TABLE 3-12. Projections for Energy Demand in BTUs by Economic Sectors, Controlled Growth Scenario, County of Kauai, 1978 - 2000

[10^9 BTU]

	1978	1980	1985	1990	1995	2000
Non-Electrical Energy						
Transportation						
Highway (1)	2050.0	1867.7	1779.2	1892.6	2018.1	2347.4
Aviation (2)	88.7	98.0	125.9	161.6	207.5	266.5
Total	2138.7	1965.7	1905.1	2054.2	2226.3	2613.9
Industrial (3)	4592.5	4685.3	4925.5	5178.0	5581.3	6016.6
Commercial (4)	115.9	121.9	138.0	156.0	172.0	191.3
Residential (5)	115.9	119.5	128.0	138.8	147.2	154.8
Total	6963.0	6892.4	7097.3	7527.0	8126.8	8976.0
Percent of total Energy Demand	(65.6)	(63.6)	(59.6)	(56.3)	(53.3)	(50.9)
Electrical Energy						
Electrical Generation (6)	3648.4	3946.1	4801.1	5841.2	7106.7	8646.4
(10^6 kWh)	(306.3)	(331.3)	(403.1)	(490.4)	(596.6)	(725.9)
Total Energy Demand	10,611.4	10,838.5	11,898.4	13,368.2	15,233.5	17,622.4
Percent of Changes from 1978		(2.1)	(12.1)	(26.0)	(43.6)	(66.1)

(1) See Table 3-11
(2) 5 percent per annum throughout to 2000
(3) 1 percent per annum until 1990 and 1.5 percent thereafter
(4) 2.5 percent per annum until 1998 and 2 percent thereafter
(5) 1.5 percent per annum until 1990 and 1 percent thereafter
(6) 4 percent per annum throughout to 2000

Population

It is conceivable that population may remain unchanged or increase at a very low rate of less than 1.0 percent per annum. The low population growth experience is certainly not new to this community. As was pointed out earlier, this community experienced a steady decline in population for more than two decades beginning in 1940, and has experienced slow growth only in recent years. A population growth assumption also takes into account fewer tourist arrivals than experienced in the past and slow in-migration or perhaps even net out-migration. In this scenario, it is assumed that the de facto population will grow at about 2.5 percent per annum. The implication is that the corresponding energy requirements are also smaller.

Real Per Capita Income

When low population growth is coupled with low real income due to economic slowdown and/or high inflation, these factors would likely further slow the growth of energy demand. Any rate of less than 1 percent per year increase in real personal income would likely lead to lower subsequent demands in housing; less use of energy-using goods such as refrigerators, color television, and other household appliances; and fewer low gasoline mileage automobiles. A large reduction in energy use also would come from a reduction of tourist activities on the island. All of these contribute to a lower level of energy demand.

Real Price of Petroleum and Conservation

Petroleum prices that rise at a rate of greater than 5 percent per annum in constant dollars would likely bring about quick response in the area of conservation efforts from the transportation sector, and more than likely from the industrial and other non-transportation sectors on a long-term basis. For example, Table 3-10 assumes that the fleet fuel economy would improve 28.5 percent by 1990 and as much as 39.3 percent by 2000 under rapidly rising petroleum prices assumed here. Other energy using sectors may not be able to realize such drastic improvements in conservation as the transportation sector. It is assumed, however, that on the average 10 percent or greater savings may be realized by conservation efforts in other sectors and this certainly would contribute to a lower level of overall energy demand. This assumption is incorporated in determining the growth ratio for each sector's energy demand as shown in Tables 3-11 and 3-12.

Changes in Economic Structure

Under the controlled growth scenario, we assume that no new industries are introduced to the island's economy. We further assume that although changes in the economic structure may take place (e.g., declining sugar production offset by increasing tourism), overall economic expansion does not occur. It would be a status quo situation which may in fact result in a declining real per capita income.

When all of the above described conditions occur, we may expect that the level of primary energy demand would grow only 12.1 percent by 1985 and 26.0 percent by 1990 as shown in Tables 3-11 and 3-12. We wish to re-emphasize, however, that the projected low growth demand may very well be the result of technological breakthrough in many of the energy using activities, as well as of consumer education and the resulting reduction in consumption. Further, the low energy demand scenario reveals a real challenge to be faced: to make the best effort as rapidly as possible to conserve energy in areas which can be improved upon. In other areas, where improvements in conservation will be slow in coming, any reduction in energy supply will necessarily mean a corresponding reduction in activities and ultimately a corresponding reduction in economic well-being.

As in the case for the Business as Usual Scenario, the Controlled Growth Scenario also indicates steadily decreasing use of non-electrical energy and increasing use of electrical energy. The share will shift from 65.6 percent for non-electrical energy in 1978 to 56.3 percent in 1990 and 50.9 percent by the year 2000.

D. Stimulated Growth Scenario

The assumption for the Stimulated Growth Scenario are presented in Tables 3-13 through 3-16. The stimulated growth scenario attempts to project energy needs for the County under the condition in which a vigorous economic growth takes place over the next decade or so. Accelerated growth can come about as a result of carefully planned development activities or of purely external factors. In either case, the energy demands are quite high relative to the other two scenarios.

