded by the USDOE to evaluate the ability of energy storage to alleviate electricity transmission and reliability issues on the Big Island of Hawai‘i. These issues are expected to increase due to growth in the use of distributed energy resources and renewable energy.

k. Study of Distributed Energy Resources Management as a Microgrid

DBEDT and HELCO used additional funding competitively awarded by the USDOE to evaluate the combination of hybrid, controllable distributed energy resources (DER) systems that will encourage development of renewable and distributed resources. Hybrid DER combines distributed generation from renewable resources, electrical storage, thermal energy storage, and building energy management systems.

l. Kona Base Yard Grid-Connected PV System

To demonstrate a PV system for a small commercial or residential net metered system, HELCO installed a 5.4 kW system along with battery back-up and an educational display at their Kona base yard. The system also provides HELCO staff with an opportunity to gain experience with a net energy metered PV system.

m. Ocean Wave Energy Demonstration

Ocean wave energy is a developing technology with potential application in Hawai‘i. Under a contract with the Navy, Ocean Power Technologies is assessing the technical and economic feasibility of ocean wave energy by conducting an at-sea demonstration of a buoy wave energy system at Kāne‘ohe Marine Corps Base Hawai‘i on O‘ahu. HECO is monitoring the project, serving as the Navy′s technical advisor, and providing engineering interconnection support.

I. *Other States' Renewable Energy Policies*

Other states use a variety of additional measures or incentives to encourage renewable energy. These include public benefit funds, renewable energy equipment subsidies or direct equipment sales, green power purchasing, and green tags. A brief summary of each of these programs is presented in Appendix A21. See the DSIRE *Database of Incentives for Renewable Energy* (http://www.dsireusa.org) for examples and details of what individual states are doing.

J. *Recommendations to Enhance and Increase Renewable Energy in Hawai'i*

This section will summarize the recommendations from the *Hawai'i Energy Strategy 2000* (DBEDT, 2000) that were intended to enhance renewable energy and then will look at specific projects recommended in *Selected Hawai'i Renewable Energy Project Cost and Performance Estimates, 2004*. The user of this case study is also encouraged to review *Strategies to Facilitate the Development and Use of Renewable Energy Resources in Hawai'i*, discussed above, to identify barriers to the use of renewable energy. Policies, administrative rules, and legislation could be developed to handle many of these issues.

1. Hawai'i Energy Strategy 2000 Recommendations

A number of actions were recommended to increase renewable energy use in Hawai'i including:

- Obtain accurate cost data for use in Integrated Resource Planning (a problem which persists today).
- Use state income tax credits to encourage renewable energy use (this recommendation was intended to encourage the extension of the existing state income tax credits which were scheduled to expire at the end of 2003, but were extended by the 2006 legislative session to 2008).
- Asking the Hawai'i Congressional Delegation to encourage extension of the federal income tax credits for renewable energy (these were mostly extended by the Energy Policy Act of 2005).
- Continue to increase the use of solar water heating (state income tax credits and utility DSM programs continue to stimulate solar water heating installations).
- Implement the recommendations of the Public Utilities Commission's renewable energy resource docket (discussed in more detail above).
- Consider implementing a renewable portfolio standard, a public benefits charge, or green pricing to increase renewable energy use (as noted above, a renewable energy portfolio standard was implemented in 2004).

2. Projects Recommended in Selected Hawai'i Renewable Energy Project Cost and Performance Estimates, 2004

In 2004, Global Energy Concepts (GEC, 2004), under contract to DBEDT, updated its characteristics and performance estimates for what it regarded as the sites with the greatest potential for development. The following three tables summarize the recommendations of their report. Table 20 shows the recommendations based upon available technology in 2004. Tables 21 and 22 show estimates for 2014 and 2020 based upon technological improvements expected by those times. Note that cost and performance improve over time.

The GEC analysis and report were originally developed to provide objective analytical support to the ultimately successful efforts to pass the RPS in 2004. In developing cost and performance estimates, GEC combined information on the status of the technology and its future implementation with a practical perspective on the elements necessary to deploy a project in Hawai'i. GEC further explained their approach as follows.

The realistic estimates are bounded by optimistic and conservative ranges that express the uncertainty associated with technology development or resource availability. The optimistic, nominal, and conservative cases differ from each other because of uncertainty in energy production, project costs, or a combination of both. Energy production estimates vary reflecting the uncertainty of the resource and the difference between the expected and actual energy conversion efficiency of the technology. Cost estimates vary reflecting uncertainties in factors such as the development pace of the technology, changes in market conditions, variations between suppliers and developers, and other uncertainties inherent in estimating project costs in an environment where few projects of this type have been completed. The nominal value represents the best estimate but is not necessarily the mean value of the range.

Potential Renewable Energy Projects for Hawaii - Current

Technology	Island	Location	Capacity (MW)	Nominal Energy (MWh)	COE ($/kWh)
Photovoltaics	Hawaii	N. Kohala	5	11,695	0.219
	Oahu	Pearl Harbor	5	10,257	0.257
Wind	Hawaii	Lalamilo Wells	3	9,154	0.047
		Lalamilo Wells	30	92,802	0.047
		Lalamilo Wells	50	154,670	0.045
		N. Kohala	5	17,469	0.044
		N. Kohala	10	38,840	0.047
	Kauai	Port Allen	5	9,774	0.069
	Maui	Kaheawa Pastures	20	70,338	0.043
		NW Haleakala	10	27,493	0.052
		NW Haleakala	30	75,214	0.06
		NW Haleakala	50	125,357	0.057
		Puunene	10	20,689	0.068
		Puunene	30	56,601	0.078
	Oahu	Kaena Point	3	6,461	0.066
		Kaena Point	15	33,201	0.066
		Kahuku	30	68,181	0.063
		Kahuku	50	113,635	0.063
		Kahuku	80	181,816	0.066

Table 20. Potential Renewable Energy Projects for Hawai'i - Current (GEC, 2004).

For most technologies, three conceptual project designs were developed. One design was based on project components that are commercially available for installation within the next year (current technology). The second design was based on components that are realistically expected to be commercially deployed within the next decade (2014 technology). The third design was based on long-term expectations of technology advances (2020 technology).

Project performance estimates are based on the conceptual project designs, expected technology performance, potential project sizes, and the best available resource data. The net energy estimates are the amount of energy expected to be delivered to the utility grid (GEC, 2004).

It is recommended that the reader of this case study examine *Select Hawai'i Renewable Energy Project Cost and Performance Estimates*, 2004 in more detail to see the thoroughness of the estimates. The estimates are available at: http://www.hawaii.gov/dbedt/info/energy/publications/shrep04.pdf/.

3. State Commitment to Assist in Renewable Energy Development

One of the provisions of Act 95, SLH 2004, the bill that enacted the RPS, committed the State Department of Land and Natural Resources and the Department of Business, Economic

Development, and Tourism to assist with implementation of the RPS. This requirement became Section 196-41, which specifies the following:

> **[§196-41] State Support for Achieving Renewable Portfolio Standards.**
> (a) The Department of Land and Natural Resources and Department of Business, Economic Development, and Tourism shall facilitate the private sector's development of renewable energy projects by supporting the private sector's attainment of the renewable portfolio standards in Section 269-92. Both departments shall provide meaningful support in areas relevant to the mission and functions of each department as provided in this section, as well as in other areas the directors of each department may deem appropriate.

Representative Renewable Energy Projects – Future 2014					
Technology	Island	Location	Capacity (MW)	Nominal Energy (MWh)	COE ($/kWh)
Biomass	Hawaii	East Side of Island	10	65,700	0.051
Geothermal	Hawaii	Kilauea	10	252,200	0.058
Hydroelectric	Hawaii	Umauma Stream	13.8	40,199	0.083
	Kauai	Wailua River	6.6	16,435	0.101
Photovoltaics	Hawaii	N. Kohala	5	12,136	0.168
	Oahu	Pearl Harbor	5	10,643	0.199
Wind	Hawaii	Lalamilo Wells	3	12,115	0.045
		Lalamilo Wells	30	111,857	0.046
		Lalamilo Wells	50	184,565	0.044
		N. Kohala	5	20,977	0.042
		N. Kohala	10	41,534	0.046
		Kahua Ranch	10	31,384	0.052
	Kauai	N. Hanapepe	10	22,627	0.068
		Port Allen	5	11,393	0.069
	Maui	Kaheawa Pastures	10 expand	37,471	0.039
		NW Haleakala	10	30,748	0.05
		NW Haleakala	30	95,097	0.056
		NW Haleakala	50	156,910	0.053
		Puunene	10	22,499	0.066
		Puunene	30	69,583	0.074
	Oahu	Kaena Point	3	8,628	0.063
		Kaena Point	15	41,602	0.063
		Kahuku	30	84,302	0.06
		Kahuku	50	139,098	0.059
		Kahuku	80	223,400	0.062

Table 21. Potential Renewable Energy Projects for Hawai'i – 2014 (GEC, 2004).

Representative Renewable Energy Projects – Future 2020					
Technology	Island	Location	Capacity (MW)	Nominal Energy (MWh)	COE ($/kWh)
Biomass	Hawaii	East Side of Island	10	65,700	0.044
Geothermal	Hawaii	Kilauea	10	252,200	0.058
Hydroelectric	Hawaii	Umauma Stream	13.8	40,199	0.082
	Kauai	Wailua River	6.6	16,435	0.1
Photovoltaics	Hawaii	N. Kohala	5	12,280	0.128
	Oahu	Pearl Harbor	5	10,769	0.152
Wind	Hawaii	Lalamilo Wells	3	13,932	0.039
		Lalamilo Wells	30	128,636	0.04
		Lalamilo Wells	50	212,249	0.038
		N. Kohala	5	24,123	0.036
		N. Kohala	10	47,764	0.04
		Kahua Ranch	10	36,091	0.045
	Kauai	N. Hanapepe	10	26,021	0.058
		Port Allen	5	13,102	0.06
	Maui	NW Haleakala	10	35,360	0.043
		NW Haleakala	30	109,362	0.048
		NW Haleakala	50	180,447	0.046
		Puunene	10	25,873	0.057
		Puunene	30	80,021	0.064
	Oahu	Kaena Point	3	9,922	0.054
		Kaena Point	15	47,842	0.054
		Kahuku	30	96,947	0.052
		Kahuku	50	159,963	0.051
		Kahuku	80	256,910	0.054

Table 22. Potential Renewable Energy Projects for Hawai'i – 2020 (GEC, 2004).

(b) The Department of Land and Natural Resources shall:

(1) Develop and publish a catalog by December 31, 2006 and every five years thereafter of potential sites for the development of renewable energy.

(2) Work with electric utility companies and with other renewable energy developers on all applicable planning and permitting processes to expedite the development of renewable energy resources.

(c) The Department of Business, Economic Development, and Tourism shall:

(1) Develop a program to maximize the use of renewable energy and cost-effective conservation measures by state government agencies.

(2) Work with federal agencies to develop as much research, development and demonstration funding, and technical assistance as possible to support Hawai'i in its efforts to achieve its renewable portfolio standards.

(3) Biennially, beginning in January 2006, issue a progress report to the governor and legislature.

The work outlined in the statute is now underway and will also include adding potential sites or areas for potential renewable energy to the State Office of Planning GIS system.

K. Conclusions

Hawai'i has many underutilized renewable energy sources including wind, solar, hydro, geothermal, waves and tides, biomass production, and ocean thermal energy conversion. There is historical precedence in the state for significant renewable energy generation. In 1962 the state got 18 percent of its electricity from bagasse and hydroelectric plants. The state presently obtains only 6 percent of its energy from renewables, and there is room for significant growth. The state government has enacted legislation that requires each utility company selling electricity for consumption to generate 20 percent of its net electricity sales from renewable sources by the year 2020. Compliance with this legislation should increase the use of renewable energy. Having reviewed how improving end-use efficiencies can reduce demand for electricity generation, and also how renewable energy can replace fossil fuel sources, we will now review how the state can improve fossil fuel energy generation efficiency while moving towards greater energy sustainability.

VII. Improving the Efficiency of Fossil-Fueled Electricity Generation

A. Improving the Efficiency of Fossil-Fueled Electricity Generation

In preceding chapters, we discussed how end-use energy efficiency can reduce the demand for electricity generation and how renewable energy can replace fossil fuel electricity generation. However, due to the extent of the existing fossil fuel infrastructure and the advantages of fossil-fueled generation as a source of base load, firm power, and other factors, we expect that Hawai'i will depend upon significant amounts of fossil fuel energy generation for the foreseeable future. There are options that could make Hawai'i's current and future fossil fuel infrastructure more efficient. These options include increasing the efficiency of the existing generators, adding distributed generation, fuel switching, clean coal technologies, and eventually moving to biofuels and/or hydrogen fuels.

B. Supplying Fossil Fuels

As the USDOE points out on the Office of Fossil Energy's web site:

> "Oil and natural gas are the lifeblood of the U.S. economy. Together they account for more than 60 percent of the energy consumed in the United States. Although the United States is a mature producing region, over 40 percent of oil consumed comes from domestic fields (the rest is imported from foreign sources), and two-thirds of all the oil discovered in the country remains in the ground. Natural gas resources are plentiful, but as demand increases U.S. production must increasingly come from more difficult-to-produce, technically challenging resources and settings."

1. Natural Gas as an Option for Hawai'i.

Almost 90 percent of Hawai'i's energy comes from oil. Currently, natural gas is not imported. Instead, utility gas is locally produced synthetic natural gas and propane air mixtures. Natural gas offers a cleaner burning option to oil, and at one time was less expensive, especially when used in a modern dual train combined cycle unit. Several natural gas companies have visited Hawai'i over the last few years to discuss the possibility of importing liquefied natural gas (LNG) into Hawai'i. The main customer would be HECO, but to date there have been no known negotiations or detailed planning for such a project.

Among the major obstacles to using natural gas in Hawai'i would be finding a location for the receiving terminal and re-gasification facility. In addition, if HECO switched to LNG and the refineries lost their major market for heavy fuel oil, it is not clear whether they could stay in business or what the effects on the cost of other refined products might be. The question may be moot, however, for in the last few years demand from the U.S. mainland has grown tremendously, outgrowing continental supply, and efforts are underway to import LNG into the mainland and Mexico. LNG prices have increased significantly reducing that advantage and Hawai'i's small market has become less appealing to exporters.

2. USDOE Research and Development to Improve the Sustainability of Fossil Fuel Use.

The following is a summary of research and development in areas that could result in more sustainable uses of fossil fuel energy. It is based on the USDOE Office of Fossil Energy web site at http://www.fossil.energy.gov where additional details may be found (USDOE Fossil Energy website).

The USDOE is also working on developing other resources and alternatives to oil and natural gas. These include:

a. Methane Hydrates

Methane molecules deep in the ocean may be the most plentiful source of methane, which is also known as natural gas. USDOE is seeking ways to access this large energy potential.

b. Drilling R&D

Most natural gas presently comes from wells shallower than 5,000 feet. The DOE is developing new drilling techniques that will go much deeper and into harder, more geologically complex formations to produce natural gas.

c. Enhanced Oil Recovery/CO_2 Injection

USDOE is developing technologies to access the two-thirds of the nation′s known oil resource that is termed "stranded", which means it was left behind after previous extraction efforts. One method under investigation is to inject carbon dioxide into wells, which could provide the collateral benefit of sequestering the greenhouse gas (USDOE Oil and Gas website).

Other USDOE research is seeking to improve access to fossil energy in the following areas:

Microhole Systems R&D seeks to reduce exploration and production costs of hydrocarbons by reducing borehole size and miniaturizing drilling equipment.

The Marginal & Stripper Well Revitalization seeks to increase production from some of the hundreds of thousands of wells in the United States where production has slowed to a relative trickle, yet the tapped formations still contain large quantities of hydrocarbons.

Environmental Protection. Researching methods to reduce air emissions could result in ways to minimize waste and lower the cost of environmental compliance in oil and gas extraction.

Liquefied Natural Gas (LNG). Until recently, the United States relied exclusively on domestic or Canadian natural gas. USDOE is seeking to gain access to the world's natural gas markets and to ensure that LNG can be safely and securely imported into the United States (USDOE Oil and Gas website).

C. Improving Fossil Fuel Generator Efficiency

Typically, a diesel or natural gas-fired combustion turbine-generator operating in a "simple cycle" converts between 25 and 35 percent of the heating value of its fuel to usable electricity. Today, on the mainland, most new smaller power plants also install a recuperator to capture waste heat from the turbine's exhaust to preheat combustion air and boost efficiencies. KIUC installed a steam injection system on its most recent power plant. However, the HECO companies have typically moved to larger plants where a "heat recovery steam generator" is installed to recover waste heat in the exhaust in order to generate steam for a steam turbine-generator. This configuration is called a "combined cycle combustion turbine."

USDOE has focused on various technical barriers to improved combustion turbine efficiency. By developing turbine systems that could operate at higher temperatures, they were able to achieve combustion efficiencies above 60 percent. At the same time, new combustion techniques were developed to limit the formation of nitrogen oxide (NOx) emissions. Nitrogen oxide is the principal air pollutant released by combustion turbines. As a result, future high-efficiency natural gas turbines will continue to be one of the cleanest ways to generate electricity from fossil fuels.

The gas turbine fuel produced from coal offers an attractive means for efficiently generating electric power from America's most abundant fossil fuel. It has been demonstrated that gas turbine technologies can be adapted to work with fuels produced from coal gasification. USDOE is now working on technologies that will enable advanced turbines to operate cleanly and efficiently when fueled with coal derived synthesis gas and hydrogen fuels (USDOE Oil and Gas website).

D. Carbon Sequestration Research and Development

Carbon sequestration involves capturing and permanently isolating greenhouse gases that contribute to global climate change. USDOE is seeking to develop affordable and safe sequestration methods to help stabilize atmospheric levels of carbon dioxide, without requiring the U.S. and other countries to make large-scale and potentially costly changes to their energy infrastructures.

Using present technology, estimates of sequestration costs are in the range of $100 to $300/ton of carbon emissions avoided. The goal of the program is to reduce the cost of carbon sequestration to $10 or less per net ton of carbon emissions avoided by 2015. Achieving this goal would save the U.S. trillions of dollars.

The USDOE research program covers the entire carbon sequestration "life cycle" of capture, separation, transportation, and storage or reuse, as well as research needs for the two other major energy related greenhouse gases of concern, methane (CH_4) and nitrous oxides (N_2O). Specifically, the program has these elements:

- Cost-effective CO_2 capture and separation processes.
- CO_2 sequestration in geological formations including oil and gas reservoirs, unmineable coal seams, and deep saline reservoirs.
- Direct injection of CO_2 into the deep ocean and stimulation of phytoplankton growth, via iron fertilization.
- Improved full life-cycle carbon uptake of terrestrial ecosystems.
- Advanced chemical, biological, and decarbonization concepts (USDOE Fossil Energy website).

In 2000-2001, a U.S/Japanese/Norwegian deep ocean carbon sequestration experiment was planned at the National Energy Laboratory of Hawai‘i Authority at Keahole on the Big Island. The facility offered access to deep ocean water through pipelines established originally for experiments into ocean thermal energy conversion (DBEDT, 2000). However, due to local opposition and fear of potential unknown and unintended consequences, the project had to move elsewhere.

E. Distributed Energy Resources (DER) for Hawai'i

1. Distributed Energy Resources (DER).

Most of America's electricity is produced by centralized utility electric systems that generate electricity at one or more central power stations and provide that electricity to customers over a "grid" of transmission and distribution (T&D) lines. DER refers to a variety of small, modular power-generating technologies that can be combined with energy management and storage systems and used to improve the operation of the electricity delivery system, whether or not those technologies are connected to an electricity grid.

DER can be as simple as installing a small electricity generator to provide backup power at an electricity user's site. Alternatively, it can be a more complex, highly integrated system operating in parallel with the electricity grid and consisting of fossil and renewable electricity generation, energy storage, and power management systems. DER systems range in size and capacity from a few kW to several MW. DER devices provide opportunities for greater local control of electricity delivery and use. Combined heat and power (CHP) applications use the waste heat from a DER generator, boosting efficiency and lowering air pollution and greenhouse gas emissions. CHP systems provide electricity plus hot water, heat for industrial processes, space heating and cooling, refrigeration, and/or humidity control to improve indoor air quality and comfort. DER technologies are playing an increasingly important role in the nation's and Hawai'i's electricity portfolios. They can be used to meet baseload power, peaking power, backup power, remote power, power reliability and quality, as well as cooling and heating needs.

DER may be owned and operated by customers, utilities, or by third parties. If the DER does not provide 100 percent of the customer's energy needs at all times, it can be used in conjunction with a distributed energy storage device or with a connection to the local grid for supplemental or backup power. Computerized control systems, typically operating over telephone lines, make it possible to operate the distributed generators under the control of the local utility and to use them to generate electricity as needed (USDOE Energy Efficiency and Renewable Energy website). If DER is connected to the utility grid, the grid may be used to backup the DER system for maintenance. Ideally, in such cases, routine maintenance should be coordinated with the utility to avoid negative impacts on the system.

On the mainland, fossil fuel distributed energy is usually natural gas-generated. In Hawai'i, diesel fuel is the least costly alternative. While LPG or synthetic natural gas are more expensive fuel options, they offer reduced emissions, the possibility of pipeline delivery, and less risk of fuel spills.

2. USDOE Efforts to Advance DER Technologies.

a. Gas-Fired Reciprocating Engines and Industrial Gas Turbines.

The U.S. Department of Energy is seeking to improve the next generation of reciprocating engine and industrial gas turbine generators for use as DER and has set the following performance targets for the next generation of these engines:

- **High efficiency.** Increase the average fuel to electricity efficiency from about 35 percent today to 50 percent by 2010.

- **Reduced environmental impact.** Improvements in efficiency, combustion, strategy, and emissions will substantially reduce overall emissions to the environment.

- **Fuel flexibility**. Much of the work on the mainland is done on natural gas-fired engines. Consideration is being given to fuel flexibility to allow multiple fuel options.

- **Additional work** is being done to reduce the costs of power and to assure availability, reliability, and maintainability equal to today's standards.

b. Advanced Micro-turbine Program.

The USDOE Advanced Micro-turbine Program is a six-year, $60 million program, which concluded in 2006. The objective is to create a new generation of "ultra-clean, high-efficiency" micro-turbine product designs. Targets include fuel-to-electricity conversion efficiency of at least 40 percent, NOx less than 7 ppm, increased durability of 11,000 hours of reliable operations between major overhauls, a service life of at least 45,000 hours and system costs less than $500/kW. Meeting these targets would make the design, which is competitive with alternatives, (including grid) efficient enough for market applications. Fuel options include natural gas, diesel, ethanol, landfill gas, and biofuels (USDOE Energy Efficiency and Renewable Energy website).

c. Combined Heat and Power (CHP) and Thermally Activated Technologies (TAT).

CHP is the combined use of the electricity produced by a distributed energy system and the use of its exhaust heat. This combined use greatly increases the fuel efficiency of a distributed energy system. The most common use of CHP exhaust heat is for water heating. A broader term for the application of exhaust heat is TAT.