Population

It was already noted that the tourist population makes up approximately 18 percent of the total resident population (as of 1978), and the trend is continuously rising. From 1970 to 1978, the de facto population rose at an average annual rate of 3.2 percent compared to 1.9 percent for the resident population. The state of Hawaii's official projection for Kauai's resident population gives an average annual rate of 2.1 percent for 1975 to 1985, 2.5 percent for 1985 to 1995, and 1.5 percent for 1995 to 2000 (see Table 3-3). The overall average annual forecasted growth rate is 2.6 percent. This growth rate does not take into account the continuously growing tourist population, however, which is expected to have a significant influence on overall energy

TABLE 3-13

Transportation: Assumptions for Stimulated Growth Scenario

Base Year - 1978	Baseline Assumptions
. Number of autos registered: (1) 27,716 . Average miles driven per automobile: 7,862 . Fleet fuel economy: 14.0 mpg . Auto sales mix: Passenger Cars: 79.5 4-seater : 33.4 6-seater : 46.1 Trucks & Other: 20.1 . Auto Registrations 1965 to 78: Annual Average: 7.0% Compound Growth: 6.7% New Car Sales	. The number of automobiles on the highways increases slightly faster than the de facto population growth rate of 4.0%. . Annual miles driven per vehicle per year remains constant at 1978 level. . Auto sales mix is such that fleet mpg improves to 17.0 by 1990 and 1990 and 19.0 by 2000.

(1) Includes all types of vehicles.
Source [3-1]

TABLE 3-14. Estimated Number of Vehicles, Travel Miles, and Consumption of Gasoline Assumed for Stimulated Growth Scenario, County of Kauai, 1978 - 2000

Year	Number of Autos (1)	Annual Miles Driven per auto	Total Vehicle Miles (10^6)	Miles Per Gallon	Total Gas Consumption (10^6 Gal.)	Gallons per Vehicle
1978	27,716	7862	217.9	14.0	15.6	562.9
1980	32,002	7862	251.6	15.0	16.8	524.9
1985	45,732	7862	359.5	16.0	22.5	492.0
1990	65,160	7862	512.3	17.0	30.1	461.9
1995	79,280	7862	623.3	18.0	34.6	436.4
2000	96,450	7862	758.3	19.0	39.9	384.8
Increase 1978 to 1990	135.1%	No Change	135.1%	+21.4%	92.9%	-18.0%
Increase 1978 to 2000	348.0%		348.0%	28.6%	155.8	-31.6%

(1) Based on de facto population growth rate of 4% per annum and per capita automobile rising from 0.681 for 1978 to 0.727 for 1980, 0.854 for 1985, 1.00 for 1990, and remaining constant thereafter.

TABLE 3-15. Projections for Energy Demand in Barrels by Economic Sectors, Stimulated Growth Scenario, County of Kauai, 1978 - 2000

[10^3 BBL]

	1978	1980	1985	1990	1995	2000
Non-Electrical Energy						
Transportation						
Highway (1)	386.8	400.0	535.7	716.7	823.8	950.0
Aviation (2)	16.1	19.5	31.4	50.5	81.4	131.1
Total	402.9	419.5	567.1	767.2	905.2	1081.1
Industrial (3)	1001.2	1041.7	1150.1	1269.8	1401.9	1547.8
Commercial (4)	28.9	31.3	38.0	46.3	53.6	62.2
Residential (5)	28.9	30.2	33.8	37.7	41.1	44.8
Total	1461.9	1522.7	1789.0	2121.0	2401.8	2735.9
Electrical Energy						
Electrical Generation (6) (10^6 kWh)	607.4 (306.3)	688.9 (347.4)	943.9 (476.0)	1293.2 (652.1)	1771.8 (893.5)	2427.5 (1224.2)
Total Energy Demand	2069.3	2211.6	2732.9	3414.2	4173.6	5163.4

(1) See Table 3-14
(2) 10 percent per annum throughout to 2000
(3) 2 percent per annum throughout to 2000
(4) 4 percent per annum until 1990 and 3 percent thereafter
(5) 2.25 percent per annum throughout to 2000
(6) 6.5 percent per annum throughout to 2000

TABLE 3-16. Projections for Energy Demand in BTUs by Economic Sectors, Stimulated Growth Scenario, County of Kauai, 1978 - 2000

[10^9 BTU]

Non Electrical Energy	1978	1980	1985	1990	1995	2000
Transportation						
Highway (1)	2050.0	2120.0	2839.2	3798.5	4366.1	5035.0
Aviation (2)	88.7	108.3	178.6	294.5	485.5	800.5
Total	2138.7	2228.3	3017.8	4093.0	4851.6	5835.5
Industrial (3)	4592.5	4780.0	5282.6	5838.2	6452.2	7130.8
Commercial (4)	115.9	125.5	152.4	185.7	214.9	249.4
Residential (5)	115.9	121.1	135.6	151.2	164.8	179.7
Total	6963.0	7254.9	8588.4	10,268.1	11,683.5	13,395.4
Percent of Total Energy Demand	(65.6)	(63.7)	(60.2)	(56.9)	(52.3)	(47.9)
Electrical Energy						
Electrical Generation (6)	3648.4	4138.1	5669.6	7767.8	10,642.6	14,587.2
(10^6 kWh)	(306.3)	(347.4)	(476.0)	(652.1)	(893.5)	(1224.2)
Total Energy Demand	10,611.4	11,393.0	14,258.0	18,035.9	22,326.1	27,976.6
Percent of Changes from 1978		(7.4)	(34.4)	(70.0)	(110.4)	(163.6)

(1) See Table 3-15
(2) 10 percent per annum throughout for 2000
(3) 2 percent per annum throughout to 2000
(4) 4 percent per annum until 1990 and 3 percent thereafter
(5) 2.25 percent per annum throughout to 2000
(6) 6.5 percent per annum throughout to 2000

demands. Table 3-1 showed that the de facto population assumption for this scenario shows a rise of 4 percent per annum for the decade of the 1980's and 3 percent for the 1990's to the year 2000.

Real Per Capita Income

It has been pointed out that the energy use per person is very closely related to the economic well-being of the population (usually measured by per capita income) up to a certain point. There are considerable difficulties in assessing what the real per capita income might be for the next five years, much less for the next twenty years. Past trends as shown in Table 3-1 show that the per capita income in constant dollars has been rising about 1.3 percent per year. Stimulated growth implies that the per capita income should rise much faster than the past trends more in the 2 to 3 percent range. This may come about as a result of strong growth in tourism and steady expansion in the agriculture sector in the areas of papaya, guava, revival of pineapple, and taro. Continuous expansion in the area of aquaculture, especially prawn production, is a bright spot in the future.

The energy implication for this rapid development scenario, however, is that it will add to the total energy needs. A particularly significant energy requirement would originate from growth related to tourism, as noted before.

Real Price of Oil and Conservation

In the Controlled Growth Scenario we assumed that the price of petroleum will rise 5 percent above the inflation rate throughout the rest of this century. Recognizing the inverse relationship between the real price of oil on the one hand and the consumption of it on the other, we assume that any long-term price increase of less than 2 percent per year would lead to a high level of demand. If in fact such is the case, we anticipate that energy consumption, especially in those economic sectors with a high dependency on imported oil (e.g., transportation) would not likely decrease through rapid conservation measures among users. This would delay the utility from switching from fuel-fixed electrical generation to alternative energy methods such as geothermal resources.

There is a general consensus among energy experts that conservation is the most effective way of reducing energy appetitites, at least in a short-run range. The rapid development of conservation techniques and effective implementation strategies would play important roles in shaping future energy demands. Unfortunately, measureable data are not readily available for Kauai County to determine how effective conservation efforts have been.

(5) 2.25 percent per annum throughout to 2000
(6) 6.5 percent per annum throughout to 2000

For energy demand projection purposes, various assumptions are made as to the degree of conservation measures likely to be effectively introduced over a period of time, including improvements in the transportation sector. In fact, a full chapter is devoted to the subject in this study.

Changes in Economic Structure

Currently, Kauai County's economy hinges primarily on sugar production and processing, tourism activities, and other small-scale agriculture activities, with the service sector supporting these basic economic sectors.

The future health of the sugar industry thus is vital to the economy of the County in general and to the energy picture in particular, as the role of sugar plantations as a supplier and user of energy is quite significant. A stimulated growth situation can come about if the sugar industry remains healthy for the next ten to twenty years. Also, there is a possibility that a drastic change in the economic structure could come about in the next decade with the introduction of an energy-intensive industry such as mineral processing (e.g., manganese nodules or any other electric/chemical-based industry) or ethanol alcohol production by plantations. The introduction of any such plants would require twice the energy used by Kauai County in 1978.

In addition to the energy requirements for direct industrial activities, secondary energy will be necessary to support the additional employees involved as a result of the multiplier effect. Although the actual realization of such a scenario is purely speculative at this time, the possibility may not be initially ruled out, especially for the second decade of the study (1990-2000).

Rapid growth in tourism activities must be included in the Stimulated Growth Scenario. A specific study relating tourism activities to energy requirements is only underway, and data are not yet available; however, a continued increase in tourism on Kauai for the next two decades would obviously mean a significantly different energy requirement [3-6].

Tables 3-13 through 3-16 are the energy use projections for the years 1980 to 2000. Tables 3-15 and 3-16 contain projections for energy demand by sectors. Total electric/chemical-based industries would require primary energy and end-use energy to rise 70.0 percent over the 1978 level by 1990. Table 3-16 shows that non-electrical energy constitutes 65.6 percent of the total energy use in 1978. This share, however, declines to 56.9 percent in 1990 and to 47.9 percent by the year 2000. This trend seems consistent for the three different scenarios considered. This, as we shall see, has very favorable implications for achieving the goal of energy self-sufficiency for the County of Kauai.

IV. SOURCES OF ENERGY

In the face of diminishing supplies of petroleum and increasing costs of energy, the most immediate, and prudent, actions to be taken are to eliminate as much waste as possible, to reduce consumption by avoiding excessive or unnecessary uses of energy, and to improve the efficiencies of energy-using devices. Conservation of fuels from presently available sources will alleviate difficulties until increased supplies of energy from Kauai's own natural resources can be developed.

This section discusses actions that might be taken to promote conservation and encourage the replacement of petroleum-derived energy by energy from alternate sources. It presents descriptions of the various natural energy resources existing in Hawaii, along with brief discussions of how energy conversion systems work and their potential for Kauai County. Economic factors that will influence selection of sources, including costs, are addressed and environmental impact issues are received. Finally, plans are described for research, development and demonstration programs for Kauai.

A. Conservation

The Kauai Energy Self-Sufficiency Committee has made a comprehensive study of energy conservation, with emphasis on ways Kauai County government can promote conservation and encourage the use of alternate sources. The committee report included discussions of cost savings as well as energy savings that could result from conservation measures and guidelines for their implementation. Recommendations of the committee are summarized below.

Three ways to promote energy conservation are: 1) by instituting a County energy management program that will reduce the County's own energy consumption; 2) by influencing, through regulation and incentives, the decisions and actions of the private sector, including individual citizens, businesses, and other groups; and 3) by lobbying for state and federal legislation and policies that will promote energy conservation. A County Energy Office should be established and an energy coordinator appointed to organize and coordinate these activities.

The County energy management program would motivate County employees to conserve energy by turning off unnecessary lights and similar "common sense" actions. More importantly, it would organize and secure funding for audits of all government building and operations to determine how energy is actually being used and how consumption could be reduced without impairing necessary functions and services.

Through regulations and incentives the County can influence private decisions and actions. By means of a public education program people can be made aware of energy problems and their potential social and economic consequences. Household and business energy audits could be encouraged, and ways of reducing energy consumption could be suggested. An effective public education tool is an energy demonstration house, which can be used to demonstrate energy-saving techniques including passive cooling, the use of natural ventilation and lighting, solar water heating, and the like.