USDOE defines TAT as follows:

> A diverse portfolio of equipment that transforms heat for useful purposes such as heating, cooling, humidity control, thermal storage, and shaft electrical power. CHP systems are recognized as energy-efficient devices that will supplement central-station electric power generation using discrete, economical, reliable, and secure distributed power generation. TAT are essential for CHP-integrated systems that maximize energy savings and economic return. TAT systems also enable customers to reduce seasonal peak electric demand and future electric and gas grids to operate with more level loads (USDOE Fossil Energy website).

F. Clean Coal Technologies

The USDOE uses the term "clean coal technology" to describe a new generation of energy processes that sharply reduce air emissions and other pollutants compared to older coal-burning systems.

Since the late 1980s, USDOE has conducted a joint program with industry and State agencies to demonstrate the best of these new technologies at scales large enough for companies to make commercial decisions. More than 20 of the technologies tested in the original program achieved commercial success (USDOE Clean Coal Technology website).

The early program was focused on the environmental concerns of the time—the impact of acid rain on forests and watersheds. While acid rain remains a concern, there is now additional focus on the potential health impacts of trace emissions of mercury, the effects of microscopic particles on people with respiratory problems, and the effects of greenhouse gases on global climate change (Coal contains about 20 percent more carbon per million BTU compared to heavy fuel oil).

Since coal is available in large quantities in the mainland United States and Alaska and due to its relatively low cost, it is clearly advantageous to research solutions to these disadvantages. As the President said when announcing his National Energy Policy on May 17, 2001, "More than half of the electricity generated in America today comes from coal. If we weren't blessed with this natural resource, we would face even greater [energy] shortages and higher prices today. Yet, coal presents an environmental challenge. So our plan funds research into new, clean coal technologies" (USDOE Clean Coal Technology website).

The Clean Coal Power Initiative provides government co-financing for new coal technologies that can help utilities meet the goal of the Clear Skies Initiative to cut sulfur, nitrogen, and mercury pollutants from power plants by nearly 70 percent by the year 2018. Some projects help to reduce greenhouse gases by boosting conversion efficiency using coal gas to power a combined cycle electricity generator, which can use up to 60 percent of the heat value of the fuel compared to about 30 percent in a typical coal-fired boiler steam unit. In addition, if oxygen is used in a coal gasifier instead of air, carbon dioxide is emitted as a concentrated gas stream. In this form, it can be captured more easily and at lower costs for possible sequestration (USDOE Clean Coal Technology website).

Coal gasification offers one of the cleanest and most versatile ways to convert coal into electricity, hydrogen, and other energy forms. It involves breaking down coal (or virtually any carbon-based feedstock) into its basic chemical constituents. By exposing the feedstock to hot steam and carefully controlled amounts of air or oxygen under high temperatures and pressures, the carbon molecules in coal break apart, setting off chemical reactions that result in a mixture of carbon monoxide, hydrogen and other gaseous compounds (USDOE Clean Coal Technology website).

As the USDOE Fossil Energy Office points out, gasification may be one of the best ways to produce hydrogen for tomorrow's automobiles and power-generating fuel cells. Hydrogen and other coal gases can also be used to fuel power-generating turbines or as the chemical "building blocks" for a wide range of commercial products. The Energy Department's Office of Fossil Energy is working on coal gasifier advances that enhance efficiency, environmental performance, and reliability as well as expand the gasifier's flexibility to process a variety of coals and other feedstocks (including biomass and municipal/industrial waste).

USDOE is exploring future concepts that incorporate a fuel cell or fuel cell-gas turbine hybrid that could achieve efficiencies that are nearly twice today's typical coal combustion plants. If any of the remaining waste heat can be channeled into process steam or heat, perhaps for nearby factories or district heating plants (or for chillers), the overall fuel use efficiency of future gasification plants could reach 70 - 80 percent (USDOE Clean Coal Technology website).

G. Fuel Cells

Fuel cells are the sustainable energy user's dream. They are an efficient, combustion-less, virtually pollution-free power source, usable anywhere, run almost silently, and have few moving parts. The electrochemical process used in fuel cells was discovered more than 150 years ago. Initially used for electric power for spacecraft in the 1960s, they are now used to provide on-site power (and waste heat in some cases) for military bases, banks, police stations, and office buildings from natural gas. Vehicle applications are also under development (USDOE Future Fuel Cells website). Soon, the USDOE expects fuel cells will propel automobiles and allow homeowners to generate electricity in their basements or backyards. Ultimately, this could replace much of the centralized, fossil fuel-based electricity system that we currently rely upon (USDOE Future Fuel Cells website).

H. Conclusions

Due to the extent of the fossil fuel infrastructure and the advantages of base load firm fossil fuel generated power, Hawai'i will likely depend upon significant amounts of fossil fuel generation energy for quite some time. There are ways that fossil fuel generation can be made more efficient, however, and they include increasing the efficiency of existing generators, adding distributed generation, fuel switching, clean coal technologies, biofuels, and hydrogen fuels. Ultimately, the movement from a centralized, fossil fuel-based electricity system may hinge on the viability of fuel cells. We will discuss fuel cells as a potential major step toward energy sustainability in the final chapter.

VIII. Possible Futures for Energy Sustainability for Hawaiʻi

A. Introduction

We discussed Hawaiʻi's energy situation and the current Energy Indicators for Sustainable Development for Hawaiʻi in Chapter III. In this final chapter, we will look at some possibilities for the future. With this as background, the users of this case study can certainly develop their own concepts.

Evaluation of Energy Indicators for Sustainable Development for Hawaii		
Social Indicators		
Indicator	**Description**	**Evaluation**
SOC1	Share of households without electricity or commercial energy	good
SOC2	Share of household income spent on fuel and electricity	**concern**
SOC3	Household energy use for each income group and corresponding fuel mix	no data
SOC4	Fatal accidents produced in energy fuel chain	**concern**
Economic Indicators		
Indicator	**Description**	**Evaluation**
ECO1	Energy use per capita	good
ECO2	Energy use per unit of GDP (GSP)	good
ECO3	Efficiency of conversion and distribution	**concern**
ECO4	Reserves-to-production ratio	not applicable
ECO5	Resources-to-production ratio	not applicable
ECO6	Industrial Energy Intensities	no data
ECO7	Agricultural Energy Intensities	no data
ECO8	Services/Commercial Energy Intensities	no data
ECO9	Household Energy Intensities	no data
ECO10	Transport Energy Intensities	no data
ECO11	Fuel shares in energy and electricity	**major concern**
ECO12	Non-Carbon shares in energy and electricity	**major concern**
ECO13	Renewable energy shares in energy and electricity	**major concern**
ECO14	End-use energy prices by fuel and by sector	**major concern**
ECO15	Net energy import dependency	**major concern**
ECO16	Stocks of critical fuels per corresponding fuel consumption	no data
Environmental Indicators		
Indicator	**Description**	**Evaluation**
ENV1	Greenhouse Gas emissions from energy production and use per capita and per unit of GDP	**major concern**
ENV2	Ambient concentrations of air pollutants in urban areas	**concern**
ENV3	Air pollutant emissions from energy systems	**concern**
ENV4	Contaminant discharges from liquid effluents from energy systems including oil discharges	**concern**
ENV5	Soil area where acidification exceeds critical loads	no data
ENV6	Rate of deforestation attributed to energy use	good
ENV7	Ratio of solid waste generation to units of energy produced	no data
ENV8	Ratio of solid waste properly disposed of to total generated solid waste	no data
ENV9	Ratio of solid radioactive waste to units of energy produced	not applicable
ENV10	Ratio of solid radioactive waste awaiting disposal to total generated solid radioactive waste	not applicable

Table 23. Evaluation of Energy Indicators for Sustainable Development for Hawaiʻi. Indicator explanation in Appendix A3.

As we review the Energy Indicators for Sustainable Development in Hawaiʻi (Table 23), it appears that a combination of varied policies, policy measures, and technologies will be needed to move Hawaiʻi toward a sustainable energy system. These include energy efficiency measures, using affordable, indigenous, efficient, non-fossil fuel, and non-greenhouse gas emitting energy options. Will it be possible to replace Hawaiʻi's unsustainable energy system? If not, what areas are capable of the greatest progress? We will now look at a variety of approaches to increasing sustainability.

These include:

- Business as Usual: Hawaiian Electric Company′s Integrated Resource Plan for the period 2006-2026.
- Independence from Fossil Fuels: The Hawai‘i Electric Light Company Commitment to No New Fossil Fueled Generation.
- Leading the Way to “Energy for Tomorrow” – The Hawai‘i Governor′s Comprehensive Energy Bill and the 2006 Legislature.
- The Way Ahead in the Near-Term: Base Load Renewable Electricity Generation from Biomass and Geothermal.
- The Longer Road to the Hydrogen Economy.

B. Business as Usual: The Hawaiian Electric Company Integrated Resource Plan

1. Integrated Resource Planning and Hawai‘i.

The Public Utilities Commission (PUC) requires each of Hawai‘i’s electric utilities to develop an Integrated Resource Plan (IRP) with the goal of “identifying the resources or mix of resources for meeting near and long-term consumer energy needs in an efficient and reliable manner at the lowest reasonable cost.” (Framework). It should be noted that the IRP framework was developed by a collaborative of interested stakeholders and was finalized in 1992. The utilities are in their third IRP cycle (HECO, 2005b).

The IRP Framework lists the principles that govern the process as follows:

> 1. The development of integrated resource plans is the responsibility of each utility.
>
> 2. Integrated resource plans shall comply with state and county environmental, health and safety laws and formally adopted state and county plans.
>
> 3. Integrated resource plans shall be developed upon consideration and analysis of the costs, effectiveness, and benefits of all appropriate, available, and feasible supply-side and demand-side options.
>
> 4. Integrated resource plans shall give consideration to the plans′ impacts upon the utility′s consumers, the environment, culture, community lifestyles, the state′s economy, and society.
>
> 5. Integrated resource plans shall take into consideration the utility′s financial integrity, size, and physical capability.
>
> 6. Integrated resource planning shall be an open public process. Opportunities shall be provided for participation by the public and governmental agencies in the development and in commission review of integrated resource plans.
>
> 7. The utility is entitled to recover all appropriate and reasonable integrated resource planning costs. In addition, existing disincentives should be removed and, as appropriate, incentives should be established to encourage and reward aggressive utility pursuit of demand-side management programs. Incentive mechanisms should be structured so that investments in suitable and effective demand-side

management programs are at least as attractive to the utility as investments in supply side options.

The current HECO IRP covers the time frame from 2006-2026. The development of the IRP began in September 2004, and it was filed with the PUC in October 2005. The PUC has not issued a decision on the HECO IRP docket.

HELCO and MECO are fairly well along in their own IRP processes. KIUC has just initiated its IRP process.

a. Access to IRP process documents.

Details of each utility's IRP and its IRP process can be found at the following locations on the Internet:

- HECO: http://www.heco.com , click on "Renewable Energy", then select "Integrated Resource Planning" from the drop-down menu.
- HELCO: http://www.helcoirp.com/HELCO/page/.
- KIUC: http://www.kiuc.coop/ Much information is available about the cooperative, but no details are included on IRP. KIUC initiated its process on November 3, 2005.
- MECO: http://www.mauielectric.com , click on Integrated Resource Planning in the menu on the left of the home page.

The three HECO companies' web sites include evaluation reports of the second IRP, copies of IRP-2, and presentations detailing various aspects of the process, the utility system, and considerations as presented to the utility advisory groups.

2. The HECO IRP.

HECO-owned generators are fueled by oil. HECO does not own any renewable energy systems. HECO-owned units have a maximum capacity of 1,263 MW. Additional electricity for sale to HECO customers is purchased from IPPs that operated generators with a total capacity of 433 MW. Of these, only the City and County of Honolulu's H-POWER MSW-to-energy plant produced almost all of its electricity from renewable energy. Some additional renewable energy came from the use of tires and waste oil as a supplemental fuel in the AES Hawai'i coal plant (HECO FERC 1).

a. HECO's Planning Considerations.

HECO cites the following major changes in its planning context:

(1) Since its previous IRP in 2002, electricity sales have grown more rapidly than expected due to improvements in Hawai'i's economy. Due to the present global financial crisis, this trend will most likely be interrupted.
(2) Because of more rapid growth in electricity demand than forecast, HECO may face supply shortages in terms of maintaining adequate reserve margin through 2009, the earliest time it may be possible to provide a new peaking unit.
(3) The renewable portfolio standard, passed in 2004, requires the three HECO companies together to provide 20 percent of their electricity sales from renewable energy and quantifiable energy efficiency.

HECO convened an advisory group made up of stakeholders from industry, environmental groups, business, government, and others to advise it throughout this process. HECO asked the advisory group to develop objectives for the process. The objectives were as follows (HECO FERC 1):

- Protect the environment.
- Economical electricity.
- Power quality and reliability.
- Energy security and sustainable future.
- Minimize potential negative societal and cultural impacts.
- Increase plan flexibility.
- Utility financial integrity and competitiveness.

In addition, HECO developed a number of long-term planning assumptions, which are detailed in the report. These assumptions included sales and peak demand forecasts, a fuel price forecast, financial assumptions, and externality costs. Of these assumptions, the fuel price forecast, which had been developed in 2002, was the most contentious. Several advisory group members continuously urged HECO to develop a more contemporary estimate in view of the great increase in oil prices since that time. Ultimately, HECO developed a high oil price scenario that more accurately reflected existing conditions in the marketplace. The high oil prices scenario showed that wind energy would be cost effective. Accordingly, HECO moved a planned wind farm up in time.

3. HECO's IRP Plan.

HECO states that its IRP emphasizes quantifiable energy efficiency in the form of demand-side management, or DSM, and energy savings from combined heat and power and distributed generation, and renewable electricity generation. In the previous draft, the only renewable energy generation included was slated to be installed in 2020. The advisory group urged HECO to adopt more renewable energy generation earlier to reduce oil use. HECO moved the 50 MW wind unit to 2009 and added a 300 kW photovoltaic increment in the action plan period to meet the Advisory Group's request. In the action plan period, 2006-2010, HECO states it must also install a nominal 100 MW combustion turbine for use as a peaking unit to meet demand growth. HECO's plan is illustrated by Table 24. While HECO's plan includes energy efficiency and renewable energy in significant amounts, the main HECO system would continue to burn oil as the main fuel, diluting the benefits of the additional renewable energy generation and energy efficiency.

HECO Final IRP Preferred Plan

Plan Component	Year Installed	MW Capacity
DSM Programs	2006-2010	61
CHP/DG	2006-2010	24
300 kW PV	2007	0.3
50 MW Wind	2009	50
100 MW CT	2009	100
Action Plan Period Subtotal	2006-2010	235.3
DSM Programs	2011-2025	90
CHP/DG	2011-2025	26
300 kW PV	2015	0.3
300 kW PV	2020	0.3
180 MW Coal	2022	180
300 kW PV	2025	0.3
Complete IRP Total		532.2

Source: HECO IRP
DSM = demand-side management
CHP = combined heat and power
DG = distributed generation
PV = photovoltaic

Table 24. HECO IRP Plan (HECO, 2005b).

C.　Independence from Fossil Fuels: The Hawai'i Electric Light Company Commitment to No New Fossil Fueled Generation

While the HELCO IRP is still under development and a final strategy has not been selected, HELCO President Warren Lee announced plans to initiate a rate case in 2006 to seek an increase in rates. He also stated that the rate case would mark a fundamental change in HELCO's direction. "With options like wind, biomass, pumped hydro, distributed generation, and more geothermal available from our point of view," he said, "Keahole should be the last fossil fuel power plant on our island." (Keahole is the location of HELCO's newest units: two nominal 20 MW diesel fueled combustion turbines installed in 2003 and to be completed as a DTCC with the installation of a nominal 18 MW steam recovery generator planned for 2009 (HELCO, 2005). While HELCO has used the greatest amount of renewable energy on its system from at least 1992, if not before, this commitment is a great leap forward toward sustainability. Nevertheless, a majority of HELCO's electricity will continue to be provided by existing fossil fuel units.

D.　Leading the Way to "Energy for Tomorrow" – The Hawai'i Governor's Comprehensive Energy Bill and the 2006 Legislature

Governor Linda Lingle submitted two bills – SB 2271 and HB 2308 – to the Hawai'i State Legislature in January 2006. (Note, since the 2006 Legislative session has been concluded, the URL of both of these bills can be expected to change. They will then be available through: http://www.capitol.hawaii.gov/session2006/status/SB2271.asp and http://www.capitol.hawaii.gov/session2006/status/HB2308.asp).

At the announcement ceremony, the Governor called for passage of a comprehensive energy bill that set forth an integrated, strategic policy framework for providing reliable, cost effective methods to conserve energy for tomorrow, with state agencies taking the lead to implement conservation measures. She emphasized that Hawai'i's combination of abundant renewable resources, high fossil fuel prices, limited geographic area, and recognized expertise in hydrogen technology research and development makes it an ideal location to lead the transition to a hydrogen economy over the long term and bring considerable investments of dollars and expertise to Hawai'i.

While the Legislature chose to hold the administration bills, most of the provisions of the comprehensive energy package were placed in other bills that passed. These included: SB 2957 SD2 HD2 CD1, SB 3185 SD2 HD2 CD1, and HB 2175 SD2 HD2 CD1, which are also available on line through the Legislature's web site at http://www.capitol.hawaii.gov. In citing the sources of the provisions below, we will use the basic bill number, e.g., SB 2957, SB 3185, and HB 2175. In addition, HB 3115 HD2 SD2 CD1 contains provisions related to the gasoline price cap law and data collection rules which will not be discussed further in this paper.

Based upon an analysis of the administration proposal and the bills that passed, the following lists the elements of the administration energy package and additional measures initiated by the Legislature that were passed as provisions of other bills and are expected to enhance sustainability. The bill number listed with each provision in the list is the short version. The list is organized by the main themes of Governor Lingle's "Energy for Tomorrow" plan:

1. Savings Through Efficiency

- The Public Utilities Commission (PUC) was authorized to establish a public benefits fund to support energy efficiency and demand-side management programs and determine if energy efficiency and demand-side management operations are better managed through a non-utility entity. This could greatly increase the deployment of DSM by allocating much more of the funds collected under the current surcharge. One Hawai‘i utility put about 40 percent of its money into DSM programs with the rest retained as lost-margin payments and shareholder incentives. A public benefits fund administered by a non-profit entity could put 90 percent of the money collected into programs (SB 3185).

- Newly constructed or renovated state facilities are required to meet minimum standards for energy and resource efficiency and meet a Leadership in Energy and Environmental Design (LEED) Silver rating or other nationally recognized consensus-based green building benchmark guideline (HB 2175).

- Motor vehicles purchased by the State must meet minimum federal and state alternate fuel requirements, efficiency, and use alternate fuels such as ethanol blends and biodiesel (HB 2175).

- State agencies are required to purchase Energy Star products when cost-effective (HB 2175).

- Funds were appropriated for two energy efficiency positions in DBEDT and programs to enhance energy efficiency in State facilities and equipment (HB 2175).

- Funds were appropriated for an energy efficiency coordinator for the Department of Education (HB 2175).

- The following provisions were added by the legislature:

    - An appropriation of $5 million was made for net-metered PV systems at schools (HB 2175).

    - A “pay-as-you-save” solar water heating pilot program to be administered by the PUC was established as a way to increase deployments by low income households and renters (SB 2957).

    - Counties are to set up a building permit processing system that gives priority to projects that incorporate energy-saving and environmentally sound building design standards such as LEED Silver or other nationally recognized green building guideline (HB 2175).

2. Independence Through Renewable Energy

- The Renewable Portfolio Standards law was strengthened by eliminating guaranteed utility profit language and authorizing penalties for non-compliance (SB 3185).

- The renewable energy income tax credit was increased for certain solar-thermal, wind, and photovoltaic systems and the expiration date of the credit was removed (SB 2957).

- The PUC was authorized to determine whether the existing Energy Cost Adjustment Clause fairly allocates the risk of fuel cost changes between the public utility and its customers. Currently, all cost changes are passed on to the customers (SB 3185).

- The PUC was directed to establish a ratemaking methodology that removes or significantly reduces any linkage between the utility cost of fossil fuel and payments to independent power producers using non-fossil resources. This would potentially enable utility customers to benefit from fuel cost savings (SB 3185).

3. Fuels Through Farming

- The state is required to facilitate the development of alternate fuels and support the attainment of a statewide alternate fuel standard of 10 percent of highway fuel demand to be provided by alternate fuels by 2010, 15 percent by 2015, and 20 percent by 2020 (SB 2957).

- A biofuels purchase preference is established for state fuel purchases (SB 2957).

- Funding is provided for DBEDT to conduct a statewide multi-fuel biofuels assessment (SB 2957).

- Funding is provided to the Department of Agriculture to assist farmers with developing energy projects, especially involving production of biofuels, and in seeking funding from federal and private sector sources (SB 2957).

4. Security Through Technology

- The Hawaiʻi Renewable Hydrogen Program (HRHP) was established within DBEDT to manage the state's transition to a renewable hydrogen economy (SB 2957).

- The Hydrogen Investment Capital Special Fund was established to support HRHP. $10 million was appropriated to provide seed capital for venture capital investments in private sector and federal projects for research, development, testing, and implementation of the Hawaiʻi renewable hydrogen program (SB 2957).

- A hydrogen system program manager position within the Hawaiʻi Natural Energy Institute (HNEI, 2002) was also funded (SB 2957).

E. The Way Ahead in the Near-Term: Base Load Renewable Electricity Generation from Biomass and Geothermal

1. Base Load Electricity Generation.

Base load electricity generators can produce electricity 24 hours a day, seven days a week, with availability generally limited only by the need for periodic maintenance. Utilities call this "firm power." Another term often applied is "dispatchable power." In other words, firm power can meet varying demand at any time of day, whether or not the sun is shining, the wind is blowing, or water is flowing in the river. At this time, the primary sources of renewable energy offering the capability of replacing base load fossil fuel generation in Hawaiʻi are biomass and geothermal energy. Wave or current ocean power may fall into this category, but this potential has not been fully assessed.

2. Biomass and Biofuels.

Biomass includes municipal solid waste (MSW), agricultural, and forestry wastes. These are generally burned directly to heat a boiler to produce electricity using a steam generator. Currently, sugar bagasse and MSW are used to generate electricity in Hawaiʻi. Biomass can also be used to produce biofuels, including methane, methanol, and ethanol through various processes. Methane gas formed by decay of wastes in landfills can be collected and used as a fuel. Methane is also produced as a by-product of wastewater treatment and by processing agricultural waste, MSW, and crops grown as a feedstock, or "energy crops." Such methane based biofuels are generally burned in combustion turbines or internal combustion diesels to produce electricity.

In addition, landfill methane, waste, and energy crops can be used to produce alcohol-based fuels methanol and ethanol. Waste cooking oil, grease, and energy crops can be made into biodiesel. The most common applications are gasoline/methanol or gasoline/ethanol blends, pure biodiesel, and diesel/biodiesel blends for transportation fuel. Biodiesel has been available on Maui since 1996 and on Oʻahu since 2000. The Oʻahu plant can produce 1500 gallons per day. State law mandated that there must be 10 percent ethanol by volume in 85 percent of gasoline sold in Hawaiʻi beginning on April 1, 2006. While the ethanol must currently be imported, several production facilities are being developed in Hawaiʻi. The ethanol mandate reduced gasoline use by about 50 million gallons in 2007. Many vehicles produced for U.S. markets are "flex-fuel" vehicles capable of using gasoline/ethanol blends of up to 85 percent ethanol or methanol. These could offset even more significant amounts of gasoline in Hawaiʻi. Ethanol and biodiesel are being considered as fuel for combustion turbines and diesel engines by Hawaiʻi utilities.