Planning and zoning ordinances, building codes, and other regulatory controls should be reviewed to see how each presently affects energy use and how it might reasonably be changed to promote conservation.

Kauai County should encourage and support lobbying at state and federal levels for energy-conserving policies and legislation, for example, energy efficiency requirements for appliances and automobiles, and tax credit for solar water heaters and other applications for renewable energy systems.

Since about 40 percent of the imported petroleum presently used on Kauai is for transportation, this sector offers the opportunity for substantial energy savings, by establishing car pools, van pools, expanding of public transportation systems, and expanding the Bikeway System. Production of alcohol-gasoline blends for automotive fuel and the introduction of electric vehicles could significantly reduce gasoline consumption.

The committee reports on Conservation and Transportation offer many detailed suggestions for changes and additions to existing planning and zoning ordinances and building codes, suggested state and federal laws and policies Kauai County should aggressively support, and guidelines for establishing car pool and van pool networks.

B. Natural Energy Technologies

Natural energy resources available to Kauai include a potential abundance of biomass, wind, direct solar insolation, the ocean, and watersheds for hydroelectric power generation. Potential development of geothermal energy sources is not promising at this time, although further exploration is warranted. All of these energy sources are discussed in the following paragraphs.

Biomass

Biomass energy is energy that can be extracted from plant and animal material. This includes standing vegetation, aquatic crops, forestry and agriculture residues, and animal waste. The values of biomass are twofold: it is a renewable source, and it possesses the potential to produce both solid and liquid fuels (methanol, ethanol).

Bagasse

The burning of bagasse, or sugar processing waste, has proven to be an effective means of generating electricity. The bagasse is fed into a boiler and burned to heat water and produce steam, which turns a turbine to drive a generator and produce electricity. Thus, it directly replaces fuel oil, being burned in the same furnace. A schematic of a bagasse-fired power generating plant is shown in Figure 4-1. The sugar industry uses the electricity to operate its mills, and the excess energy is sold to the local electric utility.

The Kauai sugar companies include: Kekaha Sugar and Lihue Plantation (AMFAC); Olokele Sugar (C. Brewer and Co.); McBryde Sugar (Alexander & Baldwin); and Gay and Robinson (Bishop Trust). Together they produce almost 50 percent of the energy generated on the island. Approximately 299,300 dry tons of bagasse (4832 x 10^9 BTU gross heat), or 95.5 percent of the total bagasse produced, were used in power generation in 1978 [4-2].

Kauai is the second largest bagasse-producing county in the State, trailing the Big Island and followed by Maui and Oahu, respectively. Each sugar mill uses petroleum as a supplement when the quantity of bagasse is low or the moisture content too high. An interesting point is that of the four counties, Kauai sugar mills consume the least boiler fuel [4-2].

Wood Chips

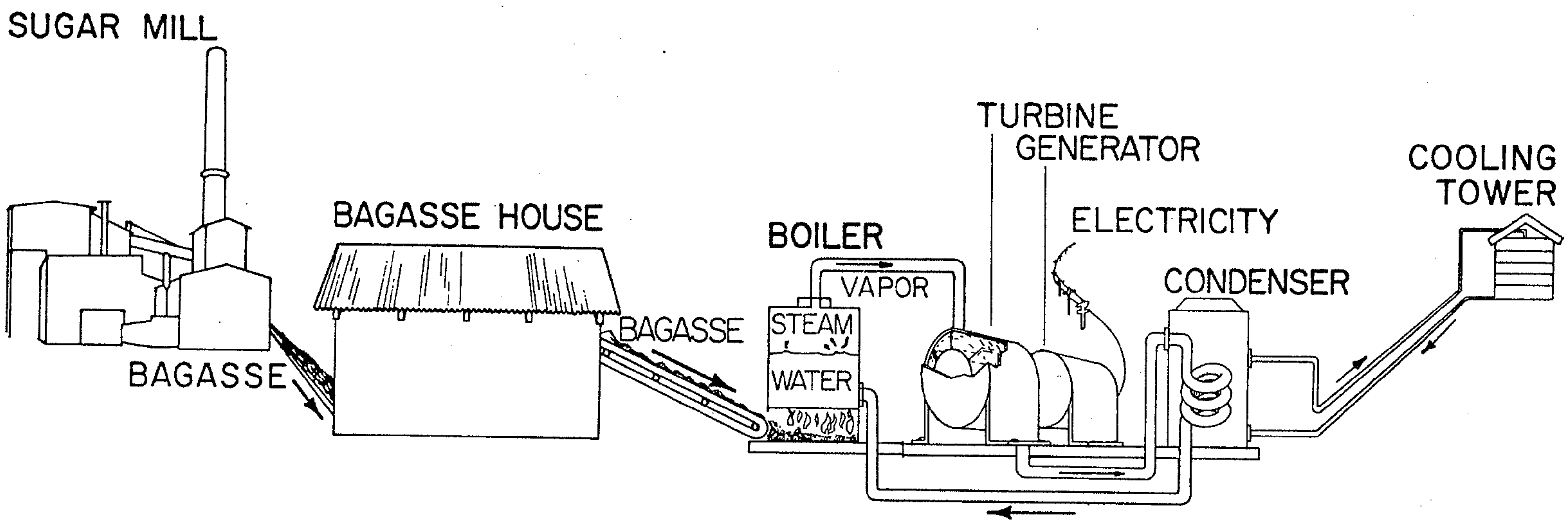
The burning of wood chips to produce electricity, which is similar to bagasse burning, is another alternative. Data on land use, land class, and forest plantation area for Kauai are presented in Tables 4-1 through 4-3; these figures indicate that Kauai has some land available for tree farms. Studies on various tree crops to be used for energy production have been performed, and eucalyptus and giant koa haole are promising candidates.

The State Division of Forestry has a nursery program in operation to produce one million eucalyptus seedlings a year. The target market is sugar mills, which are currently spending millions of dollars a year to buy oil to supplement bagasse burning. By fall 1979, 1000 acres are expected to be planted. Potentially, 2,000 to 2,500 acres of state forest land is to be used. The seedlings will be sold at an anticipated price of 5 cents each [4-5].

Other Crops

Other crops besides sugarcane have energy-producing possibility on Kauai. Studies of the various locally-grown plants have been conducted to see which plants are favorable for biomass conversion. Characteristics such as fiber yield per unit area per unit time, dry weight, growing

BAGASSE FIRED POWER GENERATING PLANT



- SUGAR MILL PRODUCES BAGASSE
- BAGASSE IS BURNED IN BOILER
- FIRE IN BOILER TURNS WATER TO STEAM VAPOR
- STEAM TURNS TURBINE AND TURBINE TURNS GENERATOR
- GENERATOR DEVELOPS ELECTRICITY
- STEAM FROM TURBINE GOES TO CONDENSER
- COLD CONDENSER TURNS STEAM VAPOR BACK TO WATER
- WATER FROM CONDENSER RETURNS TO BOILER
- CYCLE STARTS OVER AGAIN

Figure 4-1. Schematic of Bagasse Fired Power Generating Plant

TABLE 4-1. Land Use on Kauai

Land Use	Number of Acres	
Plantation Agriculture		45,900
Pineapple	--	
Sugarcane	45,900	
Nonplantation Agriculture		55,311
Vegetable	339	
Orchard	455	
Water Crop	305	
Forage	229	
Grazing	53,637	
Dairy	8	
Poultry	5	
Swine	--	
Feed Lot	--	
Salt Bed	--	
Idle Agricultural Land	333	
Forest & Forest Reserve		196,271
Forest	38,716	
Forest Reserve	157,555	
Recreation		11,244
Recreation	9,524	
Game Management	1,720	
National Park	--	
Military		1,886
Urban		4,550
Underdeveloped Subdivision	--	
Military	150	
Civilian	4,400	
Pali and Barren Land		22,235
Quarry		23
Military	--	
Civilian	23	
Water		966
GRAND TOTAL:		338,386

Source [4-3]

TABLE 4-2. Area by Land Class for Kauai County, 1970 (in thousand acres)

Land Class	Kauai	Niihau
Forest Land:		
Commercial:		
Plantations	5.6	--
Native and Naturalized Forests	140.3	--
Total	145.9	--
Noncommercial:		
Productive Reserved	2.3	--
Unproductive	71.7	31.1
Total	74.0	31.1
Total Forest Land:	219.9	31.1
Total Nonforest Land:[1]	131.3	13.4
Total, All Land Classes:	351.2	44.5

[1]Includes areas of water less than 40 acres in size defined by the Bureau of Census as land.

Source [4-4]

TABLE 4-3. Area of Forest Plantations for All Ownerships by Forest Type, County of Kauai, 1970.
(in thousands of acres)

Island	Total All Types	Total Non-Commercial Types	Total Commercial Types	Commercial Types			
				Eucalyptus	Other Hardwoods	Conifers	Unclassified
Kauai	5,588	2,164	3,424	1,698	475	1,251	--

Source [4-4]

conditions, and irrigation were considered for feasibility purposes. Six species were recommended for dry regions (less than 40 inches of rainfall per year). These plants are: cutch tree, siris tree, white monekypod, ironwood, sunn hemp, opiuma, and kiawe. The seven species recommended for further research in the humid warm regions (greater than 40 inches of rainfall per year) are: California grass, sunn hemp, kenaf, koa haole, opiuma, and Albizia falcotaria [4-6].

Solid Waste

Using solid waste as a supplementary fuel is one of the most common types of biomass conversion today. The term "solid waste" is defined as those presently unwanted residues of natural or man-made resources and of human activity.

Municipal refuse collection methods in Kauai are a mixture of private and public enterprises. Presently Kauai's disposal facilities consist of three land fills and two open dumps [4-5]. Of the total municipal wastes on Kauai, approximately 20,000 tons per year of combustible solids could be burned.

An energy study in 1975 gave some projections of the amount of solid waste that Kauai County might have during 1980 and 1990. With the anticipated growth in population and tourism the solid waste contributions will undoubtedly grow [4-7]. These projections for available recyclable materials are shown in Table 4-4. These materials vary widely in heat content, from approximately 2500 BTU per pound for animal waste to 8500 BTU per pound to wood fiber [4-8]. A conservative value, 5000 BTU per pound, was used for calculations.

Liquid Fuels

One of the greatest advantages of biomass as a natural energy source is the potential for liquid fuel production. Ethanol may be produced from several feedstocks. The best known is molasses—a by-product of sugarcane processing. The Kauai sugar companies produce about 65,300 tons of molasses annually [4-9]. Potentially, 4.6 million gallons of ethanol can be produced if all the molasses is fermented.

Another method of obtaining ethanol from biomass is to first hydrolyze the carbohydrates or cellulose of the crop to fermentable sugars by chemical reaction (acid hydrolysis) or enzymatic action. Work in this field is in the developmental stage, although the former method was examined during the early 1940's. The biomass crops with high carbohydrates content and relatively high yields (tons per acre) would be the best candidate for this process. The most promising plants are: aroids, yams, sweet potato, and cassava [4-10].