On March 21, 2006, HECO, in a press release, asked the ethanol industry to supply fuel for HECO's planned new Campbell Industrial Park Generating Station. Per Mike May, HECO president and CEO, in a 2006 press release, "We would love to use locally produced ethanol in the new Campbell Industrial Park plant from day one of operation in 2009. We are also investigating the use of an ethanol-diesel blend in existing diesel-fired electricity generating units. We know that reducing our reliance on fossil fuels is the right path for our community. Renewable ethanol represents a clear opportunity to grow a significant portion of our own fuel locally and begin to break the hold imported fuels has on us." Furthermore, May explained, "Our goal is to replace imported fossil fuel with 'local' agricultural energy to the extent possible. Encouraging local production of renewable bio-fuels would protect open space and keep it green with energy crops, create jobs here in agriculture, manufacturing and other sectors, and keep more money at home by growing a sustainable economy" (HECO, 2005b).

A study produced in late 2004 (Greene, 2005) for the Natural Resources Defense Council (NRDC), entitled *GROWING ENERGY: How Biofuels Can Help End America's Oil Dependence* reminded us that "America's oil dependence threatens our national security, economy, and environment. We consume 25 percent of the world's total oil production, but we have three percent of its known reserves. We spend tens of billions of dollars each year to import oil from some of the most unstable regions of the world. This costly habit endangers our health: America's cars, trucks, and buses account for 27 percent of U.S. global warming pollution, as well as soot and smog that damage human lungs."

NRDC argues that we can replace much of our oil with biofuels—fuels made from plant materials grown by American farmers. NRDC believes that using an aggressive plan to develop cellulosic biofuels between now and 2015, America could produce the equivalent of nearly 7.9 million barrels of oil per day by 2050. This is an amount more than 50 percent of US transportation oil use in 2004. NRDC cites the following benefits:

- By 2025, producing crops for biofuels could provide farmers with profits of more than $5 billion per year.
- Biofuels could be cheaper than gasoline and diesel, saving us about $20 billion per year on fuel costs by 2050.
- Biofuels could reduce U.S. greenhouse gas emissions by 1.7 billion tons per year— equal to more than 80 percent of transportation-related emissions and 22 percent of total emissions in 2002.

NRDC recommends three steps to make biofuels affordable and sustainable. Hawai'i has already taken some of them independently of the NRDC study as shown below:

<u>NRDC Recommendation</u>: Invest in a package of research, development, and demonstration. About $1.1 billion invested between 2006 and 2015 in applied fundamentals, innovation, and demonstration will make biofuels affordable for American consumers. The focus should be on the best ways to process cellulosic biomass, create other multiple byproducts while producing biofuels, and improve feedstock production.

Hawai'i Activities: Hawai'i has little in the way of funding for RD&D at the present time. The main research in earlier years evaluated potential feedstocks that could be grown in Hawai'i. In the late 1990s, an experimental biomass gasifier was built at Paia Mill on Maui to produce ethanol from sugar cane bagasse. While the gasifier did operate, there were problems with the feed mechanism and the project was terminated and scrapped. As noted previously, the 2006 Legislature funded a Lingle administration initiative to conduct a statewide multi-fuel biofuels production assessment of potential feedstocks and technologies, the economics of the various renewable fuels pathways, and the potential for ethanol, biodiesel, and renewable hydrogen production to contribute to Hawai'i's near-, mid-, and long-term energy needs (SB 2957).

<u>NRDC Recommendation</u>: Federal government funding for deployment policies to drive the deployment of the first billion gallons of cellulosic biofuels. The federal government

should ensure the first billion gallons of production by 2015 by making about $900 million in incentives available. The government should also encourage the use of production incentives whenever possible and leave the industry self-sufficient by phasing out subsidies as the industry grows.

Hawai'i Activities: Hawai'i has the following incentives to encourage production and use of biofuels:

In September 2005, Governor Lingle signed new administrative rules that require at least 85 percent of Hawai'i's gasoline to contain 10 percent ethanol beginning in April 2006. It is estimated that at least 40 million gallons of ethanol per year will be required to meet the mandate. Studies have pegged Hawai'i's ethanol production potential at 90 million gallons per year in the short term, and over 400 million gallons per year as a mature industry.

Another law passed in 2004 reduces total state fuel taxes by 50 percent for ethanol, methanol, biodiesel and other alternative fuels, excepting liquefied petroleum gas, starting in calendar year 2004. The state fuel tax for biodiesel is now four cents per gallon, versus 16 cents for regular diesel. The state fuel tax for ethanol is now 2.3 cents per gallon, compared to 16 cents for regular gasoline. Kaua'i County passed an ordinance providing a 100 percent county fuel tax exemption for alternate fuels. While all counties provide alternative fuel tax incentives, only Maui and Kaua'i provide 100 percent exemptions for biodiesel.

NRDC Recommendation: Adopt a renewable fuels standard for cars and trucks. This standard should offer incentives for environmental performance and include safeguards for air and water quality as the use of ethanol increases. NRDC recommends requiring that all vehicles sold by 2015 be able to use both traditional fuels and biofuels.

Hawai'i Activities: The state is required to facilitate the development of alternate fuels and support a statewide alternate fuel standard of 10 percent of highway fuel demand provided by alternate fuels by 2010, 15 percent by 2015, and 20 percent by 2020 (SB 2957).

3. Ethanol – Hawai'i's Principal Biomass Opportunity.

A draft study, *Hawai'i Ethanol Alternatives* (Stillwater Associates, 2003b), assessed the impact of blending ethanol into Hawai'i's gasoline pool on the overall fuel balance, refinery economics, and gasoline distribution costs. The overall conclusion was that Hawai'i has significant potential to economically produce ethanol from sugarcane, which could add as much as $300 million to the local economy in direct and indirect value. However, it was the study's assessment that, "in the near to midterm future, it would be more beneficial for consumers, producers, the existing petroleum industry and the State of Hawai'i's public finances if locally produced ethanol is not used in Hawai'i but exported to California." Other key findings:

- Hawai'i's ethanol potential, according to prior studies cited in the report, is up to 90 million gallons per year of ethanol for gasoline blending when sugarcane is used as energy crop.

- Up to 85,500 acres of suitable land were identified in prior studies.

- On Maui, O'ahu and the Big Island, highly integrated processing plants can combine ethanol production with efficient heat and electric power generation replacing diesel fuel in the electricity generation role.

- Ethanol could be produced from lignocellulosic biomass from waste if the technologies are commercialized. However, the study states that "given Hawai'i's high electricity prices, it is likely to be more economical to use this additional biomass for power generation through direct combustion rather than for ethanol production."

The key recommendation from *Hawai'i Ethanol Alternatives* was for Hawai'i to pursue a public policy to promote production of ethanol from sugarcane and the use of energy crops for power generation, but not to mandate local use. Specific recommendations were to:

- Support industry efforts to produce and/or market ethanol, especially directed at exports of ethanol to California.

- Repeal the ethanol mandate for 10 percent ethanol in 85 percent of Hawai'i gasoline.

- Evaluate the potential of ethanol production in the context of an integrated energy policy which includes potential distributed power generation from biomass, upgrades of refineries, and alternative fuels for power generation.

- Evaluate the potential for production of Ethyl Tertiary Butyl Ether (ETBE) using locally produced ethanol and isobutylene from the local refineries as an alternative to the problems that can arise when blending ethanol with gasoline.

- Since the study was completed in 2003, the economics may have changed. Higher gasoline prices may have made Hawai'i's use of ethanol more advantageous. In addition, clear interest by the largest utility in ethanol as a diesel fuel replacement may add to the advantages of Hawai'i production and use. Viewed from the perspective of Hawai'i's environmental sustainability, local use perhaps exceeds the economic value from exports.

4. Geothermal as a Firm Power Source.

Geothermal power has been sold to HELCO by Puna Geothermal Venture (PGV) on the Big Island of Hawai'i since 1992. Geothermal power is nominally a base load source of electricity generation, although problems with its wells forced PGV to operate at levels below less than the contracted amount in 2002. PGV drilled new wells in 2003 and 2004 and resumed operation at 25 MW in 2005. An additional well will be needed to resume production at the pre-2002 level of 30 MW. PGV intends to install new equipment that will generate electricity from the 400-degree brine brought up through its wells. PGV expects that expansion to boost its production to about 38 MW in 2007. PGV holds a permit allowing it to generate up to 60 MW. It is seeking to negotiate a power purchase agreement with HELCO for the additional amount.

Given the low night-time load on the HELCO system, there may be some difficulty in accommodating additional geothermal and keeping steam units operating over night. Renewable resources such as wind and hydro may need to be curtailed. This problem may be solved by using excess geothermal and renewable capacity, especially at night, to produce hydrogen as part of a future hydrogen economy. There is significant additional geothermal potential on the Big Island of Hawai'i and on Maui, according to a 2005 assessment by GeothermEx, Inc. (GeothemEx, 2005). GeothermEx identified seven geothermal resource areas with significant potential for electrical generation with the capacities indicated. The areas are shown in Table 25.

	Estimated Reserves (MW)		Likely Deployments (MW)			Upside Scenario Development (MW)		
Location	10th Percentile	Mean	2010	2015	2020	2010	2015	2020
Island of Hawaii								
Kilauea East Rift Zone	291	778	46	62	70	50	70	80
Kilauea Southwest Rift Zone	133	393						
Mauna Loa Southwest Rift Zone	35	125				10	20	40
Mauna Loa Northeast Rift Zone	22	75						
Hualalai	7	25				5	15	20
total	**488**	**1396**	46	62	70	65	105	140
Maui								
Haleakala Southwest Rift Zone	20	69				5	10	20
Haleakala East Rift Zone	18	70						
total	**38**	**139**	0	0	0	5	10	20
Hawaii and Maui Total	**526**	**1535**	**46**	**62**	**70**	**70**	**115**	**160**

Table 25. Estimates of Geothermal Reserves, Likely Deployments, and Upside Scenario Deployments (GeothermEx, 2005).

GeothermEx qualifies the above estimate as follows:

> "It is important to note that these estimates of reserves reflect the amount of recoverable heat energy anticipated to be present at drillable depths, without implying that this energy can necessarily be exploited commercially. For commercial exploitation to be feasible, conditions must be adequate for productive wells to be drilled and operated over the lifetime of a power generation project. In addition, significant portions of the identified resource areas may be unavailable for geothermal development, for a variety of reasons. Therefore, the geothermal energy reserves available for development are a subset of the estimates presented above."

GeothermEx estimated the levelized cost of power from a hypothetical, new 30-MW geothermal power plant on the Big Island of Hawai'i. They assumed unit capital costs in the range of $2,500 to $5,000 per installed kilowatt (with a most likely value of $3,500 per installed kilowatt) and O&M costs in the range of four to six cents per kW/hr. From these parameters and several others, levelized cost was estimated at 7.0 cents/kWh to 8.7 cents/kWh. This compares quite favorably with HELCO's costs of 18.8 cents/ kWh on-peak and 15.9 cents/ kWh off-peak (HELCO Annual Report to PUC). It may be that additional deployments will occur to meet the requirements for hydrogen production that could develop as the world moves toward a hydrogen economy.

F. The Longer Road to the Hydrogen Economy

Many believe that Hawai'i's main hope for a sustainable future is a hydrogen powered energy system. This is often called "The Hydrogen Economy." In concept, most of the state's energy needs would be met by hydrogen produced from renewable energy resources. Hydrogen would serve as a means of storing energy produced at times when direct use of electricity from renewable energy would not be required. It would also be an energy carrier providing a way for vehicles to be powered by renewable-derived fuel, in addition to biodiesel, methanol, and ethanol.

Hydrogen would be most efficiently used to produce electricity using highly efficient fuel cells. Fuel cells produce electricity through a chemical reaction and emit only water and heat. Fuel cells can power ground and marine transportation vehicles, portable machinery, and other mobile uses. Stationary fuel cells are ideal for distributed energy applications such as providing electric power for residential, commercial, and industrial uses. Some applications face difficulty in using hydrogen, especially aircraft, but work is underway on hydrogen powered jet aircraft.

Hawai'i's Roadmap to a Hydrogen Economy

Recognizing its overdependence on oil as previously discussed, Hawai'i is exploring ways to develop and use renewable energy produced primarily from solar, wind, and geothermal resources. Energy crops and wave energy are also potential sources. Hydrogen could help further diversify Hawai'i's energy mix – especially in the state's transportation and distributed power generation sectors. This would reduce fossil fuel use, improve efficiency, and reduce pollution and greenhouse gases. The eventual large-scale use of hydrogen fuel will require low cost production (preferably using renewable energy), compact, safe, and cost-effective storage capabilities, and hydrogen-based energy infrastructure development. Proponents of the hydrogen economy note that Hawai'i, with its vast renewable energy resources, energy expertise, critical need for greater fuel diversity, and stated policy to achieve increased energy self-sufficiency, provides a natural "test bed" for hydrogen and fuel cell research. Hawai'i can make a contribution to ongoing research and development in various technologies related to hydrogen. Hawai'i faces the same challenge as the rest of the world – how can it be ready with the necessary infrastructure for hydrogen production when the various uses of hydrogen become available for consumer purchase?

In 2006, the Legislature passed provisions in SB 2957 based upon the Governor's initiative in the "Energy for Tomorrow" legislative package to create the Hawai'i Renewable Hydrogen Program (HRHP). The HRHP was established within DBEDT to manage the State's transition to a renewable hydrogen economy. The bill specifies that the HRHP program shall design, implement, and administer activities that include:

(1) Strategic partnerships for the research, development, testing, and deployment of renewable hydrogen technologies.

(2) Engineering and economic evaluations of Hawai'i's potential for renewable hydrogen use and short-term project opportunities for the State's renewable energy resources.

(3) Electric grid reliability and security projects that will enable the integration of a substantial increase of electricity from renewable energy resources on the island of Hawai'i.

(4) Hydrogen demonstration projects, including infrastructure for the production, storage, and refueling of hydrogen vehicles.

(5) A statewide hydrogen economy public education and outreach plan focusing on the island of Hawai‘i to be developed in coordination with Hawai‘i’s public education institutions.

(6) Promotion of Hawai‘i’s renewable hydrogen resources to potential partners and investors.

(7) A plan, for implementation from 2007 to 2010, to more fully deploy hydrogen technologies and infrastructure capable of supporting the island of Hawai‘i’s energy needs, including: expanded installation of hydrogen production facilities, development of integrated energy systems including hydrogen vehicles, construction of additional hydrogen refueling stations and promotion of building design and construction that fully incorporates clean energy assets, including reliance on hydrogen-fueled energy generation.

(8) A plan, for implementation from 2010 to 2020, to transition the island of Hawai‘i to a hydrogen-fueled economy and to extend the application of the plan throughout the state.

(9) Evaluation of policy recommendations to encourage the adoption of hydrogen-fueled vehicles, continually fund the hydrogen investment capital special fund, and support investment in hydrogen infrastructure including production, storage, and dispensing facilities (SB 2957).

In addition, the Hydrogen Investment Capital Special Fund was established to support HRHP and $10 million was appropriated for the fund to provide seed capital for venture capital investments in private sector and federal projects for research, development, testing, and implementation of the Hawai‘i Renewable Hydrogen Program (SB 2957).

G. Conclusions

A combination of policies, policy measures, and technologies are necessary to move Hawai‘i toward a more sustainable energy system. Energy efficiency measures and the use of affordable, indigenous, non-fossil fuel energy sources are necessary steps toward replacing Hawai‘i’s current energy system with a sustainable one. One of the biggest issues with moving toward a sustainable energy system is how to shift the state′s primary base load electricity fuel source from imported fossil fuels to renewable energy sources. Technologies like hydrogen fuel cells hold great promise, but unfortunately are not sufficiently mature at this point in time and may be decades away from being viable. In the near future, large-scale base load electricity generation from renewable sources is only possible via the energy sources of geothermal, biomass, and biofuels.

H. Concluding Remarks

The Pacific Ocean covers about 46 percent of the world's total ocean area and is home to a number of inhabited islands. These islands lack natural petroleum-based energy resources. Because of their distribution and dependence on fossil fuel energy, small island states and Pacific Islanders are particularly susceptible to fluctuations in the global energy market. They share energy-linked vulnerabilities such as pressures imposed on resources by population density, limited natural resources, and geographic isolation from energy distribution centers.

Hawaiʻi's isolation and lack of natural fossil fuel resources, in combination with its population and subsequent need for energy, requires Hawaiʻi to import oil for approximately 90 percent of its energy needs. Presently, renewable forms of energy, only account for approximately six percent of the state's energy use. The money expended on importing oil is not used to further develop the local economy.

Hawaiʻi has four electric utilities serving its six major islands. None of these four utilities are connected and thus cannot share power. Each must maintain significant reserve energy generation capacity should a generator fail. All the electric utilities presently incorporate renewable energy into their power generation capabilities, but not enough. A significant increase in new renewable capacity is necessary to reduce the state's dependence on imported oil. Solutions for a more sustainable energy system in Hawaiʻi must take into account aspects like this lack of interconnectivity of utilities.

The three highest sectors of primary energy use in Hawaiʻi are air transportation (30 percent), ground transportation (19 percent), and electricity (39 percent), with electricity being the highest. Of these, Hawaiʻi is best able to gain greater sustainability in the ground transportation and electricity sectors. The electricity sector can be made more efficient through improving end-use. In Hawaiʻi, electricity sector end-uses are primarily buildings (both residential and business) and some industrial operations. The residential sector is the largest end-use electricity sector, and the nature of its users present challenges for reducing energy demand. However, government policies such as DSM programs, tax incentives, consumer education, and building codes aimed at improving private citizens' use of energy can be very successful. In Hawaiʻi, DSM measures to encourage solar water heater use have been successful, and resulted in about 80,000 solar water heaters operating statewide. Along with improving electricity end-use efficiency, greater use of renewable energy will increase the sustainability of Hawaiʻi's energy system.

Hawaiʻi is, perhaps, the state with the best potential for alternative energy solutions, which include wind, solar, hydro, geothermal, waves and tides, biomass production, and ocean thermal energy conversion. Renewable energy has been used on a smaller scale for decades. In 1962 the state got 18 percent of its electricity from bagasse and hydroelectric plants. The state presently gets 6 percent of its energy from renewables and the opportunity should be taken to increase this percentage. The state government has passed legislation requiring each utility company in the state that sells electricity for consumption to generate 20 percent of its net electricity sales from renewable sources by the year 2020. Compliance with this legislation should increase the use of renewable energy.

Renewable energy use also offers the ability for the state to reduce fossil fuel emissions that contribute to climate change. Tourism is an important component of Hawaiʻi's economy, and any negative impact of climate change on the appeal of Hawaiʻi would be devastating to the economy. Hawaiʻi has many reasons to continue progress towards a more sustainable and reliable energy system.

Due to the extensive fossil fuel infrastructure and the advantages of base load firm fossil fuel generated power, Hawaiʻi will likely depend upon significant amounts of fossil fuel energy generation for some time to come. However, there are ways that the fossil fuel generation can be made more efficient and they include increasing the efficiency of existing generators, adding distributed generation, fuel switching, clean coal technologies, biofuels, and hydrogen fuels. Ultimately, the movement from a centralized, fossil fuel-based electricity system may hinge on the viability of fuel cells, which hold great promise but are not yet ready to be used as a technological solution.

In conclusion, the keys to a sustainable energy future in Hawaiʻi include:

- Continued efforts to maximize renewable energy use in replacing existing fossil fuel generation, or to offset oil use in daily operations.

- Major efforts by all energy users to reduce demand through a variety of demand-side management programs and energy efficiency measures.

- Energy emergency preparedness.

- Working with vehicle, equipment, and appliance manufacturers to ensure Hawaiʻi has access to the latest, high efficiency products.

- Working with government, industry, dealers, oil companies, shippers, and mainland renewable energy developers to ensure maximum reduction in oil use by changing demand.

- Increasing the focus on environmental consequences of energy use and developing a program to make those consequences clear to consumers with the hope of favorable changes in the way the community deals with the problem of "peak oil" and the state's energy future.

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X. Appendices - Energy Case Studies

A1. Population of Hawai'i Counties from 1831 to 2000 (DBEDT, 2004). (Chapter 2)

Census Date	Total population		City and County of Honolulu	Hawai'i County	Kaua'i County	Maui County
	Number	%change				
1831-32	130,313	(X)	29,755	45,792	12,024	42,742
1835-36	108,579	-4.6	27,809	39,364	9,927	31,479
1850: Jan.	84,165	-1.8	25,440	25,864	7,670	25,191
1853: Dec. 26	73,138	-3.5	19,126	24,450	7,781	21,781
1860: Dec. 24	69,800	-0.7	21,275	21,481	7,134	19,910
1866: Dec. 7	62,959	-1.7	19,799	19,808	6,624	16,728
1872: Dec. 27	56,897	-1.7	20,671	16,001	5,194	15,031
1878: Dec. 27	57,985	0.3	20,236	17,034	5,811	14,904
1884: Dec. 27	80,578	5.5	28,068	24,991	8,935	18,584
1890: Dec. 28	89,990	1.8	31,194	26,754	11,859	20,183
1896: Sept. 27	109,020	3.3	40,205	33,285	15,392	20,138
1900: June 1	154,001	9.4	58,504	46,843	20,734	27,920
1910: April 15	191,874	2.2	81,993	55,382	23,952	30,547
1920: Jan. 1	255,881	3.0	123,496	64,895	29,438	38,052
1930: April 1	368,300	3.6	202,887	73,325	35,942	56,146
1940: April 1	422,770	1.4	257,696	73,276	35,818	55,980
1950: April 1	499,794	1.7	353,020	68,350	29,905	48,519
1960: April 1	632,772	2.4	500,409	61,332	28,176	42,855
1970: April 1	769,913	2.0	630,528	63,468	29,761	46,156
1980: April 1	964,691	2.3	762,565	92,053	39,082	70,991
1990: April 1	1,108,229	1.4	836,231	120,317	51,177	100,504
2000: April 1	1,211,537	0.9	876,156	148,677	58,463	128,241

A2. Hawai'i's Primary Energy by Fuel or Renewable Energy in 2003 (DBEDT Energy Data, 2003). (Chapter 2)

Hawaii's Primary Energy by Fuel or Renewable Energy Source 2003			
Fuel or Energy Source	(Million Btu)	Fuel or Energy Source	(Million Btu)
Fossil Fuel		**Renewable Energy**	
Aviation Gasoline	35,645	Bagasse	6,276,900
Coal	18,227,913	Geothermal	1,818,100
Diesel	42,051,624	Hydroelectricity	796,200
Gasoline	55,948,111	Municipal Solid	4,654,500
Jet Fuel	88,000,299	Solar PV	19,300
LPG	2,444,203	Solar Water Heating	4,068,700
Naphtha	4,985,122	Wind	113,700
Residual	86,820,723		
Synthetic Natural Gas	3,370,331		
Oil Subtotal	283,656,059	**Renewable Subtotal**	17,747,400
Fossil Fuel Subtotal	301,883,972	**Total Energy**	319,631,372

Source: DBEDT Energy Data, 2003

Source: DBEDT Energy Data, 2003.

A3. Social (SOC), Environmental (ENV), and Economic (ECO) Energy Indicators for Sustainable Development. (Chapter 3)

The Social Energy Indicators for Sustainable Development (SOC)

1. SOC1 Share of Households without Electricity Service. (EVALUATION: No data)

Electricity is essential to providing adequate food, shelter, water, sanitation, medical care, education and access to communication. Adequate, affordable and reliable electricity services are necessary for sustainable economic and human development. The International Energy Agency estimates that 2 billion people, or about one-third of the world's population, depend mainly on traditional biomass sources of energy and 1.7 billion people are without electricity (IAEA, 2005).

This indicator best fits the global context. A search of U.S. Census information and DBEDT's State of Hawai'i Data Book and other sources did not provide a number of households in Hawai'i without electricity although there are probably very few, especially on O'ahu. There are areas on the Big Island of Hawai'i that do not have electric utility service. Some households in these areas produce their own electricity using photovoltaic systems or portable generators and most have access to fuels for vehicles, etc.

2. SOC2 Share of Household Income Spent on Fuel and Electricity. (EVALUATION: Concern)

This indicator provides a measure of energy affordability. The developers of the EISD believe that, from a sustainable development perspective, it is important to examine income, wealth and in particular affordability of modern energy services across the population to ensure that low income groups can also afford energy services (IAEA, 2005).

According to the U.S. Bureau of Labor Statistics, as cited in the State of Hawai'i Data Book on-line, for 2003-2004, the latest years for which average household expenditure data are available, the average annual income for Honolulu households was about $64,082, before taxes. Of this amount, the average annual household expenditures for the two year period were $48,339.

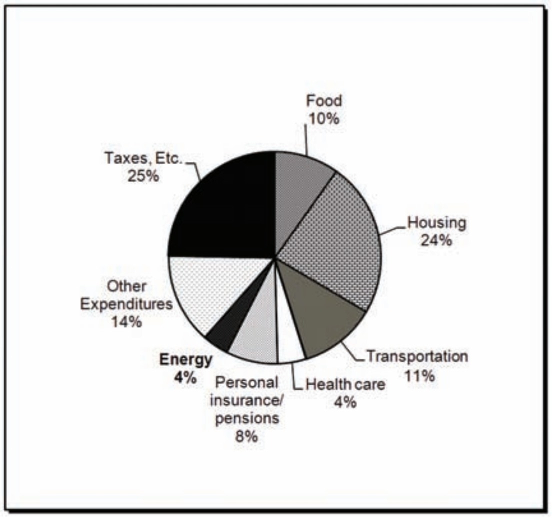


Figure A3-1. Annual Average O'ahu Household Expenditures, 2003-2004 (HECO website and DBEDT Energy Data, 2003).

As depicted in Figure A3-1, Honolulu household energy expenditures ranked seventh among household expenditure categories. While the eighth category, "other expenditures", represented 14 percent of the total, the category includes seven additional categories of which none exceeded 3.9 percent.

When household energy expenditures are a relatively small component of total household expenditures, many consumers are not especially concerned about energy prices or availability. Recent higher energy prices have resulted in more press coverage about energy prices, sources, and the increasing demand for energy in other countries, which has created more concerned consumers. An average O'ahu household saw energy bills go up about 33 percent above 2003 levels of $2787 to an estimated $3709 in 2005 taking an increasing share of household income.

The estimated average annual Honolulu household expenditures for gasoline went from $1142 in 2003 to at least $2186 for 2005, a 91 percent increase. Average annual electricity expenditures for 2005 grew from $1159 to $1471, a 27 percent increase. Utility gas expenditures were $486 in 2003, up 15 percent in 2005 to $563 per residential gas customer. According to DBEDT personal income grew 7 percent in 2005, which if reflected in household income, results in an estimated household income of $68,570 for 2005 of which about 5.4 percent was spent on energy.

The growth in energy prices puts inflationary pressures on the economy and could result in a reduced portion of household budgets being available for other things. A major concern for Hawai'i is the possibility that if energy costs become a more significant portion of potential visitors' family incomes, their disposable income could be reduced. This could make it less likely that tourists would visit Hawai'i as happened after the 1991 Gulf War, negatively impacting Hawai'i's tourism based economy.

3. SOC3 Household Energy Use for Each Income Group and Corresponding Fuel Mix. (EVALUATION: No data)

SOC3 is intended to measure any energy disparity and affordability issues by comparing the amount of electricity and fuels used by the population relative to income level and the corresponding fuel mix. This is a further effort to examine income, wealth and affordability of modern energy services across the population in particular (IAEA, 2005). However, we were unable to locate data on household energy use for each income group and their corresponding fuel mix for Hawai'i.

4. SOC4. Fatal Accidents Produced in the Energy Fuel Chain. (EVALUATION: Concern)

This indicator shows the number of fatalities per energy produced in energy systems and related activities. The indicator is used to assess the risk to human health derived from energy systems, and in particular by various fuel chains. The extraction, transport, use and waste management of energy options involve important health hazards and high risks that in many cases result in fatalities (IAEA, 2005).

Hawaiʻi has no indigenous fossil energy resources and thus most all fatal accidents in the energy fuel chain occur in supplier countries or states. While data on fatal accidents at locations supplying Hawaiʻi with fossil fuel may be available, we have not conducted research in this area. Within the State of Hawaiʻi, there is potential for serious accidents or injury in the course of shipping fossil fuels to Hawaiʻi, operating refineries, shipping fuels between the islands, transporting fuels by truck, operating power plants, maintaining transmission and distribution systems for electricity systems, fueling vehicles and other energy related activities.

Since 1980, Honolulu has had at least two significant fuel storage tank fires and one involved fatalities. The first, in 1980, involved a gasoline tank at the Chevron Tank Terminal with a floating top. The tank was overfilled and the vapors ignited. Two Chevron workers were killed (Persson and Lonnermar, 2004). In October 1985, a fuel tank fire occurred after the floating top of a jet fuel tank at the Navy storage facility on the Pearl City Peninsula sank due to rain. The top was foamed and the tank had been mostly drained over a three day period when vapors ignited (Persson and Lonnermar, 2004).

The Economic Energy Indicators for Sustainable Development (ECO)

1. ECO1 Energy Use Per Capita. (EVALUATION: Good)

This indicator measures the level of energy use on a per capita basis and reflects the energy-use patterns and aggregate energy intensity of a society. While energy is a key factor in economic development and quality of life, its production, use, and byproducts put major pressures on the environment by depleting resources and by creating pollution (IAEA, 2005).

ECO1 measures the efficiency of energy use relative to population. Energy efficiency is measured in BTU, or British thermal units per capita and electricity efficiency is measured in kilowatt hours (kWh) per capita of de facto population. De facto population includes the resident population of Hawaiʻi and the average number of visitors present at any one time on an annual basis.

2. ECO2 Energy Use per Unit of Gross State Product (GSP). (EVALUATION: Good)

Energy and electricity use per dollar of GSP (gross state product) are indicators of energy efficiency in support of the operation of the economy, indicating the general relationship of energy use to economic development. Improving energy efficiency and decoupling economic development from energy use are important sustainable development objectives (IAEA, 2005).

Table A3-1 shows the measures used to calculate and show changes in intensity of electricity and energy use in Hawai'i from 1970 to 2003. Electricity sales grew the most during this period, increasing by 172 percent. This reflects Hawai'i's modernization; the construction of new office buildings, condominiums, and resorts that all employ the latest electric technologies. The growth of electricity use was supported by a rapid growth in the GSP. Both significantly overshadow the growth in population which increased only 71 percent. Energy use overall increased 42 percent. Of the measures of efficiency, only electricity use per capita and electricity use per dollar of GSP increased over the period. On the other hand, energy use per capita and electricity use per capita declined 17 percent and 38 percent, respectively, over the period.

Table A3-1. Change in Intensity of Electricity and Energy Use in Hawai'i from 1970-2003 (DBEDT Energy Data, 2003).

Measures of Changes in the Intensity of Electricity and Energy Use in Hawaii, 1970 - 2003

	1970	2003	Increase/ Decrease
Electricity Sales (kWh)	3,758,094,000	10,206,406,000	172%
GSP (millions of 1996 $)	18,094	41,196	128%
DeFacto Population	798,600	1,365,210	71%
Electricity (kWh)/Capita	4,706	7,476	59%
Energy (MMBtu)	225,229,900	320,435,789	42%
Electricity (kWh)/$ GSP	208	248	19%
Energy (Btu)/Capita	282	235	-17%
Energy (Btu)/$ GSP	12,448	7,778	-38%

Source: DBEDT Energy Data Base

Figure A3-2 clearly depicts the changes in Hawai'i energy and electricity use intensity per capita and per dollar by indexing the values from 1970 to 2003 on the basis of the 1970 value for each of the four measures equaling 1.

3. ECO3 Efficiency of Energy Conversion and Distribution. (EVALUATION: Concern)

This indicator is intended to measure the efficiency of energy conversion and distribution systems in various energy supply chains including losses occurring during both electricity transmission and distribution and gas transportation and distribution. Improving energy supply efficiency and reducing losses are important sustainable development objectives. More effective use of energy resources reduces negative environmental impacts (IAEA, 2005). For Hawai'i, the indicator ECO3 is used to examine the efficiency of the electric utility system.

Table A3-2 depicts the percentage of electric utility net generation and purchased power lost mainly in the transmission and distribution systems. Each of the utilities, except HELCO (The Hawai'i Electric Light Company, which is owned by the Hawai'i Electric Company or HECO), has improved the efficiency of its system since 1990. HELCO faces difficulties due to major load growth on West Hawai'i while most of its generation capacity is in East Hawai'i. This leads to greater line losses due to the distance electricity must be transmitted. The HECO system on O'ahu has the advantage of using 138 kilovolt (kV) transmission lines which are more efficient than the 69 kV transmission lines used by the other utilities. Other factors include the distances between generation facilities and the main loads and the configuration of transmission systems on the different islands, which again generally favors O'ahu. The Kaua'i Independent Utility Cooperative apparently gained considerable efficiency by locating a new power plant closer to its load center at Līhu'e than at the Port Allen site where all older utility generation is located.

Figure A3-2. ECO1 and ECO2 Energy and Electricity Intensity Per Capita and Per Dollar of GSP (DBEDT Energy Data, 2003).

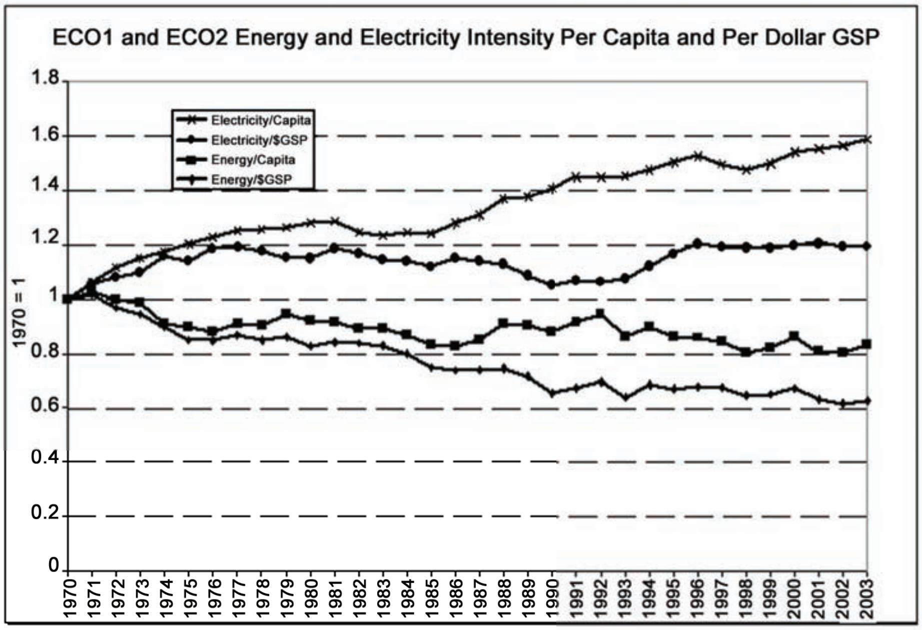


Table A3-2. ECO3 Efficiency of Electricity Distribution and Conversion by Hawai'i Utilities.

ECO3 Efficiency of Conversion and Distribution of Electricity by Hawaii Utilities (Percent of Net Generation and Purchased Power Lost)

	1990	2000	2004
HECO	5.04%	5.02%	4.66%
HELCO	8.10%	8.73%	8.25%
KIUC	6.99%	4.90%	4.33%
MECO	7.27%	6.32%	6.06%

Sources: HECO and MECO FERC Forms 1 and HELCO and KIUC Annual Reports to PUC.

4. ECO4 Reserves to Production Ratio and ECO5 Resources to Production Ratio. (EVALUATION: Not applicable)

The developers of the EISD intended to use this indicator to measure the availability of national energy reserves with respect to corresponding fuel production. The indicator considers fuels such as oil, natural gas, coal and uranium, and provides a relative measure of the length of time that proven reserves would last if production were to continue at current levels (IAEA, 2005).

Hawai'i has no indigenous fossil energy resources and is totally dependent on imported fossil fuels. Many are concerned that petroleum has reached or is near its peak of production and production may decline in the future. With rapidly growing world demand, this is one of factors driving up oil prices. Hawai'i's oil and coal requirements are relatively small on a global scale and its relative wealth should allow it to purchase necessary supplies at increasingly higher world market prices.

5. ECO6 through ECO10 Indicators for Energy Intensity by End-Use Sector. (EVALUATION: No data on intensity, but descriptive data substituted)

These indicators are intended to measure energy intensity by individual sectors of the economy. Sectors in the original list of indicators included industrial, agricultural, services/ commercial, household, and transport. It was intended that energy use compared against value added would be used to determine energy intensity in each sector. Data for value added by sector were not available for Hawaiʻi. Figure A3-3 depicts Hawaiʻi primary energy use in the residential, commercial/ industrial, transportation, and electric power sectors in 2003 to show their relative importance.

Hawaiʻi's primary residential energy use is extremely low and is almost exclusively utility gas and LPG, solar water heating, and photovoltaics. It is difficult to separate commercial and industrial primary energy uses in Hawaiʻi. These include oil, bagasse, coal, and MSW used for boilers, industrial equipment, and process heat, some combined heat and power units, and some wind and photovoltaics used directly by end users. The transportation sector mostly uses oil. Due to its geographical location, air transportation energy use is the highest of any state. The electricity sector includes electric utilities and independent power producers that use oil, coal, and a variety of renewable energy resources to produce electricity.

Figure A3-3. Hawaiʻi Primary Energy Use by Sector, 2003 (DBEDT Energy Data, 2003).

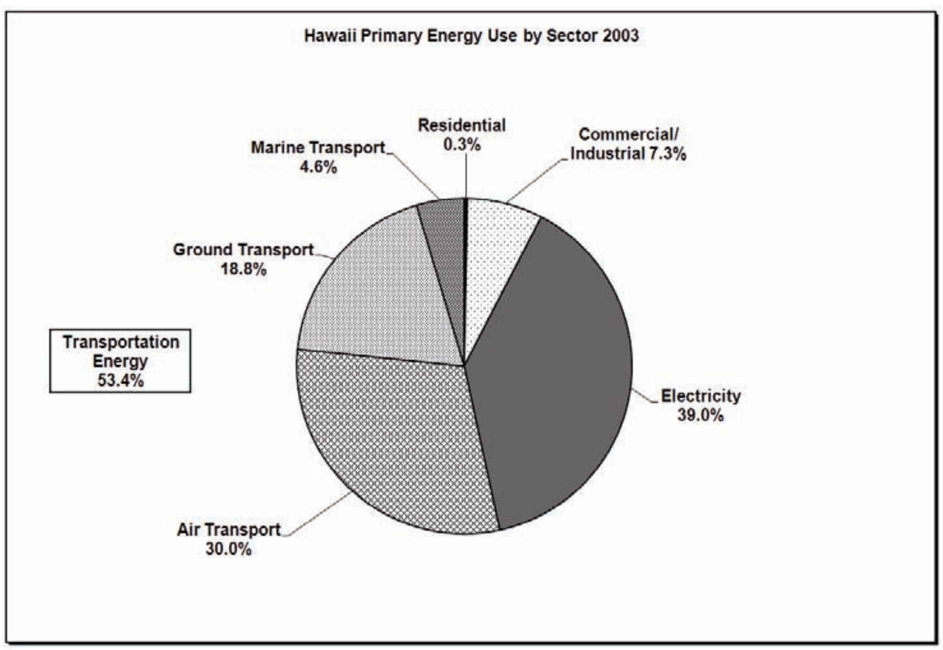


Figure A3-4 shows the growth in energy use in Hawai'i by end use sector. Since 1960, transportation energy use and energy for electric power have grown most rapidly. Industrial uses have declined somewhat due to closure of sugar mills.

Figure A3-4. ECO6 thru 10 Growth in Energy Use in Hawai'i by End-Use Sector (USEIA, 2004).

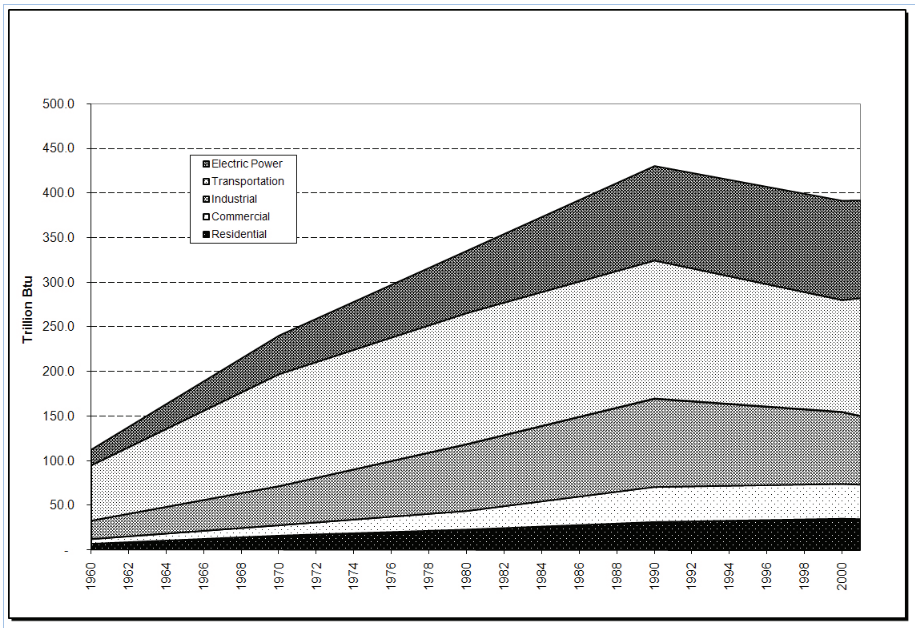
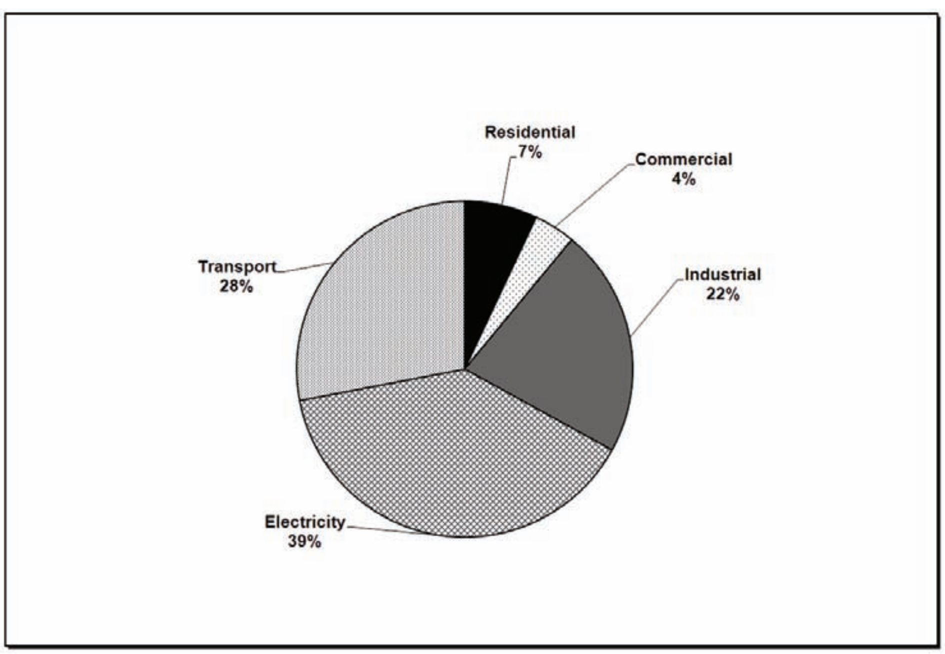


Figure A3-5 depicts U.S. primary energy use by sector. In the United States as a whole, as with Hawai'i about 39 percent of primary energy use is for electricity generation. There are much larger residential use direct uses of energy in the form of fossil fuels, especially fuel oil and natural gas used for home heating. In the country at large, there are also larger direct industrial uses of energy.

Figure A3-5. U.S. Primary Energy Use by Sector, 2003 (USEIA, 2005b).



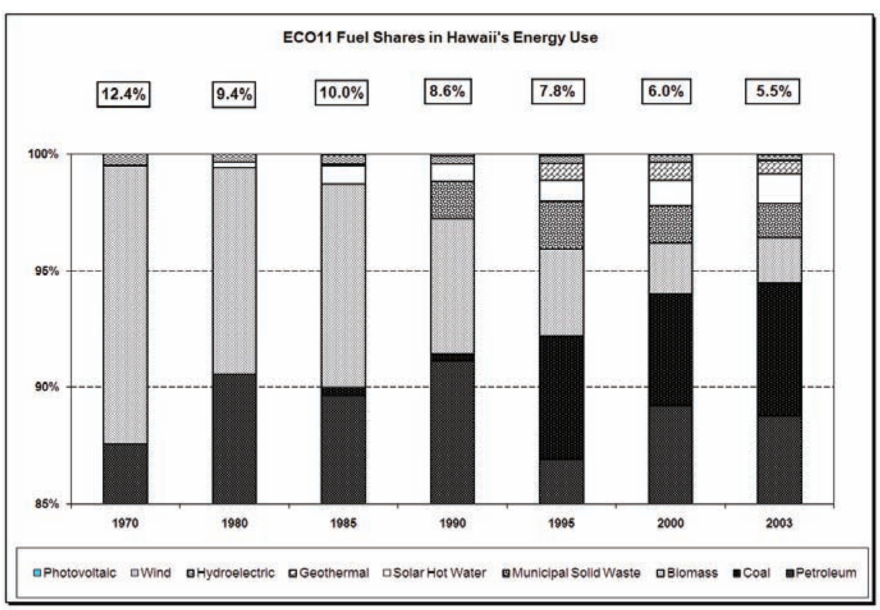
6. ECO11 Fuel Shares in Energy and Electricity and ECO13 Renewable Energy Shares in Energy and Electricity. (EVALUATION: Major Concern)

The diversity of the energy supply mix is a key determinant of energy security. The ideal is a well-diversified portfolio of domestic and imported or regionally traded fuels and sources of energy. Also, the particular mix of fuels used in energy and electricity affects energy intensities. With respect to the environmental dimension, the energy supply mix has a major effect since the environmental impacts of each energy source differ greatly and include the following: (i) traditional local or regional atmospheric pollution related to the combustion of fossil fuels (e.g. urban smog, acid rain, etc), (ii) global climate change related to the emission of greenhouse gases generated by fossil fuel production, transport and use, (iii) land use for a range of energy activities and notably for mining and for hydroelectric reservoirs, and (iv) risks attributed to various fuel chain cycles (e.g., fires, explosions, spills, radioactive emissions, etc (IAEA, 2005).