TABLE 4-4. Kauai Available Recyclable Materials Projections: 1970, 1980, and 1990. (Tons)

Type of Material and Year	Kauai
1970:	
Paper	4,270
Trimmings	1,930
Rags	400
Wood	150
Food	1,150
Plastics & Misc	950
1980:	
Paper	6,900
Trimmings	3,030
Rags	730
Wood	290
Food	1,820
Plastics & Misc	1,570
1990:	
Paper	11,080
Trimmings	5,040
Rags	1,170
Wood	440
Food	2,960
Plastics & Misc	2,450

Source [4-7]

Methanol, another liquid fuel, also can be produced from biomass, including wood and other plant fiber and agricultural and industrial waste. A number of processes can be used, all involving gasification and then conversion to liquid form. From a 15,000-acre tree farm, approximately 25.8 million gallons of methanol can be produced.

Solar

Biomass, wind, and ocean energy are all solar energy resources—derived from the sun. Direct solar energy is obtained by collecting and/or focusing the sun's rays. The three main categories of direct solar energy are: solar thermal, utilizing solar radiation as a heat source; solar thermal conversion, utilizing the heat from the sun for the process of electricity production; and photovoltaic, utilizing solar cells to produce an electrical current.

Two problems are hindering full commercialization of direct solar energy. The first is that it is an intermittent energy source, varying over the course of a day according to the sun's position and the degree of cloud cover. Seasonal changes in the sun's position also alter the intensity of the available insolation. Thus, solar technologies are best applied to interruptible demands. Another problem is one of equipment cost. Presently, solar energy systems are very expensive, making most direct solar applications, except for solar water heating, uneconomical [4-11].

Figure 4-2 shows the insolation values recorded on Kauai by the University of Hawaii Meteorological Department and local sugar companies given in Langley per day [4-12]. As expected, the coastal plains and leeward areas have good insolation values.

The flat plate collector is the most common type of solar collector for water heating. The heat is then passed through the metal tubing to the flowing water in the system [4-13].

The basis flat plate collector consists of flat black absorbing surface, usually painted metal, attached to pipes through which a fluid, usually water, circulates to transfer heat. To prevent the heat from being dissipated by wind or reradiation, the absorber and pipes are placed in an insulated frame covered by glass or plastic. On Kauai,the use of flat plate collectors has resulted in an average water heating cost savings ranging from 20 to 25 percent [4-5].

In a solar thermal power system direct solar radiation is concentration to heat a fluid to higher temperatures that can be realized with flat plate collectors. The key elements of a solar thermal power system are: concentrators, receiver, transport fluid, and storage unit. Solar energy is collected by tracking collectors, which focus energy on the receiver. The working fluid in the receiver can provide process heat or transported to a heat engine, which converts the thermal energy into mechanical energy and in turn, into electrical energy. Energy may be stored in the system as heat, or as mechanical or electrical energy [4-11].