ECO11, fuel shares in energy and electricity, measures the percentage of energy and electricity produced from various sources of energy. It gives a useful picture of primary energy supply mix and energy diversification. ECO13 is the percentages of renewable energy used in overall energy use and in electricity production. Since they are so closely related, we will discuss them together.

Figure A3-6 shows how Hawai‘i’s dependence on oil has continued to increase while coal and more types of renewable energy have been brought into service. Note that the base of the figure begins at 85 percent, reflecting the fact that oil use in Hawai‘i has ranged from 87.6 percent of primary energy consumption in 1970 to 91.1 percent in 1990, and was 88.8 percent in 2003. As recently as 1962, renewable energy in the form of hydroelectricity and steam boilers burning bagasse operated by sugar mills made up 18 percent of Hawai‘i’s energy sources. The percentages of renewable energy to overall energy use in Hawai‘i are displayed in boxes above the column for the year. In 2003, overall renewable energy contributed 5.5 percent statewide to electricity generation. We have seen a diversification of energy use in Hawai‘i, offsetting the decline in energy produced by the sugar industry from bagasse and hydroelectricity.

Figure A3-6. ECO11 Fuel Shares in Energy (DBEDT Energy Data, 2003).

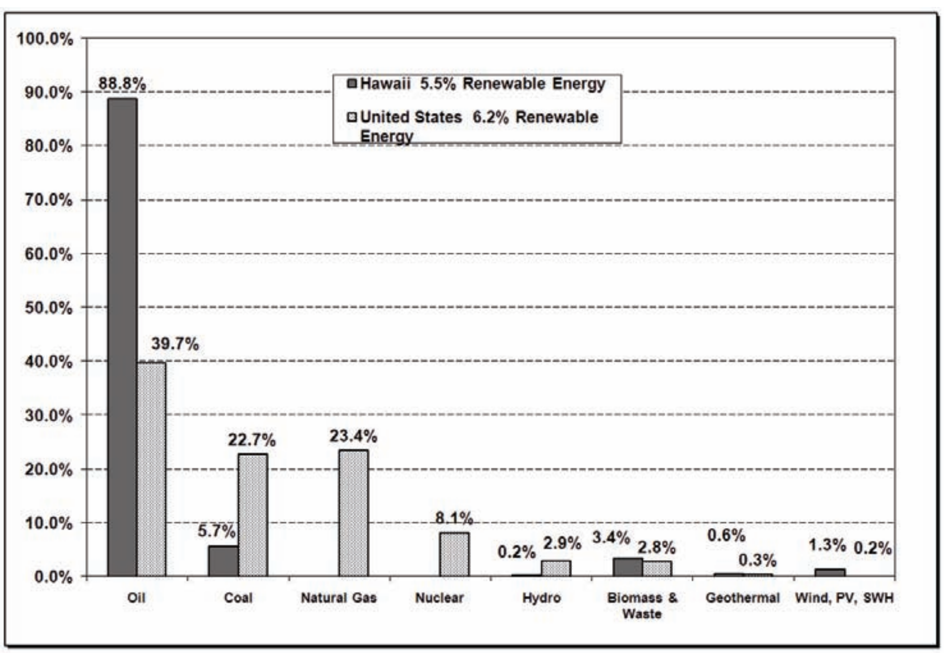


By 1980, solar hot water heaters had entered service and their use has grown rapidly since. By 1985, a limited amount of coal was being used to supplement bagasse in two sugar mills, a geothermal test well was in operation, and some wind farms were deployed. In 1990, the H-POWER waste to energy plant began operation on O'ahu. In 1992, Puna Geothermal Venture on the island of Hawai'i began commercial operation and produced 2.3 TBTU in 1995. Also in 1995, DBEDT began keeping statistics on photovoltaic energy production.

The additional renewable energy sources only partially offset a major decline in biomass energy produced by the sugar mills. By 2003, all sugar mills on O'ahu and the island of Hawai'i had closed and only one mill remained in operation on Maui and on Kaua'i. As a result, energy production from biomass declined from 26.9 TBTU in 1970 to 6.3 TBTU in 2003. Generation from landfill methane gas, a subcategory of biomass, began providing electricity to the HECO grid on O'ahu in 1990, but a catastrophic failure of its turbine in 2002 ended its operation. The wind farms that began operations in the 1980s reached production of 0.29 TBTU in 1990, but as wind turbines wore out and the wind farm on O'ahu shut down in 1996, production from wind energy declined further and was only 0.113 TBTU in 2003. Hydroelectricity generation also declined over this period as some hydro units owned by sugar mills were not maintained when the mills closed.

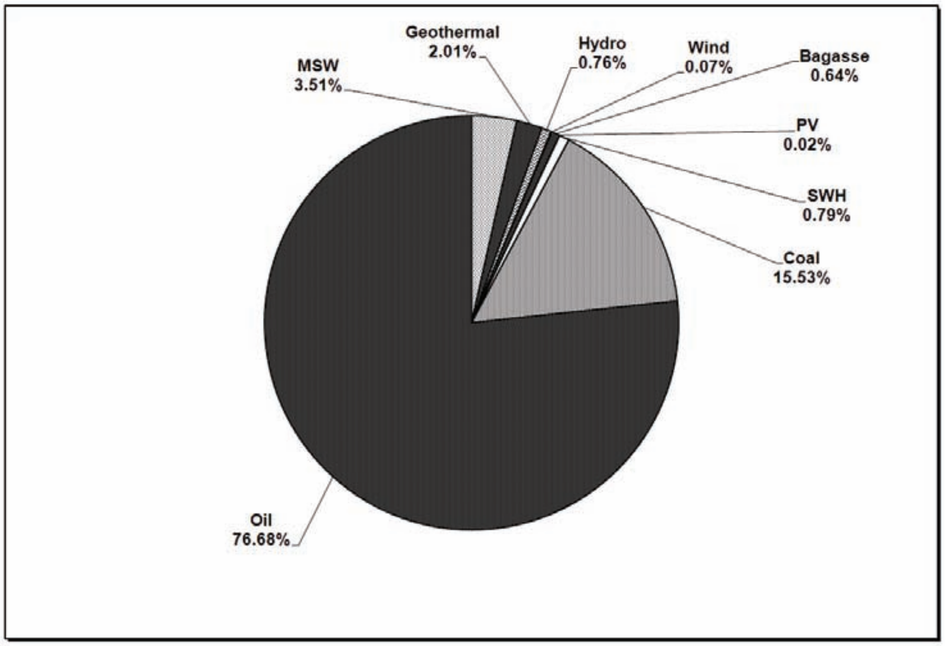
Figure A3-7 compares Hawai'i and U.S. primary energy consumption in 2003. As noted, United States renewable energy use was 6.2 percent of primary energy consumption, while Hawai'i's renewable energy use was 5.5 percent. However, it should be noted that about 2.9 percent of U.S. renewable energy is large-scale hydroelectric. Many projects are large-scale and have provided low cost power for decades; however, there have been growing concerns about the sustainability of migrating fish populations that must spawn above many of the dams. All of Hawai'i's hydro projects are run-of-the-river with much less effect upon their environment. Nevertheless, hydroelectric power is a renewable energy source.

Figure A3-7. Comparison of U.S. and Hawai'i Primary Energy Consumption, 2003 (DBEDT Energy Data, 2003; USEIA, 2005b).



Almost all of the renewable energy sources in Hawai'i are used for electricity generation. Figure A3-8 shows the energy sources of electricity generation in Hawai'i in 2003. Note that solar water heating, which provides energy direct use by making hot water, and PV, which generate electricity that may or may not be connected to the utility grid, are included in our statistics as sources of electricity generation. Together, these eight sources of renewable energy account for 8.73 percent of electricity or offset electricity demand in 2004.

Figure A3-8. Sources of Electricity Generation of Hawai'i, 2004 (HECO, 2005a and KIUC, 2005).



On O'ahu, the only renewable energy source currently available is municipal solid waste -- primarily refuse derived fuels burned by the H-POWER waste-to-energy plant, but also including shredded tires burned by the AES Hawai'i coal plant (4.77 percent), photovoltaics (0.01 percent), and solar water heating (0.61 percent), a total of 5.39 percent. Nearly 20 percent of O'ahu's electricity generation comes from coal (19.94 percent), which is used by the AES Hawai'i plant at Barbers Point. Oil, principally low sulfur fuel oil, or residual fuel oil, provides 74.67 percent of O'ahu's electricity generation.

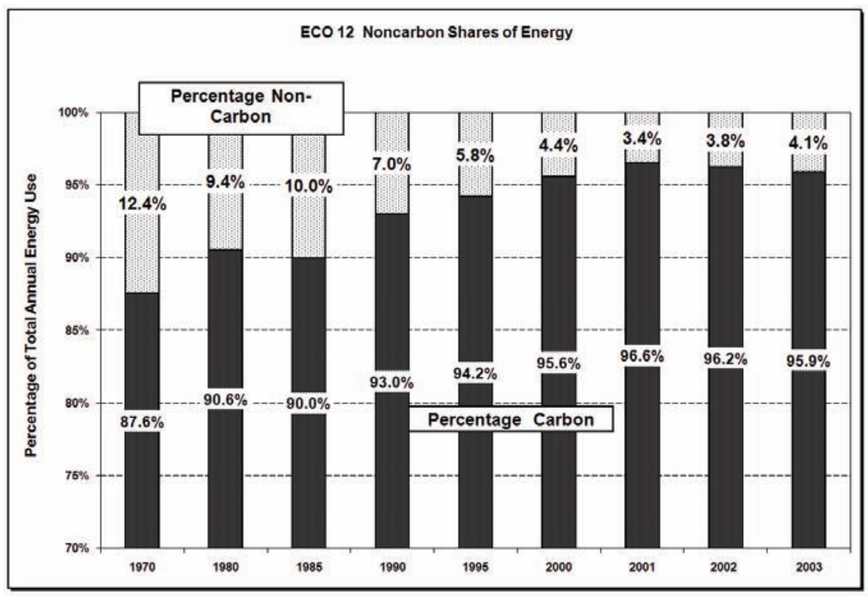
7. ECO12 Noncarbon Shares of Energy and Electricity. (EVALUATION: Concern)

This indicator measures the share of non-carbon energy sources in energy use, electricity generation and generating capacity. The promotion of energy and of electricity from non-carbon sources is a high priority for sustainable development for several reasons, ranging from environmental protection to the energy security and diversification of energy supply. An increase in the share of non-carbon fuels reduces emissions of greenhouse gases and other pollutants affecting local air quality and regional acidification (IAEA, 2005).

The indicator ECO12, Noncarbon Shares of Energy and Electricity, might initially seem to be a simplification of ECO11. In this case, oil and coal contain carbon and emit the greenhouse gases CO_2 and methane, which contribute to global warming and climate change. In addition, some renewable energy resources such as municipal solid waste and landfill methane also contain carbon and emit greenhouse gases and are included in the carbon shares. However it should be noted that municipal solid waste contained in a landfill can emit methane, which has a significantly greater impact on global warming than carbon dioxide. Thus it is better for the atmosphere for landfill methane to be flared or to be used as fuel in a landfill gas generator or waste-to-energy power plant. The emissions are then principally carbon dioxide. Biomass energy crops such as bagasse also contain carbon, but they are considered carbon neutral because they take in and sequester carbon dioxide in the growing process.

As shown in Figure A3-9, Hawai'i's noncarbon share of energy and electricity production has decreased since 1970 primarily due to the closure of all but two sugar mills. The reduction in the percentage of electricity produced by bagasse was only partially offset by the addition of other types of renewable energy resources.

Figure A3-9. ECO12 Noncarbon Shares of Energy (DBEDT Energy Data, 2003).



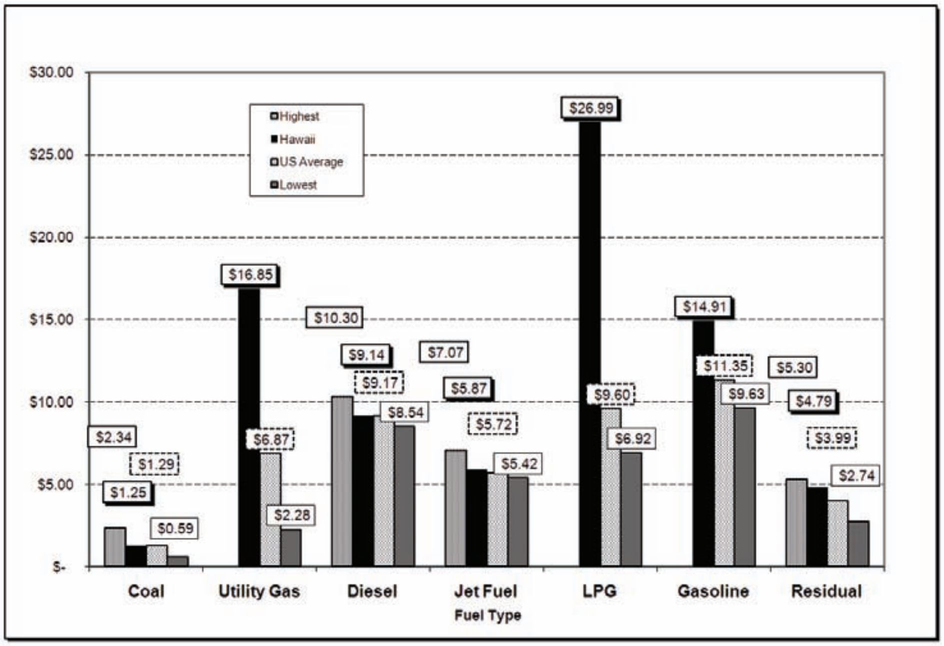
8. ECO14 End-Use energy prices by fuel and by sector (EVALUATION: Major concern)

This indicator reflects the final price paid by consumers for energy services. Energy prices are driving forces for incentives or disincentives for consumption or conservation, or efficiency improvements. Obviously, prices can affect affordability (IAEA, 2005).

The prices of end-use energy by fuel and sector (ECO14) have obvious economic importance. Efficient energy pricing is the key to efficient energy supply and use and socially efficient levels of pollution abatement. Energy prices and related subsidies and taxes can encourage efficiency of energy use or improve access levels, or they can generate inefficiencies in the supply, distribution, and use of energy.

Hawai'i has some of the highest fuel prices in the United States. Figure A3-10 is a comparison of Hawai'i and U.S. fuel prices based upon the USEIA's State Energy Data 2001: Prices and Expenditures, the latest available data. Prices are presented in dollars per million BTU. The price Hawai'i pays for coal is the only fuel price below the U.S. average. At $1.25, Hawai'i pays 97 percent of the U.S. average price. Vermont pays the highest coal prices and Nebraska pays the lowest.

Figure A3-10. Comparison of Hawai'i and U.S. Fuel Prices in 2001 (USEIA, 2004).

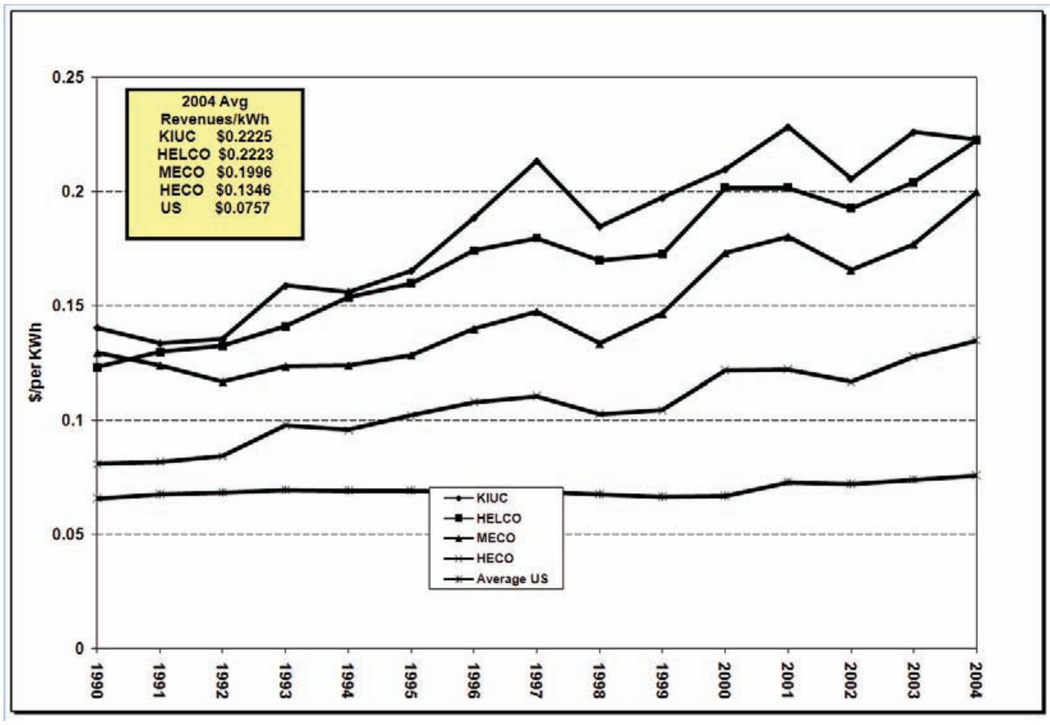


Hawai'i also pays the highest utility gas prices (245 percent of the U.S. average), principally because the Hawai'i utility gas systems provide synthetic natural gas (SNG) or propane/air mixtures in their pipeline gas service. These require special attention in the refineries and in transit compared to the natural gas used in the other 49 states. LPG turned out to be the most expensive fuel relative to the U.S. average and Hawai'i paid the largest amount.

Hawai'i's diesel price in 2001 was very close to the U.S. average. Alaska had the highest diesel prices and the District of Columbia had the lowest. Hawai'i's jet fuel prices were only 3 percent higher than average, while Montana had the highest prices and Mississippi the lowest. Hawai'i also led in gasoline prices paying 31 percent more than the U.S. average. California pays the most for residual and Missouri the least.

Hawai'i also pays the highest statewide average electricity rates in the country as shown in Figure A3-11. Over the period depicted, the increase in Hawai'i utility revenues per kWh greatly exceeded the U.S. average of 15 percent. The Hawai'i utility revenues per kWh increased by 81 percent for HELCO, 67 percent for HECO, 59 percent for KIUC, and 54 percent for MECO. All increases were greater than the Honolulu Consumer Price Index, which went up 38 percent (HECO FERC 1, MECO FERC 1, HELCO1, and KIUC Annual PUC Report).

Figure A3-11. 1990-2004 Average Revenues per kWh for Hawai'i and the U.S. (HECO FERC 1, MECO FERC 1, KUIC Annual Report to PUC, HELCO Annual Report to PUC).

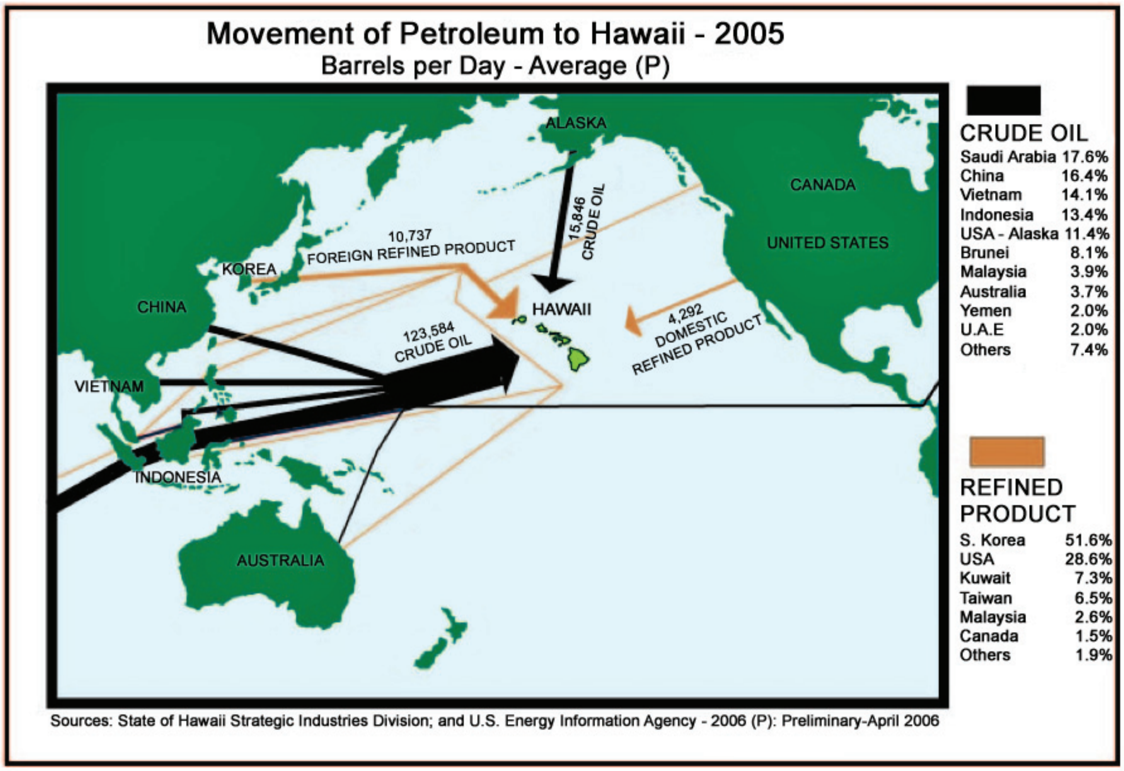


9. ECO15 Net Energy Import Dependency. (EVALUATION: Major concern)

This indicator measures reliance on imports to meet its energy requirements. Energy security is a key policy objective in the pursuit of sustainable development. Ensuring physical availability of supplies and avoidance of energy supply interruptions are aspects of energy security. There are quantity and price risks to supply of imported energy. Policies to increase indigenous energy production and enhance energy efficiency can help mitigate both risks (IAEA, 2005).

Figure A3-12 depicts oil imports into Hawai'i by source and number of barrels per day. Over the years, Hawai'i has become increasingly dependent on foreign oil. In 2005, Hawai'i's refiners received only 11.4 percent of their crude oil from Alaska (their only U.S. source). The Alaska North Slope (ANS) resource became fully operational in 1978, reached its highest level of production in 1988, but has been in decline since then. When the federal ban on sales of domestic crude to other countries was lifted in the 1990s, Japan became a major importer of ANS crude oil. The ANS share of Hawai'i's crude imports has declined from 52 percent in 1987 to 22 percent in 2003 to 11.4 percent in 2005.

Figure A3-12. Movement of Petroleum to Hawai'i, 2005 (Barrels per Day) (DBEDT Energy Data, 2003 and USEIA, 2005a).



Saudi Arabia, China, Vietnam, and Indonesia together provided 61.2 percent of Hawai'i's crude oil imports. The importing of 8 percent of Hawai'i's 2003 imports from Oman represented the first significant imports of Hawai'i's crude oil from a Middle Eastern country. In 2005, 21.6 percent came from Saudi Arabia, Yemen, and the United Arab Emirates. Figure A3-13 shows there have been significant changes in the origin of Hawai'i's crude oil imports since 1992. At that time, over 73 percent of Hawai'i's crude came from Alaska and Indonesia. Their share peaked in 1994 at 84 percent and began a decline to 34 percent by 2003. Australia and China provided increasing shares of supply in the mid-1990s and the four sources together provided a peak of 91 percent of Hawai'i supplies in 1998. In 2003, the four sources that had dominated Hawai'i's imports in the previous decade together provided only 39 percent as Alaska production declined and the other countries increasingly used their own production to meet their growing domestic demand. However, these four sources provided 44.9 percent in 2005 (DBEDT Energy Data, 2003).

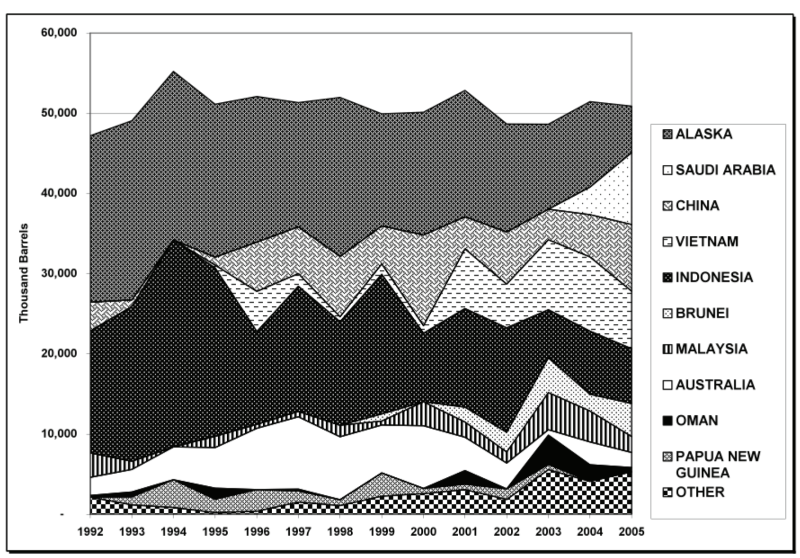


Figure A3-13. Changing Sources of Crude Oil Imports into Hawai'i, 1992 – 2005 (DBEDT Energy Data, 2005).

10. ECO16 Stocks of Critical Fuels per Corresponding Consumption. (EVALUATION: Data not available)

Other than general statements by electric utilities that they maintain 30 to 35 days of supply, there are no data in the public domain on fuel storage stocks. The purpose of ECO16 is to measure the availability of national stocks of critical fuels, such as oil, with respect to corresponding fuel consumption. The United States maintains a Strategic Petroleum Reserve of oil in anticipation of possible disruptions in oil supply. Due to Hawai'i's distance from these reserves, which are in Louisiana, Hawai'i has been granted priority access to the Strategic Petroleum Reserve in the event of an emergency.

We did not compile data on fuel storage within the Islands. If the data were available, the indicator provides a relative measure of the length of time that stocks would last if supply were disrupted and fuel use were to continue at current levels. However, the state's energy emergency plans call for various types of rationing in the event of disruptions. It would be expected that rationing would extend the length of time that stocks would last at reduced levels of activity. The availability and security of fuel supplies are key aspects of sustainability.

The Environmental Energy Indicators for Sustainable Development (ENV)

1. ENV1 Greenhouse Gas (GHG) Emissions from Energy Production and Use Per Capita and Per Unit of GSP. (EVALUATION: Major concern)

Under the Kyoto Protocol to the United Nations Framework Convention on Climate Change, signed by the United States in November 1998, the U.S. was committed to reduce its emissions by 7 percent less than 1990 emissions by 2008-2010. It is unlikely that the Protocol will ever be ratified by Congress, but the target provides an interim standard. Hawai'i's human-caused greenhouse gas emissions for the 1990 baseline year were estimated at 16,961,453 tons of CO_2, 75,717 tons of CH_4, and 680 tons of N_2O (DBEDT, 2005).

The global warming potential (GWP) was calculated to allow comparison of the relative effects of each of the different greenhouse gases on warming of the atmosphere. For such comparisons, using a 100-year time horizon, CH_4 has 22 times the radiative forcing direct impact of CO_2 and N_2O has 270 times the direct impact (USEPA, 1998b). The GWP of Hawai'i's 1990 emissions was 18,810,906 tons CO_2-equivalent (CO2E). This was only 0.3 percent of total U.S. emissions in 1990. While the Kyoto Protocol did not require the national target for emissions reduction to be apportioned among the states, a 7 percent reduction in Hawai'i's 1990 GWP would be 1,316,763 tons CO2E reducing total GHG emissions to 17,494,143 tons CO2E.

Hawai'i's energy use produced the greatest GWP in the 1990 baseline year - an estimated 16,813,006 tons CO2E, or 89.4 percent of total GWP. MSW management and wastewater management together produced 7.4 percent of Hawai'i's 1990 GWP, agricultural activities emitted 2.7 percent, and industrial processes emitted the remaining 0.6 percent.

The emissions included in the baseline were from energy use in Hawai'i only or for aircraft and ships in domestic use (i.e., flights and ships to the mainland U.S.). In accordance with United Nations Framework Convention on Climate Change and USEPA guidance, the emissions from overseas international air and marine transportation fueled in Hawai'i were not counted. In addition, about 4 percent of the energy sold or distributed in Hawai'i in 1990 was provided to the U.S. military. Because there were no data available concerning where this fuel was actually used, it was also omitted from the estimate. Hawai'i's 2003 greenhouse gas emissions were estimated at 21.7 million tons CO2E, a 15 percent increase over the baseline. United States overall GHG emissions were up 13 percent in 2003 (USEPA, 1998b).

Figure A3-14. 1990-2020 Forecast Energy Use Global Warming Potential and the Kyoto Protocol Target (DBEDT, 2000).

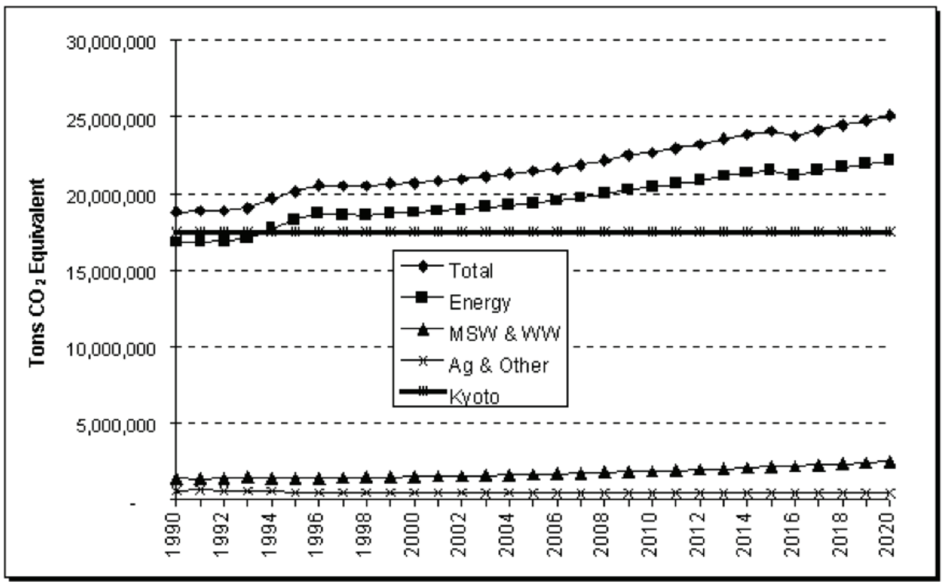


Figure A3-14 was developed for the Hawai'i Energy Strategy 2000. Based on data available at the time and continuing with "business as usual", Hawai'i's overall domestic GWP was forecast to be 22 percent over the Kyoto Protocol target by 2010 and 36 percent over the Kyoto Protocol target by 2020. The domestic GWP from energy use was forecast to be 23 percent above the energy emission Kyoto Protocol target by 2010 and 32 percent above the target in 2020 unless actions to reduce greenhouse gas emissions are taken (DBEDT, 2000).

Why is action needed? During the 20th and early 21st century, the Earth's average surface temperature increased by around 0.8°C and evidence is growing that most of this warming is attributable to increasing concentrations of GHGs in the atmosphere. The amount of carbon dioxide (CO_2), for example, has increased by more than 30 percent since preindustrial times and is currently increasing at an unprecedented rate of about 0.4 percent per year, mainly due to the combustion of fossil fuels. The concentrations of methane (CH_4) and nitrous oxide (N_2O) are increasing as well due to energy, agricultural, industrial and other activities.

Concentrations of nitrous oxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs) are also increasing as a result of anthropogenic activity. They affect atmospheric chemistry leading to an increase in tropospheric ozone, which is a greenhouse gas.

2. ENV2 Ambient Concentrations of Air Pollutants in Urban Areas (EVALUATION: Concern)

This indicator provides a measure of air quality, which can be a health concern in urban areas. It also provides an indirect measure of population exposure to impacts on human health and vegetation. An increasing percentage of the world's population and a majority of Hawai'i's population live in urban areas. Air pollution from energy use in households, industry, power stations and transportation (motor vehicles) is often a major problem. As a result, the greatest potential for human exposure to ambient air pollution and subsequent health problems occurs in urban areas (IAEA, 2005).

Hawai'i's air quality meets federal and state environmental health standards because trade winds and lack of major polluting industries reduce the build up of air pollution over the islands (Juvik and Juvik, 1998). Under the Clean Air Act, standards are set for "criteria pollutants." These include ground-level ozone, nitrogen dioxide, particles less than 10 µ in diameter (PM10), sulfur dioxide, CO, and lead. The State Health Department has set standards that are up to twice as stringent as the EPA criteria for most of these pollutants. Table A3-3 shows measurements of air quality at specified locations on O'ahu in 2004. Neither of the criteria pollutants standards, particulate matter (PM) and sulfur dioxide, was exceeded. It is interesting to note the spike in maximum PM10 due to New Year's Eve fireworks (DBEDT Energy Data, 2003).

Table A3-3. O'ahu Air Quality, 2004 (DBEDT Energy Data, 2003).

Air Quality at Specified Locations on Oahu, 2004
[24-hour average, in micrograms per cubic meter]

Sampling station	PM $_{10}$ * Annual range Minimu	PM $_{10}$ * Annual range Maximum	PM $_{10}$ * Average	Sulfur dioxide ** Annual range Minimu	Sulfur dioxide ** Annual range Maximum	Sulfur dioxide ** Average
Downtown Honolulu	6	*** 39	13	-	25	11
Liliha	4	*** 72	15	(NA)	(NA)	(NA)
Pearl City	5	*** 131	15	(NA)	(NA)	(NA)
Kapolei	4	*** 54	13	-	7	1
Makaiwa	(NA)	(NA)	(NA)	-	15	3
West Beach	3	22	13	-	4	0.3
Waimanalo	5	27	15	(NA)	(NA)	(NA)

* The State and Federal Ambient Air Standard for 24-hr PM_{10} is 150 mg/m^3.
** The State and Federal Ambient Air Standard for 24-hr SO is 365 mg/m^3.
*** Probably due to New Year's fireworks.

3. ENV3 Air Pollutant Emissions from Energy Systems. (EVALUATION: Concern)

ENV3 tracks air pollutants from energy-related activities. It is used to evaluate the environmental performance of national policies and to describe the environmental pressure in relation to air pollution abatement in energy-related activities including power generation and transportation. In many places, concentrations of various air pollutants are growing mainly due to energy use. The amount of pollution depends upon energy production and consumption patterns, which in turn are affected by both energy intensity and efficiency. Emissions of these pollutants are also influenced by national requirements for pollution abatement and control and the use of clean energy technologies. The level of emissions gives an indication of the impact of human activities on the environment.

ENV3 can be used to assess environmental pressure from energy production and use and to evaluate the environmental performance of regulations designed to address four major impacts of air pollutants on health and the environment:

- The acidification of soil and water by pollutants such as SOx and NOx.
- The damage to buildings by these acidifying substances.
- The formation of tropospheric ozone from volatile organic compounds (VOCs), NOx and CO, which indirectly affect human and animal health and vegetation.
- The direct effects on human health and ecosystems – e.g., through high atmospheric concentrations of particulates and VOCs.

Some of effects of the various pollutants are as follows. Sulphur and nitrogen compounds are a source of acidification. Anthropogenic nitrogen is predominantly emitted as NOx by transport sources as well as by other energy uses and industrial processes. Air pollutants are associated with respiratory morbidity and mortality in humans. NOx can irritate the lungs and lower resistance to respiratory infections and may cause increased incidence of acute respiratory disease. In the presence of sunlight, NOx react with VOCs to form tropospheric ozone and other oxidizing chemicals, which are toxic to living things including humans. NOx and sulphur dioxide (SO_2) are also precursors to acids in rainwater and subsequently have deleterious effects on buildings, aquatic organisms, agriculture and habitats (IAEA, 2005).

As noted above, Hawaiʻi's air quality meets federal and state environmental health standards because trade winds and lack of major polluting industries reduce the build up of air pollution over the islands (Juvik and Juvik, 1998). As a result, Hawaiʻi generally does not face the above problems. Nevertheless, there are periods of time when visibility deteriorates due to emissions (known as "vog") from the volcanoes on the island of Hawaiʻi being carried by "Kona winds" to Oʻahu.

4. ENV4 Contaminant Discharges from Liquid Effluents from Energy Systems Including Oil Discharges (EVALUATION: Major concern)

The purpose of this indicator in the global context is to monitor the discharge of harmful pollutants from energy industries, particularly coal mining and oil extraction, into rivers, lakes and marine waters. Avoiding and reducing such discharges are important because fresh water is a scarce resource and is needed for potable supply, agriculture and is the habitat for plants, fish species and other wildlife. The marine environment is also an important habitat for aquatic life and an important resource for fishing, aquaculture, and, especially in Hawaiʻi, for tourism and recreation. Oil lost or discharged into the sea represents a pollution threat that can damage coastal ecosystems, endanger or kill marine life, and pollute beaches and coastlines (IAEA, 2005).

Transportation of oil and oil products poses a risk of damage to the environment and the economy. In 2005, 50.9 million barrels of crude oil and 5.5 million barrels of refined product were imported into Hawaiʻi by sea, mostly through Barbers Point Harbor and Honolulu Harbor on Oʻahu. The crude oil is offloaded from tankers at offshore moorings operated by ChevronTexaco Hawaiʻi and Tesoro Hawaiʻi refineries. Most fuel for Hawaiʻi's neighbor islands is refined on Oʻahu and then shipped by barge (DBEDT, 2000).

The Exxon Valdez disaster in Alaska in 1989 stimulated the State of Hawaiʻi Department of Health to commission a study on the potential impacts of oil spills at sea on Hawaiʻi. The 1992 study examined a worst-case scenario developed by the Coast Guard in which a damaged tanker lost a third of its cargo, around 9.8 million gallons in the Kaiwi Channel, then the primary route used by tankers to Oʻahu. In this scenario, oil washed up on Oʻahu and Kauaʻi causing about $3 billion in lost revenues to tourism, cleanup costs of $210 to $305 million, and severe environmental damage to beaches, reefs, and wildlife. As a result of the study, tanker operators agreed to use the wider Kauaʻi channel to reduce the risk of collision.

Earlier, however, another Exxon tanker, the Exxon Houston, was grounded on March 2, 1989 after breaking away from the then Hawaiʻi Independent Refinery Inc. offshore mooring at Barbers Point during fuel transfer operations. Approximately 400 barrels of crude oil spilled from the cargo transfer hose and 200 barrels of bunker fuel leaked into the water due to hull damage. The damage to the ship was sufficient to render it a total loss and it was sold for scrap salvage value and towed to Hong Kong for dismantling. While the leaks were relatively minor, and there were no casualties, the potential danger to the environment had been huge if a larger portion of the load had spilled (USCG, 1992).

Other risks to water resources are posed by cooling water used by fossil fuel generators, leaking fuel storage tanks, and fuel spilled from trucks transporting fuel overland. In addition, there is nonpoint source pollution from energy use, such as improperly disposed of lubricating oil, run off of gasoline and oil from highways, etc.

Table A3-4 summarizes the total number of spills and their volume in the U.S. Coast Guard District 14, which includes the Hawaiian Islands.

Table A3-4. Hawaiʻi Oil Spills from 1973 to 2001 (USCG, 2001).

Oil Spills in Coast Guard District 14 (Hawaii) 1973 - 2001					
	Gallons Spilled	Number Spills		Gallons Spilled	Number Spills
1973	30,556	313	1988	18,663	156
1974	175,585	308	1989	93,557	284
1975	37,093	102	1990	47,254	294
1976	6,741	70	1991	61,916	315
1977	1,917	47	1992	20,351	337
1978	7,628	131	1993	112,357	213
1979	16,953	98	1994	37,016	221
1980	457,872	155	1995	19,506	252
1981	32,808	123	1996	46,962	191
1982	1,081,268	125	1997	28,876	231
1983	1,025,621	158	1998	143,234	182
1984	13,689	148	1999	26,074	228
1985	88,646	97	2000	5,582	229
1986	116,735	91	2001	40,715	231
1987	189,702	142	Totals	3,984,877	5,472

Source: USCG

5. ENV5 Soil Area Where Acidification Exceeds Critical Loads. (EVALUATION: No data)

This indicator describes the extent of acidification of the soil. It is used to monitor the state and trends in the severity of acidification and to evaluate the environmental performance of national air pollution abatement policies. The indicator should show acidification attributable to all sources and (where appropriate national data are available) acidification due to emissions from the energy sector alone (IAEA, 2005). Due to Hawaiʻi's climate, especially trade winds that blow pollutants out to sea, and Hawaiʻi's few emissions sources, acidification does not seem to be a problem, but no data were found to document this assertion.

6. ENV6 Rate of Deforestation Attributed to Energy Use. (EVALUATION: Good)

The purpose of this indicator is to show a change in the area covered by the forest formations of a country over time that could be attributed to using wood for energy needs. Forests provide many significant resources, including wood products, recreational opportunities and habitat for wildlife, and serve many important functions, such as filtering pollutants and playing a role in water and soil conservation. They support employment and traditional uses as well as biodiversity. Deforestation, in particular due to fuelwood harvest, is a major issue in developing countries. The issue is of less concern in developed countries where the area volume of fuelwood consumption is negligible (IAEA, 2005).

Table A3-5 gives the forest and natural area acreage by Islands in Hawai'i in 2003. According to a note accompanying this appendix in the State Data Book, this acreage has remained constant since 1996. This suggests there is little pressure on Hawai'i forests for energy purposes. On the island of Hawai'i, eucalyptus forests were planted at one time as energy crops. There have also been various efforts to establish pulpwood and plywood production from Big Island forests that would produce energy as part of the production process. However, these would be commercial forestry operations in which harvested areas would be replanted.

Table A3-5. Forest and Natural Area Acreage by Islands in 2004 (DBEDT, 2004).

Forest and Natural Area Acreage by Islands 2003				
	Conservation District Forest Land		Natural Areas	
Island	Forest Reserve	Private Forest	Number of Areas	Acres
Hawaii	438,416	106,745	8	82,535
Maui	73,227	53,180	4	17,123
Lanai	-	6,150	-	-
Molokai	16,030	-	2	2,950
Oahu	32,462	88,817	3	1,770
Kauai	82,999	73,850	2	4,786
Total	643,134	328,742	19	109,164

7. ENV7 Ratio of Solid Waste Generation to Units of Energy Produced and ENV8 Ratio of Solid Waste Properly Disposed of to Total Generated Solid Waste. (EVALUATION: Data not available)

ENV7 and ENV8 will be discussed together. The main purposes of these indicators are to provide information on the amount and type of solid waste generated each year by the energy sector for which proper disposal facilities are needed and to assess the extent of proper disposal of this solid waste (IAEA, 2005). Of the types of waste produced by the energy sector, Hawai'i produces waste from the processing and combustion of fuels. For the waste produced by this aspect of energy use, inadequate storage and disposal can lead to contamination of water bodies and soil through runoff and leaching. Moreover, much of the waste can potentially be used as a raw material — for example, as a building aggregate, which could reduce the need for quarrying, etc. — so that the non-use of this potential raw material represents a waste of resources (IAEA, 2005).

The largest sources of solid waste from combustion of fuels are the AES Hawai'i coal plant and the H-POWER waste to energy plant. It is our understanding that the coal ash and ash from the combustion of MSW are used as underlay material for road pavement or for other construction purposes. Data on the amounts of these materials is not readily available.
It appears, however that the waste is being used appropriately. The basic purpose of the H-POWER power plant is to reduce the volume of waste going in to O'ahu landfills by approximately 90 percent.

8. ENV9 Ratio of Solid Radioactive Waste to Units of Energy Produced and ENV10 Ratio of Solid Radioactive Waste Awaiting Disposal to Total Generated Solid Radioactive Waste (EVALUATION: Not applicable)

These two indicators are not relevant to this case study. There are no civilian uses of nuclear power in Hawaiʻi. While the U.S. Navy bases nuclear-powered submarines at Pearl Harbor, their radioactive waste handling procedures are beyond the scope of this case study.