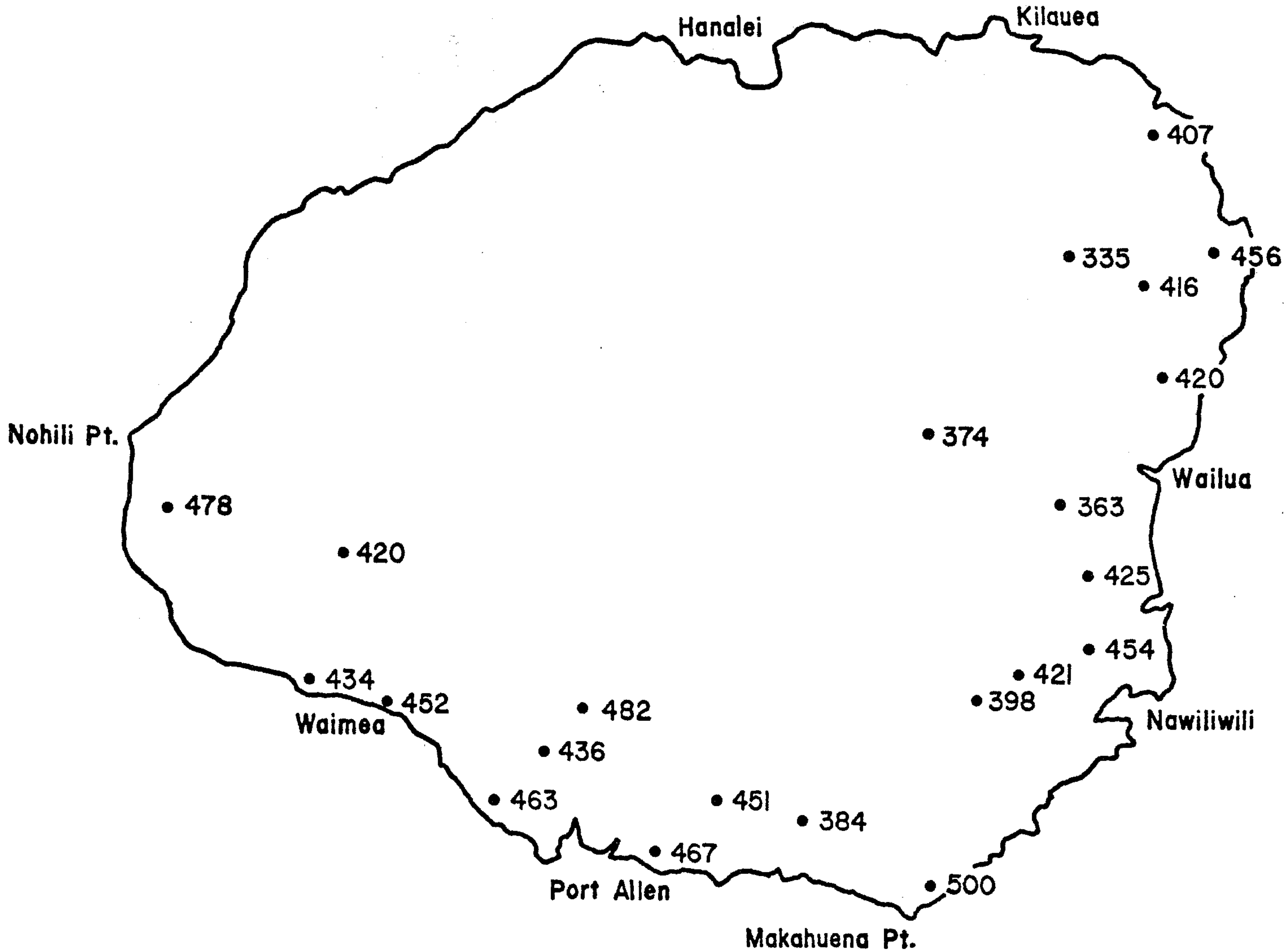


Figure 4-2. Mean Annual Solar Insolation on Kauai
[in Langley/day]
Source [4-12]

Photovoltaic conversion is direct conversion of solar to electrical energy by means of photovoltaic, or solar cells. Solar cells, usually made from silicon, release electrons when exposed to sunlight, thereby directly providing electricity. At present the cost of the cells is prohibitively high for commercial application, but research in progress promises cost reduction that should make them competitive within the next decade.

Wind

Wind energy conversion systems (WECS) are windmills made for electrical generation or pumping. Operation is simple: the wind turns the blades, which rotate a shaft to turn a generator, producing electricity or pumping water. The efficiency achieved by a well-designed turbine is about 45 percent, with an overall system efficiency of 30 to 40 percent for electricity generation. The successful utilization of a wind machine depends on local wind conditions, which must be known prior to installation. These include the intensity, direction, vertical gradient, and turbulence of the wind.

Wind funds provided by the Kauai County Council, the University of Hawaii Meteorology Department conducted a wind power survey of the island. A van-mounted anemometer was set up at each of 47 sites for at least 24 hours. The measured wind speeds, compared with simultaneous observations made at Lihue Airport, enabled researchers to estimate the probable long-term average wind speeds at each site [4-14].

Kilauea Point in the north end of the strip along the southeast coast between Makahuena Point and Kawelikoa Point is the most promising site for wind power generation. Data from fixed stations at Kilauea Point, Lihue Airport, Makahuena Point, and Kapeku Cinder Pit will be analyzed to refine and, if necessary, modify preliminary findings. Figure 4-3 shows the average vector winds and streamlines for the period of the survey.

The many advantages of wind energy utilization in Hawaii are as follows [4-11]:

- Wind power has been proven to be available with long-term consistency.
- There is an absence of environmental extremes such as freezing conditions.
- Wind energy conversion is one of the environmentally acceptable sources of energy, with relatively few and minor adverse effects.
- Wind energy conversion system technology is basically proven and will soon be economically viable on a production basis.
- The principal wind areas have relatively low populations, and there is sufficient land to site large WECS with minimum impact on communities.