A4. Electricity Generators Producing Electricity for Utility Sale on Oʻahu, 2004 (DBEDT Energy Data, 2004). (Chapter 4)

Electricity Generation for Utility Sale on Island of Oahu				
Location	**Unit**	**Type**	**Fuel**	**Capacity (MW)**
HECO-Owned				
Kahe	Kahe 1	OFS	No. 6 LSFO	92
	Kahe 2	OFS	No. 6 LSFO	90
	Kahe 3	OFS	No. 6 LSFO	92
	Kahe 4	OFS	No. 6 LSFO	93
	Kahe 5	OFS	No. 6 LSFO	142
	Kahe 6	OFS	No. 6 LSFO	142
			Kahe Subtotal	**651**
Waiau	Waiau 3	OFS	No. 6 LSFO	49
	Waiau 4	OFS	No. 6 LSFO	49
	Waiau 5	OFS	No. 6 LSFO	57
	Waiau 6	OFS	No. 6 LSFO	58
	Waiau 7	OFS	No. 6 LSFO	92
	Waiau 8	OFS	No. 6 LSFO	92
	Waiau 9	CT	No. 2 Diesel	52
	Waiau 10	CT	No. 2 Diesel	50
			Waiau Subtotal	**499**
Honolulu	Honolulu 8	OFS	No. 6 LSFO	56
	Honolulu 9	OFS	No. 6 LSFO	57
			Honolulu Subtotal	**113**
			HECO Subtotal	**1263**
Independent Power Producers				
Barbers Point	H-Power	MSW Steam	MSW	46
	Kalaeloa	STCC	No. 6 LSFO	180
	AES BP	AFBC	Coal	180
	Tesoro Refinery*	CT	Light Oils	18
	Chevron Refinery*	CT	Light Oils	9
			IPP Subtotal	**433**
			Oahu Total	**1,696**
AFBC - Atmospheric Fluidized Bed Coal		MSW - Municipal Solid Waste		
CT - Combustion Turbine		OFS - Oil Fired Steam		
LSFO - Low Sulfur (<0.5%) Fuel Oil		STCC - Single Train Combined Cycle		
* Non-firm, as available power only				

A5. Electricity Generation for HECO Customers (HECO FERC 1, DBEDT Energy Data, 2004). (Chapter 4)

Electricity Generation Sold to HECO Customers 2004 - MWh, Fuel Use and Cost, and Greenhouse Gas Emissions							
HECO Units by Fuel Type	**Net Generation (MWh)**	**Amount of Fuel**	**Units**	**Total Cost of Fuel**	**Cost of Fuel Only per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
HECO LSFO Steam	4,881,864	8,135,847	barrels	$ 328,148,772	$ 0.0672	4,677,850	1.92
HECO LS Diesel	39,819	135,875	barrels	$ 7,131,867	$ 0.1791	67,741	3.40
HECO Subtotal	4,921,683	8,271,722	barrels	$ 335,280,639	$ 0.0681	4,745,591	1.93
IPP Units and Fuel Type (s)	**Net Generation (MWh)**	**Amount of Fuel**	**Units**	**Total Paid for Electricity by HECO**	**Cost of Purchased Power per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
Kalaeloa P.P.LSFO	1,337,348	1,943,599	barrels	$ 130,523,366	$ 0.0976	1,145,225	1.71
AES Hawaii Coal	1,498,608	638,015	tons			1,399,344	
AES Hawaii Tires	43,000	6,899	tons	$ 133,910,134	$ 0.0894	23,143	1.82
AES Hawaii Waste Oil	33,576	30,890	barrels			14,427	
AES Hawaii Diesel	5,373	4,944	barrels			3,664	
C&C Honolulu MSW	325,591	360,840	tons	$ 31,265,851	$ 0.0960	227,776	1.41
C&C Honolulu Diesel		3,215	barrels			2,383	
Tesoro Hawaii Refinery Lt Oils	3,677	7788	barrels	$ 273,094	$ 0.0743	4,324	2.35
ChevronTexaco Refinery Lt Oils	90		barrels	Exchange			-
IPP Subtotal	3,247,263			$ 295,972,445	$ 0.0911	2,820,286	1.74
HECO and IPP Combined	**8,168,946**			**$ 631,253,084**	**$ 0.0773**	**7,565,877**	**1.85**

Sources: HECO 2, DBEDT Energy Databbase

A6. HELCO-Owned Electricity Generation for Utility Sale on the Island of Hawai'i, 2005 (DBEDT Energy Data, 2005). (Chapter 4)

HELCO-Owned Electricity Generation for Utility Sale on the Island of Hawaii 2005				
Location	Unit	Type	Fuel	Capacity (MW)
HELCO-Owned				
Hill	Hill 5	OFS	No. 6 MSFO	13.50
	Hill 6	OFS	No. 6 MSFO	20.20
			Hill Subtotal	**33.70**
Kanoelehua	Kanoelehua 11*	Diesel	No.2 Diesel	2.00
	Kanoelehua 15*	Diesel	No.2 Diesel	2.75
	Kanoelehua 16*	Diesel	No.2 Diesel	2.75
	Kanoelehua 17*	Diesel	No.2 Diesel	2.75
	Kanoelehua CT1*	CT	No.2 Diesel	11.50
			Kanoelehua Subtotal	**21.75**
Keahole	Keahole 21*	Diesel	No.2 Diesel	2.75
	Keahole 22*	Diesel	No.2 Diesel	2.75
	Keahole 23*	Diesel	No.2 Diesel	2.75
	Keahole CT2	CT	No.2 Diesel	13.00
	Keahole CT4 and 5	CT	No.2 Diesel	40.00
			Keahole Subtotal	**61.25**
Lalamilo Wells	Lalamilo Wells	Wind		2.28
			Lalamilo Wells Subtotal	**2.28**
Puna	Puna	OFS	No. 6 MSFO	14.10
	Puna CT3	CT	No.2 Diesel	20.40
			Puna Subtotal	**34.50**
Puueo	Puueo 1	Hydro		1.50
	Puueo 2	Hydro		0.75
			Puueo Subtotal	**2.25**
Shipman	Shipman 3	OFS	No. 6 MSFO	7.10
	Shipman 4	OFS	No. 6 MSFO	7.30
			Shipman Subtotal	**14.40**
Waiau	Waiau 1	Hydro		0.75
	Waiau 2	Hydro		0.35
			Waiau Subtotal	**1.10**
Waimea	Waimea 12*	Diesel	No.2 Diesel	2.75
	Waimea 13*	Diesel	No.2 Diesel	2.75
	Waimea 14*	Diesel	No.2 Diesel	2.75
			Waimea Subtotal	**8.25**
			HELCO No. 6 MSFO-Fueled Generation Subtotal	**62.20**
			HELCO No. 2 Diesel-Fueled Generation Subtotal	**111.65**
			HELCO-Owned Total	**173.85**

CT - Combustion Turbine MSFO - Medium Sulfur (<2.5%) Fuel Oil
DTCC - Dual Train Combined Cycle OFS - Oil Fired Steam
IC Diesel - Internal Combustion Diesel
Source: DBEDT Energy Database

A7. IPP-Owned Electricity Generation and Generation Capacity Summary for the Island of Hawai'i, 2005 (DBEDT Energy Data, 2005). (Chapter 4)

IPP-Owned Electricity Generation and Generation Capacity Summary for the Island of Hawaii 2005				
Location	Unit	Type	Fuel	Capacity (MW)
Hamakua	Hamakua Energy	DTCC	Naphtha	60.00
Puna	Puna Geothermal	Geothermal		30.00
South Point	Apollo Energy	Wind		9.30
Wailuku	Wailuku River Hydro	Hydro		12.00
Various	Small Hydro	Hydro		3.30
Various	Small Wind	Wind		0.40
			Independent Power Producers Subtotal	**55.00**
Generation Capacity Summary				
			HELCO and IPP Firm Power Subtotal	**263.85**
			HELCO and IPP Non-Firm Power Subtotal	**30.63**
			Island of Hawaii Total	**294.48**

DTCC - Dual Train Combined Cycle
Source: DBEDT Energy Database

A8. Electricity Generation for HELCO Customers (HELCO Annual Report to the PUC and DBEDT Energy Data, 2004). (Chapter 4)

Electricity Generation Sold to HELCO Customers 2004 - kWh, Fuel Use and Cost, and Greenhouse Gas Emissions							
HELCO Units by Fuel Type	**Net Generation (kWh)**	**Amount of Fuel**	**Units**	**Total Cost of Fuel**	**Cost of Fuel Only per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
HELCO MSFO Steam	289,142,370	589,434	barrels	$ 20,245,563	$ 0.0700	233,631	1.62
HELCO MS Diesel	143,756,000	310,290	barrels	$ 17,826,685	$ 0.1240	89,499	1.25
HELCO Wind and Hydro	11,462,000						-
HELCO Subtotal	444,360,370	899,724	barrels	$ 38,072,248	$ 0.0857	323,130	1.45
IPP Units by Fuel Type(s)	**Net Generation (kWh)**	**Amount of Fuel**	**Units**	**Total Paid for Electricity by HELCO**	**Cost of Purchased Power per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
Hamakua Naptha	441,533,153	724,584	barrels (est)			289,515	1.31
Hilo Coast Power Company Coal		57,310	tons			129,020	
Diesel		7,975	barrels			4,009	
HCPC Overall	87,815,970					133,029	3.03
Puna Geothermal Venture	210,614,413						
Wailuku River Hydro	17,633,000						
Apollo Wind	6,181,000						
IPP Subtotal	763,777,536			$ 91,024,174	$ 0.1192	422,544	1.11
HELCO and IPP Combined	**1,208,137,906**			**$ 129,096,422**	**$ 0.1069**	**745,674**	**1.23**

A9. Electricity Generation for Utility Sale on Kauaʻi 2005 (DBEDT Energy Data, 2005). (Chapter 4)

Electricity Generation for Utility Sale on the Island of Kauai				
Location	**Unit**	**Type**	**Fuel**	**Capacity (MW)**
KIUC-Owned				
Port Allen	Gas Turbine 1	CT	No. 2 Diesel	19.20
	Gas Turbine 2	CT	No. 2 Diesel	23.70
	Steam Plant	OFS	No.2 Diesel	10.00
	EMD Diesel 1	IC Diesel	No.2 Diesel	2.00
	EMD Diesel 2	IC Diesel	No.2 Diesel	2.00
	EMD Diesel 3	IC Diesel	No.2 Diesel	2.75
	EMD Diesel 4	IC Diesel	No.2 Diesel	2.75
	EMD Diesel 5	IC Diesel	No.2 Diesel	2.75
	SWD Diesel 6	IC Diesel	No.2 Diesel	7.85
	SWD Diesel 7	IC Diesel	No.2 Diesel	7.85
	SWD Diesel 8	IC Diesel	No.2 Diesel	7.85
	SWD Diesel 9	IC Diesel	No.2 Diesel	7.85
Kapaia Power Station	Steam Injected Gas Turbine	CT	Naphtha	26.40
			KIUC Subtotal	**122.95**
Upper and Lower Waiahi	KIUC Hydro	Hydro		1.30
			KIUC Hydro Subtotal	**1.30**
			KIUC Owned Subtotal	**124.25**
Independent Power Producers				
Eleele	Kauai Coffee	Hydro		3.80
Kaumakani	Gay & Robinson Sugar	Steam	Bagasse	4.00
		Hydro		1.20
		IC Diesel	No. 2 Diesel	0.90
Ag Devel Corp	former Kekaha	Hydro		1.50
			IPP Total	**11.40**
			Firm Power Subtotal	**127.85**
			Non-Firm Power Subtotal	**7.80**
			Kauai Total	**135.65**
CT - Combustion Turbine		IC Diesel - Internal Combustion Diesel		

A10. Electricity Generation for KIUC Customers (KIUC Annual Report to the PUC and DBEDT Energy Data, 2004). (Chapter 4)

Electricity Generation Sold to KIUC Customers 2004 - kWh, Fuel Use and Cost, and Greenhouse Gas Emissions							
Owner and Type of Unit(s)	**Net Generation (kWh)**	**Amount of Fuel**	**Units**	**Total Cost of Fuel**	**Cost of Fuel Only per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
KIUC Naphtha	213,958,927	356,222	barrels	$ 17,600,507	$ 0.0823	145,458	1.36
KIUC MS Diesel	217,175,895	383,504	barrels	$ 23,294,802	$ 0.1073	191,197	1.76
KIUC Hydro	1,764,782						-
KIUC Subtotal	432,899,604	739,726	barrels	$ 40,895,309	$ 0.0945	336,655	1.56
Owner and Type of Unit(s)	**Net Generation (kWh)**	**Amount of Fuel**	**Units**	**Total Paid for Electricity by KIUC**	**Cost of Purchased Power per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
Kauai Coffee Hydro	**30,599,871**						
Gay & Robinson Sugar (Bagasse and Hydro	2,980,360						
Agricultural Development Corporation	2,138,665						
IPP Subtotal	35,718,896			$ 3,884,078	$ 0.1087		
KIUC and IPP Combined	**468,618,500**	**739,726**	**barrels**	**$ 44,779,387**	**$ 0.0956**	**336,655**	**1.44**

Sources: KIUC Annual Report, DBEDT Energy Database

A11. Electricity Generation for Utility Sale on Maui, 2005 (DBEDT Energy Data, 2005). (Chapter 4)

Electricity Generation for Utility Sale on Island of Maui				
Location	**Unit**	**Type**	**Fuel**	**Capacity (MW)**
MECO-Owned				
Kahului	Kahului 1	OFS	No. 6 MSFO	4.7
	Kahului 2	OFS	No. 6 MSFO	4.8
	Kahului 3	OFS	No. 6 MSFO	11.0
	Kahului 4	OFS	No. 6 MSFO	11.9
			Kahului Subtotal	**32.4**
Maalaea	Maalaea 1	IC Diesel	No. 2 Diesel	2.5
	Maalaea 2	IC Diesel	No. 2 Diesel	2.5
	Maalaea 3	IC Diesel	No. 2 Diesel	2.5
	Maalaea X1	IC Diesel	No. 2 Diesel	2.5
	Maalaea X2	IC Diesel	No. 2 Diesel	2.5
	Maalaea 4	IC Diesel	No. 2 Diesel	5.5
	Maalaea 5	IC Diesel	No. 2 Diesel	5.5
	Maalaea 6	IC Diesel	No. 2 Diesel	5.5
	Maalaea 7	IC Diesel	No. 2 Diesel	5.5
	Maalaea 8	IC Diesel	No. 2 Diesel	5.5
	Maalaea 9	IC Diesel	No. 2 Diesel	5.5
	Maalaea 10	IC Diesel	No. 2 Diesel	12.3
	Maalaea 11	IC Diesel	No. 2 Diesel	12.3
	Maalaea 12	IC Diesel	No. 2 Diesel	12.3
	Maalaea 13	IC Diesel	No. 2 Diesel	12.3
	Maalaea 14, 15, 16	DTCC	No. 2 Diesel	58.6
	Maalaea 17	CT	No. 2 Diesel	20.8
	Maalaea 19	CT	No. 2 Diesel	20.8
			Maalaea Subtotal	**194.9**
Hana	L7	IC Diesel	No. 2 Diesel	**1.0**
	L8	IC Diesel	No. 2 Diesel	**1.0**
			Hana Subtotal	**2.0**
			MECO SUBTOTAL	**229.3**
Independent Power Producer				
Puunene	Hawaiian Commercial & Sugar Company	Steam (44 MW)* Hydro (5.9 MW)*	Bagasse No. 6 MSFO Coal No. 2 Diesel	12
		49.9 MW*	**Puunene Subtotal**	**12**
			Maui Total	**239**

CT - Combustion Turbine
DTCC - Dual Train Combined Cycle
IC - Internal Combustion
MSFO - Medium Sulfur (<2.5%) Fuel Oil
OFS - Oil Fired Steam
* HC&S is under contract to provide 12 MW to MECO, remaining capacity used by HC&S

A12. Electricity Generation for Utility Sale on Lānaʻi, 2005 (DBEDT Energy Data, 2005). (Chapter 4)

Electricity Generation for Utility Sale on Island of Lanai				
Location	**Unit**	**Type**	**Fuel**	**Capacity (MW)**
MECO-Owned				
Miki Basin	LL1	IC Diesel	No. 2 Diesel	1.0
	LL2	IC Diesel	No. 2 Diesel	1.0
	LL3	IC Diesel	No. 2 Diesel	1.0
	LL4	IC Diesel	No. 2 Diesel	1.0
	LL5	IC Diesel	No. 2 Diesel	1.0
	LL6	IC Diesel	No. 2 Diesel	1.0
	LL7	IC Diesel	No. 2 Diesel	2.2
	LL8	IC Diesel	No. 2 Diesel	2.2
			Miki Basin/Lanai Subtotal	10.4
IC - Internal Combustion				

A13. Electricity Generation for Utility Sale on Molokaʻi, 2005 (DBEDT Energy Data, 2005). (Chapter 4)

Electricity Generation for Utility Sale on Island of Molokai				
Location	**Unit**	**Type**	**Fuel**	**Capacity (MW)**
MECO-Owned				
Palaau	Caterpillar 1	IC Diesel	No. 2 Diesel	1.25
	Caterpillar 2	IC Diesel	No. 2 Diesel	1.25
	Gas Turbine	CT	No. 2 Diesel	2.50
	Cummins 3	IC Diesel	No. 2 Diesel	0.90
	Cummins 4	IC Diesel	No. 2 Diesel	0.90
	Cummins 5	IC Diesel	No. 2 Diesel	0.90
	Cummins 6	CT	No. 2 Diesel	0.90
	Caterpillar 7	IC Diesel	No. 2 Diesel	2.20
	Caterpillar 8	IC Diesel	No. 2 Diesel	2.20
	Caterpillar 9	IC Diesel	No. 2 Diesel	2.20
			Palaau / Molokai Total	15.20
CT - Combustion Turbine			IC - Internal Combustion	

A14. Electricity Generation for MECO Customers (MECO FERC 1 and DBEDT Energy Data, 2003). (Chapter 4)

Electricity Generation for Sale to MECO Customers - kWh, Fuel Use and Cost, and Greenhouse Gas Emissions							
Owner and Type of Unit(s)	**Net Generation (kWh)**	**Amount of Fuel**	**Units**	**Total Cost of Fuel**	**Cost of Fuel Only per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
MECO MSFO Steam	227,322,220	524,617	barrels	$ 16,906,118	$ 0.0744	286,215	2.52
MECO MS Diesel	1,008,263,439	1,632,642	barrels	$ 93,156,918	$ 0.0924	857,917	1.70
MECO Subtotal	1,235,585,659	2,157,259	barrels	$ 110,063,036	$ 0.0891	1,144,132	1.85
Owner and Type of Unit(s)	**Net Generation (kWh)**	**Amount of Fuel**	**Units**	**Total Paid for Electricity by MECO**	**Cost of Purchased Power per kWh**	**Greenhouse Gas Emissions (Tons CO2E)**	**GHG Emissions Lbs. per kWh**
Hawaii Commercial and Sugar							
Bagasse	67,435,371	182,190	tons			-	-
No. 6 Fuel Oil	413,547	1,504	barrels	9,454.99		820	3.97
No. 2 Fuel Oil	568,491	2,246	barrels	$ 13,081		1,049	3.69
Waste Oil (No. 2)	51,286	269	barrels	$ 1,566		126	4.91
Coal	17,365,064	16,577	tons	$ 372,974		39,071	4.50
Hydro	8,664,242				-		-
IPP Subtotal	94,498,000			$ 11,848,956	$ 0.1254	41,066	0.87
MECO and IPP Combined	**1,330,083,659**			**$ 121,911,992**	**$ 0.0917**	**1,185,198**	**1.78**

Sources: MECO FERC Form 1, DBEDT Energy Database

A15. Additional Energy Efficiency Programs for Consideration. (Chapter 5)

1. Rules, Regulations & Policies

The following is a list of rules, regulations, and policies, which are intended to enhance the use of energy efficiency and increase the use of renewable energy at the state level.

a. Construction and Design Policies

Construction and design policies include state construction policies, green building programs, and energy codes. State construction policies are typically legislative mandates requiring an evaluation of the cost and performance benefits of incorporating renewable energy technologies into state construction projects such as schools and office buildings. Many cities are developing "Green Building" guidelines that require or encourage consideration of renewable energy technologies.

Some guidelines are voluntary measures for all building types, while others are requirements for municipal building projects or residential construction. Local energy codes are used to achieve energy efficiency in new construction and renovations by requiring that certain building projects surpass state requirements for resource conservation. Incorporating renewables is one way to meet code requirements.

b. Contractor Licensing

Many states have rules regarding the licensing of renewable energy contractors. Contractor licensing requirements can be enacted for solar water heat, active and passive solar space heat, solar industrial process heat, solar thermal electricity, and photovoltaics. These requirements--where they do exist--are designed to ensure that contractors have the necessary experience and knowledge to properly install systems.

c. Equipment Certifications

Statutes requiring renewable energy equipment to meet certain standards are generally seen as a tool for reducing the chance that consumers will be sold inferior equipment. Beyond being a consumer protecting measure, equipment certification benefits renewables by reducing the number of problem systems and the resulting bad publicity.

d. Generation Disclosure Rules

"Disclosure" typically refers to the requirement that utilities provide their customers with additional information about the energy they are supplying. This information often includes fuel mix percentages and emissions statistics. Fuel mix information, for example, can be presented as a pie chart on customers' monthly bills. "Certification" is a related issue which refers to the assessment of green power offerings to assure that they are indeed utilizing the type and amount of renewable energy as advertised. One example of green power certification is the Green-e stamp.

Both disclosure and certification are designed to help consumers make informed decisions about the energy and supplier they choose. It is worth noting, though, that two states that have not moved ahead with restructure--Florida and Colorado--have enacted disclosure provisions. Indeed, disclosure is often thought of as a good policy to help educate customers about electricity and thereby to prepare markets in advance of retail competition.

e. Green Power Purchasing/Aggregation Policies

Municipalities, state governments, businesses, and other non-residential customers can play a critical role in supporting renewable energy technologies by buying electricity from renewable resources. At the local level, green power purchasing can mandate buying green power for municipal facilities, streetlights, water pumping stations and the like. Several states require that a certain percentage of electricity purchased for state government buildings come from renewable resources. A few states allow local governments to aggregate the electricity loads of the entire community to purchase green power and even to join with other communities to form an even larger green power purchasing block. This is often referred to as "Community Choice." Green power purchasing can be achieved via utility green pricing programs, green power marketers (in states with retail competition), special contracts, or community aggregation.

f. Line Extension Analysis

When an electric customer requests service for a location not currently serviced by the electric grid, they are charged a distance-based fee for the cost of extending power lines to their load. In many cases it is cheaper to have an on-site renewable energy system to meet their electricity needs. Certain states require utilities to provide their customers with information on renewable energy options when a line extension is requested.

g. Net Metering Rules

For those consumers who have their own electricity generating units, net metering allows for the flow of electricity both to and from the customer through a single, bi-directional meter. With net metering, during times when the customer's generation exceeds his or her use, electricity from the customer to the utility offsets electricity consumed at another time. In effect, the customer is using the excess generation to offset electricity that would have been purchased at the retail rate. Under most state rules, residential, commercial, and industrial customers are eligible for net metering, but some states restrict eligibility to particular customer classes.

h. Public Benefit Funds

Public Benefit Funds (PBF) are typically state-level programs developed through the electric utility restructuring process as a measure to assure continued support for renewable energy resources, energy efficiency initiatives, and low-income support programs. These funds are also frequently referred to as a system benefits charge, or SBC. Such a fund is most commonly supported through a charge to all customers on electricity consumption (e.g., 0.2 cents/kWh). Examples of how the funds are used include: (1) rebates on renewable energy systems, (2) funding for renewable energy R&D, and (3) development of renewable energy education programs.

i. Renewables Portfolio Standards/Set Asides

Renewables Portfolio Standards (RPS) require that a certain percentage of a utility's overall or new generating capacity or energy sales must be derived from renewable resources -

i.e., 20 percent of electric sales in Hawaiʻi must be from renewable energy in the year 2020. Portfolio Standards most commonly are based upon electric sales measured in megawatt-hours (MWh) as opposed to electric capacity measured in megawatts (MW). The term "set asides" is frequently used to refer to programs where a utility is required to include a certain amount of renewables capacity in new installations.

j. Required Utility Green Power Option

A handful of states require certain classes of utilities to offer customers the option to purchase power generated from renewable sources. Typically, utilities may provide green power using renewable resources they own or for which they contract or they may purchase credits from a renewable energy provider certified by the state's Public Utilities Commission.

k. Solar and Wind Access Laws

These statutes provide for solar or wind easements or access rights. Easements allow for the rights to existing access to a renewable resource on the part of one property owner to be secured from an owner whose property could be developed in such a way as to restrict that resource. This easement is transferred with the property title. Access rights, conversely, automatically provide for the right to continued access to a renewable resource. Solar easements are the most common type of state solar access rule. Furthermore, some states prohibit neighborhood covenants that preclude the use of renewables.

At the local level, communities use many different mechanisms to protect solar access, including solar access ordinances, development guidelines requiring proper street orientation, zoning ordinances that contain building height restrictions, and solar permits.

2. Financial Incentives

Financial incentives can vary significantly from state to state. It would be useful to evaluate whether there is a relationship between the level of the incentives and the deployment of those incentive measures.

a. Corporate Tax Incentives

Corporate tax incentives allow corporations to receive credits or deductions ranging from 10 percent to 35 percent against the cost of equipment or installation to promote renewable energy equipment. In some cases, the incentive decreases over time. Some states allow the tax credit only if a corporation has invested a certain dollar amount into a given renewable energy project. In most cases, there is no maximum limit imposed on the amount of the deductible or credit.

b. Direct Equipment Sales

A few utilities sell renewable energy equipment to their customers as part of a buy-down, low-income assistance, lease, or remote power program.

c. Grant Programs

States offer a variety of grant programs to encourage the use and development of renewable energy technologies. Most programs offer support for a broad range of renewable energy technologies, while some states focus on promoting one particular type of renewable energy such as wind technology or alternative fuels.

Grants are available primarily to the commercial, industrial, utility, education, and government sectors. Some grant programs focus on research and development, while others are designed to help a project achieve commercialization. Programs vary in the amount offered--from $500 to $1,000,000--with some states not setting a limit.

d. Industrial Recruitment Incentives

This category focuses on special efforts and programs designed to attract renewable energy equipment manufacturers to locate within a state or city. Renewable energy industrial recruitment usually consists of financial incentives like tax credits, grants, or a commitment to purchase a specific amount of the product for use by a government agency.

The recruitment incentives are designed to attract industries that will benefit the environment and create jobs. In most cases, the financial incentives are temporary measures that will help support the industries in their early years but include a sunset provision to encourage the industries to become self-sufficient within a number of years.

e. Leasing/Lease Purchase Programs

Utility leasing programs target remote power customers for which line extension would be very costly. The customers can lease the technology (e.g., photovoltaics) from the utility and in some cases the customer can opt to purchase the system after a specified number of years.

f. Loan Programs

Loan programs offer financing for the purchase of renewable energy equipment. Low-interest or no-interest loans for energy efficiency are a very common strategy for demand-side management by utilities. State governments also offer loans to assist in the purchase of renewable energy equipment. A broad range of renewable energy technologies are eligible. In many states, loans are available to residential, commercial, industrial, transportation, public, and nonprofit sectors. Repayment schedules vary and while most are determined on an individual project basis, some offer a 7-10 year loan term.

g. Personal Income Tax Incentives

Many states offer personal income tax credits or deductions to cover the expense of purchasing and installing renewable energy equipment. Some states offer personal income tax credits up to a certain percentage or predetermined dollar amount for the cost or installation of renewable energy equipment. Allowable credit may be limited to a certain number of years following the purchase or installation of renewable energy equipment. Eligible technologies may include solar and photovoltaic energy systems, geothermal energy, wind energy, biomass, hydroelectric, and alternative fuel technologies.

h. Production Incentives

Production incentives provide project owners with cash payments based on electricity production on a $/kWh basis as is the case with the Federal Renewable Energy Production Incentive, or based on the volume of renewable fuels produced on a $/gallon basis as is the case with a number of state ethanol production incentives. Payments based on performance rather than capital investments can often be a more effective mechanism for ensuring quality projects.

i. Property Tax Incentives

Property tax incentives typically follow one of three basic structures: exemptions, exclusions, and credits. The majority of the property tax provisions for renewable energy follow a simple model that provides that the added value of the renewable device is not included in the valuation of the property for taxation purposes. That is if a renewable energy heating system costs $1,500 to install versus $1000 for a conventional heating system then the renewable energy system is assessed at $1000.

j. Rebate Programs

Rebate programs are offered at the state, local, and utility levels to promote the installation of renewable energy equipment. The majority of the programs is available from state agencies and municipally-owned utilities and support solar water heating and/or photovoltaic systems. Eligible sectors usually include residents and businesses, although some programs are available to industry, institutions, and government agencies as well. Rebates typically range from $150 to $4000. In some cases, rebate programs are combined with low or no-interest loans.

k. Sales Tax Incentives

Sales tax incentives typically provide an exemption from the state sales tax for the cost of renewable energy equipment.

A16. Summary of High and Medium Emerging Technologies (Nadel et al., 1998). (Chapter 5)

Summary of High and Medium Priority Emerging Technologies					
		2015 Potential		Cost of Conserved Energy	
Measure	**Category**	**GWH**	**TBtu**	**/kWh**	**/MMBtu**
High Priority					
High-Efficiency Vertical-Axis Clothes Washers	Appliance	40,100	590	Negative	N/A
Aerosol-Based Duct Sealing	HVAC	45,600	1,090	$0.02	$2.00
Commissioning Existing Commercial Buildings	HVAC	45,900	610	$0.03	N/A
Dual Source Heat Pumps	HVAC	64,600	650	$0.02	N/A
Improved Ducts and Fittings	HVAC	43,400	430	$0.00	$0.00
Improved Heat Exchangers	HVAC	52,200	520	$0.01	N/A
Integrated Lighting Fixtures and Controls	Lighting	49,600	500	$0.02	N/A
Reduced-Cost and/or Higher Efficiency CFLs	Lighting	122,500	1,230	$0.00	N/A
Metal Halide Replacements for Incandescents	Lighting	84,100	840	$0.00	N/A
Integrated New Home Design	Practice	123,800	1,240	$0.03	$2.80
Integrated Commercial Building Design	Practice	169,800	1,700	$0.03	$3.00
Integrated Gas- and Oil-Fired Space/Water Heating Systems	DHW	N/A	710	N/A	$2.30
Medium Priority					
"Low leak" Home Electronics	Appliance	27,400	280	$0.02	N/A
One kwh/day Refrigerator/Freezers	Appliance	15,600	160	$0.05	N/A
High-Efficiency Dishwashers	Appliance	5,000	140	Negative	Negative
Improved Efficiency Air Conditioning Compressors	Appliance	24,300	240	$0.06	N/A
Improved Efficiency Refrigeration Compressors	Appliance	15,600	160	$0.02	N/A
Advanced Clothes Washer and Dishwasher Controls	Appliance	9,600	230	$0.06	$4.40
Switched Reluctance Drives	Drive	9,900	100	$0.05	N/A
Commercial Distribution System Air Sealing	HVAC	32,500	330	$0.02	$1.70
Indirect-Direct Evaporative Coolers	HVAC	14,100	140	$0.05	N/A
Evaporative Condenser Air Conditioning	HVAC	20,000	200	$0.04	N/A
Advanced Metering/Billing Systems	Information	12,700	130	$0.00	N/A
Improved Fluorescent Dimming Ballasts	Lighting	46,500	470	$0.04	N/A
One-Lamp Fixtures and Task Lighting	Lighting	28,700	290	$0.03	N/A
Compact Fluorescent Floor and Table Lamps	Lighting	25,800	260	$0.01	N/A
Fuel Cells	Power	63,500	360	$0.05	N/A
Microturbines	Power	63,500	200	$0.04	N/A
Dry-Type Distribution Transformers	Power	10,900	110	$0.03	N/A
Heat Reflecting Roof Coatings	Shell	16,600	170	$0.04	N/A
High R (>4) Windows	Shell	N/A	140	N/A	$4.00
Integrated Electric Space Conditioning/Water Heating Systems	DHW	12,500	130	$0.02	N/A
Residential Heat Pump Water Heaters	DHW	31,400	320	$0.04	N/A

Lower Priority					
Laundry Microfiltration Wastewater Recovery	Laundry	N/A	10	N/A	Negative
Ozonated Commercial Laundering	Laundry	N/A	10	N/A	Negative
Copper Rotor Motors	Drive	4,500	50	$0.00	N/A
Electronically Commutated Permanent Magnet Motors	Drive	2,600	30	$0.04	N/A
Premium Lubricants	Drive	7,100	70	Negative	N/A
Written Pole Motors	Drive	800	10	$0.08	N/A
Motor Systems Performance Optimization	Drive	32,800	330	Negative	N/A
Residential Absorption Heat Pumps	HVAC	N/A	220	N/A	$3.10
Ductless Thermal Distribution Systems	HVAC	16,700	170	$0.04	$4.20
High-Efficiency Commercial Packaged Acs	HVAC	6,800	70	$0.04	N/A
Condensing Commercial Boilers and Furnaces	HVAC	N/A	80	N/A	$4.40
Cool Storage Roof	HVAC	9,100	90	$0.05	N/A
Engine Driven Vapor Compression Heat Pumps	HVAC	56,100	-30	$0.07	N/A
Geothermal Heat Pumps	HVAC	12,600	130	$0.06	N/A
Transpired Solar Collectors for Preheating Ventilation Air	HVAC	1,600	70	N/A	$2.00
Smart Residential HVAC Controls	HVAC	5,700	60	$0.04	N/A
Integrated Chillers with Heat Recovery	HVAC	3,600	80	$0.05	$4.90
Modulating Gas Furnaces	HVAC	N/A	210	N/A	$4.40
Indirect Lighting	Lighting	8,600	90	$0.03	N/A
Electrodeless Lamps, Power Supplies and Luminaires	Lighting	7,100	70	$0.04	N/A
Sulphur Lighting	Lighting	12,600	130	$0.04	N/A
General Service Halogen Infrared Reflecting Lamps	Lighting	13,300	130	$0.03	N/A
Improved Daylighting Controls	Lighting	7,400	70	$0.03	N/A
Daylighting Devices	Lighting	30,700	310	$0.05	N/A
Advanced Lighting Distribution Systems	Lighting	14,900	150	$0.04	N/A
Plastic Downlight Luminaires	Lighting	5,100	50	$0.00	N/A
LED Lighting	Lighting	48,800	490	$0.08	N/A
Energy Star Multifunction Devices	Office Eq	1,600	20	$0.00	N/A
High-Efficiency Packaged Refrigeration Equipment	Refrig.	8,000	80	$0.01	N/A
Electrochromic Glazing	Shell	7,400	70	$0.06	N/A
Low-e Spectrally Selective Retrofit Window Films	Shell	22,400	220	$0.07	N/A
GFX Drain Water Heat Recovery Device	DHW	3,500	90	$0.03	N/A
Very Low-Flow Showerheads	DHW	8,900	190	$0.00	$0.00
Thermosiphon/Free Siphon Solar Water Heaters	DHW	28,600	290	$0.07	N/A
Commercial Heat Pump Water Heaters	DHW	4,100	40	$0.03	N/A

DHW = domestic hot water; HVAC = heating, ventilation, and air-conditioning

A17. Electricity Generated by Renewable Energy Resources in Hawai'i, 2004 (HECO, 2005a and KIUC, 2005). (Chapter 6)

Electricity Generated by Renewable Energy Resources				
Utility and Renewable Energy System	Energy Source	Electricity Generated for Utility Use (MWh)	Percent of Each Utility's Sales	Percent of Statewide Sales
HECO				
H-POWER	Municipal Solid Waste	326,000	4.216%	3.102%
AES Coal Plant*	Used Tires, Waste Oil	43,000	0.556%	0.409%
Photovoltaic Systems	Sun	400	0.005%	0.004%
Solar Water Heating	Sun	47,000	0.608%	0.447%
	HECO Subtotal	**416,400**	**5.385%**	**3.962%**
HELCO				
Puna Geothermal	Geothermal	211,000	19.486%	2.008%
Wailuku Hydro	Hydroelectricity	26,000	2.401%	0.247%
Other Small Hydro	Hydroelectricity	1,000	0.092%	0.010%
HELCO-Owned Hydro Wailuku	Hydroelectricity	10,000	0.924%	0.095%
HELCO-Owned Hydro Puueo	Hydroelectricity	included above		
Kamaoa Wind Farm and other small wind	Wind	6,000	0.554%	0.057%
HELCO-Owned Wind Lalamilo	Wind	1,000	0.092%	0.010%
Photovoltaic Systems	Sun	1,500	0.139%	0.014%
Solar Water Heating	Sun	9,000	0.831%	0.086%
	HELCO Subtotal	**265,500**	**24.520%**	**2.526%**
MECO				
Hawaii Commercial and Sugar**	Bagasse and Hydroelectricity	74,000	5.931%	0.704%
Photovoltaic Systems	Sun	200	0.016%	0.002%
Solar Water Heating	Sun	19,000	1.523%	0.181%
	MECO Subtotal	**93,200**	**7.470%**	**0.887%**
	HECO Utilities Combined Su	**775,100**	**7.702%**	**7.375%**
KIUC				
Gay & Robinson Sugar	Bagasse and Hydroelectricity	2844	0.636%	0.027%
KIUC Hydro	Hydroelectricity	1684	0.377%	0.016%
Kauai Coffee Hydro	Hydroelectricity	29199	6.533%	0.278%
Agriculture Developmnt Corp Hyd	Hydroelectricity	2070	0.463%	0.020%
KIUC Steam unit	Waste Oil	257	0.058%	0.002%
Photovoltaic	Sun	90	0.020%	0.001%
Solar Water Heating	Sun	7558	1.691%	0.072%
	KIUC Subtotal	**43702**	**9.778%**	**0.416%**
	State of Hawaii Total	**818,802**		**7.791%**

* Principal fuel is coal ** Principal boiler fuel is bagasse, but HC&S supplements bagasse with oil and coal.

A18. Renewable Energy Generation Capacity in Hawai'i, 2005 (DBEDT Energy Data, 2005). (Chapter 6)

Renewable Energy Generation Capacity in Hawaii 2005			
Ownership	**Unit**	**RE Source**	**MW**
HECO IPP	***H-POWER***	***MSW***	***46.0***
	AES Hawaii Coal Plant	Tires, WO	N/A*
	Various Photovoltaic		0.089
		HECO Subtotal	46.1
HELCO-Owned	Lalamilo Wells	Wind	2.3
	Puueo 1	Hydro	1.5
	Puueo 2	Hydro	0.8
HELCO IPP	***Puna Geothermal***	***Geothermal***	***30.0***
	Apollo Energy	Wind	9.3
	Wailuku River Hydro	Hydro	12.0
	Small Hydro	Hydro	3.3
	Small Wind	Wind	0.4
	Various Photovoltaic	Solar	0.981
		HELCO Subtotal	60.5
KIUC-Owned	KIUC Hydro	Hydro	1.3
	KIUC Steam Plant	WO	N/A*
KIUC IPP	Kauai Coffee	Hydro	3.8
	Gay & Robinson Sugar**	Bagasse	4.0
		Hydro	1.2
	Ag Development Corp	Hydro	1.5
	Various Photovoltaic	Solar	0.025
		KIUC Subtotal	11.8
MECO IPP	***Hawaiian Commercial & Sugar Company****	***Steam (44 MW)*** Hydro (5.9 MW)	*12.0*
	Various Photovoltaic	Solar	0.052
		MECO Subtotal	12.1
		State Total	130.48

* Capacity not included as renewable for fossil units that burn tires or waste oil as a supplemental fuel

** Gay & Robinson sells small amounts of electricity on an as available basis

*** HC&S provides 12 MW of firm power using bagasse, supplemented by coal, MSFO, and diesel in its steam unit and from its hydro units. Typically 80% of the electricity generated by HC&S is from bagasse or hydro.

Firm power resources are in bold italics.

A19. A Summary of Major Solar Photovoltaic Projects in Hawai'i, 2005 (DBEDT Energy Data, 2005). (Chapter 6)

A Summary of Major Solar Photovoltaic Projects in Hawaii			
Island/Project	**Capacity (kW)**	**Island/Project**	**Capacity (kW)**
Oahu		**Island of Hawaii**	
JN Automotive Wholesale Motors	50	NELHA Gateway Center	40.0
Ford Island Navy Boat House	2	Mauni Lani Resort	674.0
Hickam Air Force Base	18	Parker Ranch Wind/Solar Hybrid	
Sunpower for Schools		Wind	50.0
Campbell High	2	Solar	175.0
Castle High	2	Hapuna Prince Hotel	20.0
Kaimuki High	2	Kailua-Kona Gymnasium	15.0
Kalihi High	2	HELCO Kona Engineering Office	5.4
Kalanianaole Elem and Intermed	1	Sunpower for Schools	
McKinley	2	Hilo High	1.0
Mililani High	2	Kealakehe High	1.0
Waialua High	2	Current Solar Total	981.4
Waianae High	2	**Island/Project**	**Capacity (kW)**
Waipahu High	2	**Maui, Molokai, and Lanai**	
Current Solar Total	89.0	JN Motors Harley-Davidson Group	30.0
3000 Planned New Army Housing	7,000.0	Island Dodge (Planned)	32.4
Island/Project	**Capacity (kW)**	National Marine Sanctuary	2.8
Kauai		PVUSA	20.0
King Auto Center	25.0	Sunpower for Schools	
		Baldwin High	1.0
		Molokai High	1
Current Solar Total	25.0	Current Solar Total	87.2
		STATEWIDE CURRENT SOLAR TOTAL	**1,182.60**

A20. Federal Programs Supporting Renewable Energy. (The following is based upon a Summary of Provisions of the Energy Bill by the Congressional Quarterly). (Chapter 6)

1. Federal Policies on Renewable Energy

Energy Policy Act of 2005 (NEP) or EPACT 2005, signed by the President in August 2005, has many critics of the fact that it continues to subsidize the oil and coal industries and that renewable energy and energy efficiency did not get greater prominence. EPACT 2005 does contain many provisions to encourage the use of renewable energy, which can help Hawai'i reduce its use of fossil fuels. USDOE is directed to annually review and report on renewable energy sources in the United States to provide an analytical base. Let's now move on to specific provisions.

2. Geothermal Leases

To improve the competitiveness of geothermal energy with fossil fuels for generating electricity, the Interior Department is required to hold a competitive lease sale every two years for areas that may produce geothermal energy. If there are no bids for a specific area, the Department may hold a non-competitive lease sale. Since the Agriculture Department must also approve geothermal leases, the law requires the two Departments to speed the process and reduce the backlog by developing coordinated procedures for processing lease applications.

3. Hydroelectric Licensing and Incentive Payments

EPACT 2005 streamlines hydroelectric licensing and provides for appeals to be heard by the Federal Energy Regulatory Commission. Incentives of up to $750,000 are available to hydroelectric facilities that begin operation within 10 years of enactment of the legislation. Existing hydroelectric facilities that improve their efficiency by at least 3 percent can also receive payments of $750,000 or 10 percent of the cost of the upgrade.

4. Ethanol Production

Ethanol is mostly viewed as a transportation fuel or transportation fuel additive, but it could be used for fuel in electric generators. To help reduce fossil-fuel consumption, EPACT 2005 triples the specified amount of renewable fuel that must be in gasoline sold in the United States to 7.5 billion gallons by 2012.

5. Other Biofuel Provisions

EPACT 2005 authorizes $110 million in each of fiscal years 2005 through 2009 for demonstration projects to produce biodiesel fuel from biomass ethanol. It authorizes grants totaling $100 million in FY 2006, $250 million in FY 2007 and $400 million in FY 2008 to assist in constructing facilities to make ethanol or other renewable fuels. In addition, loan guarantees for projects that could produce ethanol using sugarcane or sugarcane by-products are provided. Theses provisions have clear application to Hawai‘i.

6. Encouraging Federal Consumption of Renewable Energy

Beginning in 2006, the federal government must purchase at least 3 percent of its electricity from renewable sources starting in FY 2007. The requirement increases incrementally to 7.5 percent in FY 2013. Qualifying sources of renewable energy include solar, wind, biomass, landfill gas, geothermal, and municipal solid waste. New hydroelectric capacity achieved from increased efficiency or additions of new capacity at an existing hydroelectric project also qualify. In evaluating compliance with the mandate, renewable energy used by a federal facility will count double if the renewable energy is produced at a federal facility, on federal land, or on American Indian land.

7. Production Tax Credit for Wind Energy & Biomass Electricity

A tax credit is provided for the production of electricity from wind, "closed-loop" biomass produced from plants grown specifically to produce electricity, poultry-waste, "open-loop" biomass (including agricultural livestock waste nutrients), geothermal energy, solar energy, small irrigation power, landfill gas, and MSW.

For 2005, the tax credit is 0.9 cents per kWh for open-loop biomass, small irrigation power facilities, landfill gas facilities and MSW facilities, and 1.9 cents per kWh for all other qualified renewable electricity. The credit is available for a 10-year period for facilities placed in service by the end of 2007. The amount of the credit is to be reduced as the market price of electricity exceeds certain levels. The credit is available for five years for the remaining facilities.

8. Clean Renewable Energy Bonds

The measure authorizes the issuance of $800 million of Clean Renewable Energy Bonds, through 2007, to support renewable investment by municipal power authorities, rural cooperatives and others. We would expect this provision to apply to KIUC.

9. Renewable Energy Research and Development

EPACT authorizes $632 million in FY 2007, $743 million in FY 2008, and $852 million in FY 2009 for R&D in the areas of solar power, renewable energy in public buildings, and bioenergy.

10. Bioenergy Programs

$200 million in each of fiscal years 2006 through 2015 is provided to encourage "abundant commercial production of biobased fuels at prices competitive with fossil fuels." The initiative seeks to produce 1 billion gallons of biofuels by 2015, and to produce biofuels at a competitive cost after 2015. USDOE can give grants to small businesses for biofuel marketing and requires the Agriculture Department to conduct public education and outreach about biofuels.

A21. Other States' Renewable Energy Policies. (Chapter 6)

1. Public Benefit Funds

Public Benefit Funds (PBF) (also known as public benefit charges and systems benefit charges) are typically state-level programs developed as a measure to assure continued support for renewable energy resources, energy efficiency initiatives, and low-income support programs after competition has been introduced into state systems. The funds are usually created by charging all customers a fee based on their electricity consumption (e.g., x cents/kWh). Typically uses include rebates on renewable energy systems, funding for renewable energy R&D and development of renewable energy education programs.

2. Renewable Energy Equipment Subsidies and Direct Equipment Sales

Some utilities in some jurisdictions subsidize the purchase of renewable energy equipment. An example is in California where photovoltaic systems are subsidized in the Los Angeles area to encourage creation of a PV production industry. Some utilities sell renewable energy equipment to customers and buy down the cost. They also provide leasing arrangements and assist low income purchasers to buy renewable equipment. In some cases, such as an Idaho, utilities provide a remote power program to customers off the grid.

3. Green Power Purchasing Policies

Municipalities, federal agencies, state governments, businesses, and other customers can support renewable energy technologies by buying electricity from renewable resources. A few states allow local governments to aggregate the electricity loads of the entire community to purchase green power and even to join with other communities to form an even larger green power purchasing block. This is often referred to as "Community Choice." Green power purchasing can be achieved via utility green pricing programs, green power marketers in states with retail competition, special contracts, or community aggregation. HECO's Sunpower for Schools program is based on customer donations which are used to purchase photovoltaic systems. However, it is not a green power program since electricity is not purchased for the customer.

A few states require certain classes of utilities to offer customers the option to purchase power generated from renewable sources. Under these programs, utilities provide green power using their own renewable resources, those for which they contract, or they may purchase credits from a renewable energy provider certified by the state's Public Utilities Commission.

4. Green Tags and Renewable Energy Certificates

Under a green tag or renewable energy certificate (REC) system, credits are created when a renewable energy facility produces electricity. These credits are traded, like stocks, through brokers. Buyers of the credits are in effect supporting the production of renewable energy often without directly using the energy produced. Much of the money used to purchase credits goes to the renewable energy producers to help offset higher costs. The price paid for green tags is intended to represent the difference between renewable energy cost and commodity energy price, allowing renewables to be priced competitively in the energy market.