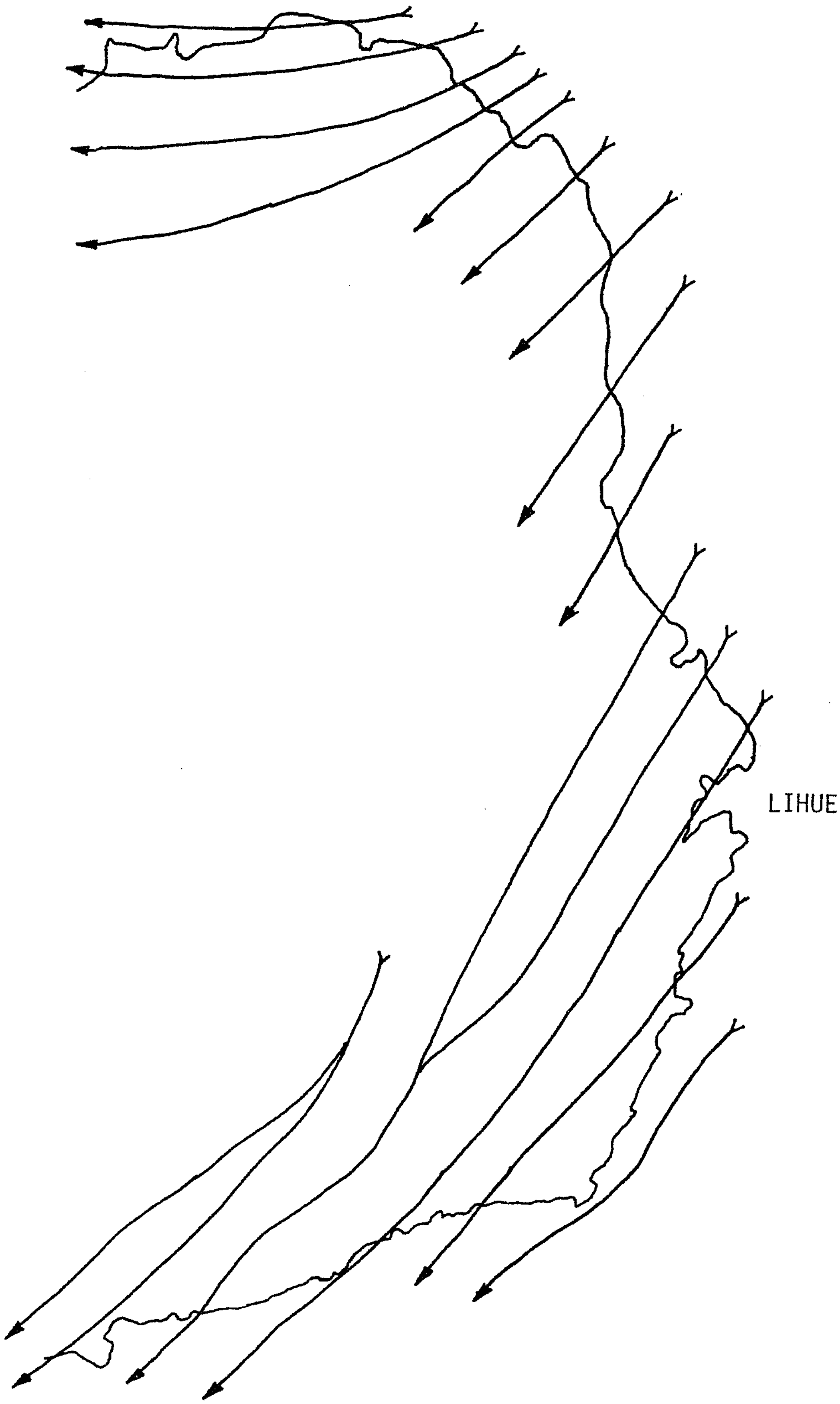


Figure 4-3. Estimated Wind and Streamlines for the Period of Examination (19 August - 5 September 1977)

Source [4-14]

Some disadvantages of wind power are listed as follows [4-11]:

- Wind power is intermittent and upredictable.
- Large WECS require towers for 30 to 90 ft meters (100 to 300 ft), which could be considered by some to create a visual or aesthetic problem.
- WECS with metal blades may possibly interfere with television and microwave signals within a short distance of the machines.
- There is a possible safety concern if the blades should break loose or the tower should fall.
- Kauai's salty air will accelerate corrosion.

Hydroelectric

Kauai has one of the wettest spots in the world at Mount Waialeale. Over 480 inches of rainfall are recorded annually in that area. Currently, Kauai has seven hydroelectric plants in operation by the local sugar companies, which generate 7900 KW of power.

Hydroelectric plants may be classified by the manner in which they use available streamflows—with or without storage. Run-of-river plants without storage use water as it comes to them. Most of these plants are capable of maintaining a base electrical load throughout the year; consequently, their full plant discharge is seldom greater than the minimum flow of the stream or river. Run-of-river plants with storage can use their stored water to take care of daily or hourly fluctuations in the electrical load. Hydroelectric plants are especially useful as reserve units in systems subject to sharp demand peaks, since they are capable of starting quickly and responding rapidly to sudden changes in demand. Table 4-5 contains a listing of potential rivers for hydroelectric power.

The following is a general listing of possible advantages of hydropower plants [4-7]:

- Minimal impact of the environment—no resource depletion; no air pollution, no water pollution; no toxicity.
- Operation and maintenance costs are low.
- Long life and low depreciation expenses.
- Starts quickly and makes rapid changes in power output.
- Fish and wildlife enhancement.
- Flood control.

Belt, Collins, & Associates examined the potential of damming the Wailua River in their Waialeale Hydropower Study [4-16]. Two units of 4600 KW each would generate energy for an

TABLE 4-5. Potential Rivers on Kauai for Hydroelectric Power

USGS Sta. No.	Name of River	Power Potential (KW)	
		Storage	Run-of-River
1030	Hanalei River	2,486	175
1080	Wainiha River	1,566	254
310	Waimea River	1,478	0
710	North Fork Wailua River	1,434	15
600	South Fork Wailua River	1,303	12
1060	Lumahai River	1,281	153
371	Makaweli River	1,150	22
360	Makaweli River	992	23
490	Hanapepe River	962	37
470	Hanapepe River	814	80
	Total Power Potential:	13,466	771

Source [4-15]

average of 90 million gallons per day of water. One unit would develop firm energy, while the second unit would be a standby for the first as well as generate additional energy when streamflows are high. The total cost of this project was calculated to be about 72 million dollars with a 50-year payback period.

Ocean Thermal Energy Conversion

Ocean Thermal Energy Conversion (OTEC) is a system of obtaining electrical energy from the ocean using the temperature differential between warm surface ocean water and deep cold water. In a closed-cycle system, a fluid such as ammonia is heated in an evaporator by warm ocean surface waters. The heating process turns the liquid ammonia, which has a very low boiling point, to vapor and the vapor drives an electricity-producing turbine-generator. The vapor then passes into a condenser where it is cooled by cold ocean water pumped up from a depth of about 2000 feet below the surface. The cooling process changes the vapor back to liquid, the liquid is sent to the evaporator, and the cycle, now completed, begins anew.

The theoretical maximum efficiency of OTEC systems is about 7 percent. Because of thermal and other losses in the systems, the practical net efficiency is calculated to be about 2 percent. Even with this low efficiency, OTEC systems should still be economically feasible because they use a free and virtually inexhaustible fuel: warm ocean water. Figure 4-4 is a general schematic of a floating OTEC power plant.

The bulk of OTEC research has been set for Ke-Ahole Point on the Big Island. Mini-OTEC, OTEC-1, and the Seacoast Test Facility will all be operating around that area, which is probably the best location in the State for this type of research [4-5].

Kauai has the potential for an OTEC facility when it becomes commercially available. Nearly three-quarters of the island has sufficient depth near shore and water temperature differences that should fall within the range necessary to operate such a facility.

Wave Energy

Another form of ocean energy is wave energy. Kauai has good surfing conditions and is literally surrounded by the ocean. Although waves seem to be very powerful, especially when seen crashing up on the shore, the actual amount of energy per foot of wave crest is relatively small. From the average wave, the total amount of energy would be about 7 KW/ft. Realistically, the efficiency would be approximately 10 percent of this figure [4-7, 4-13].

Floating OTEC Power Generating Plant

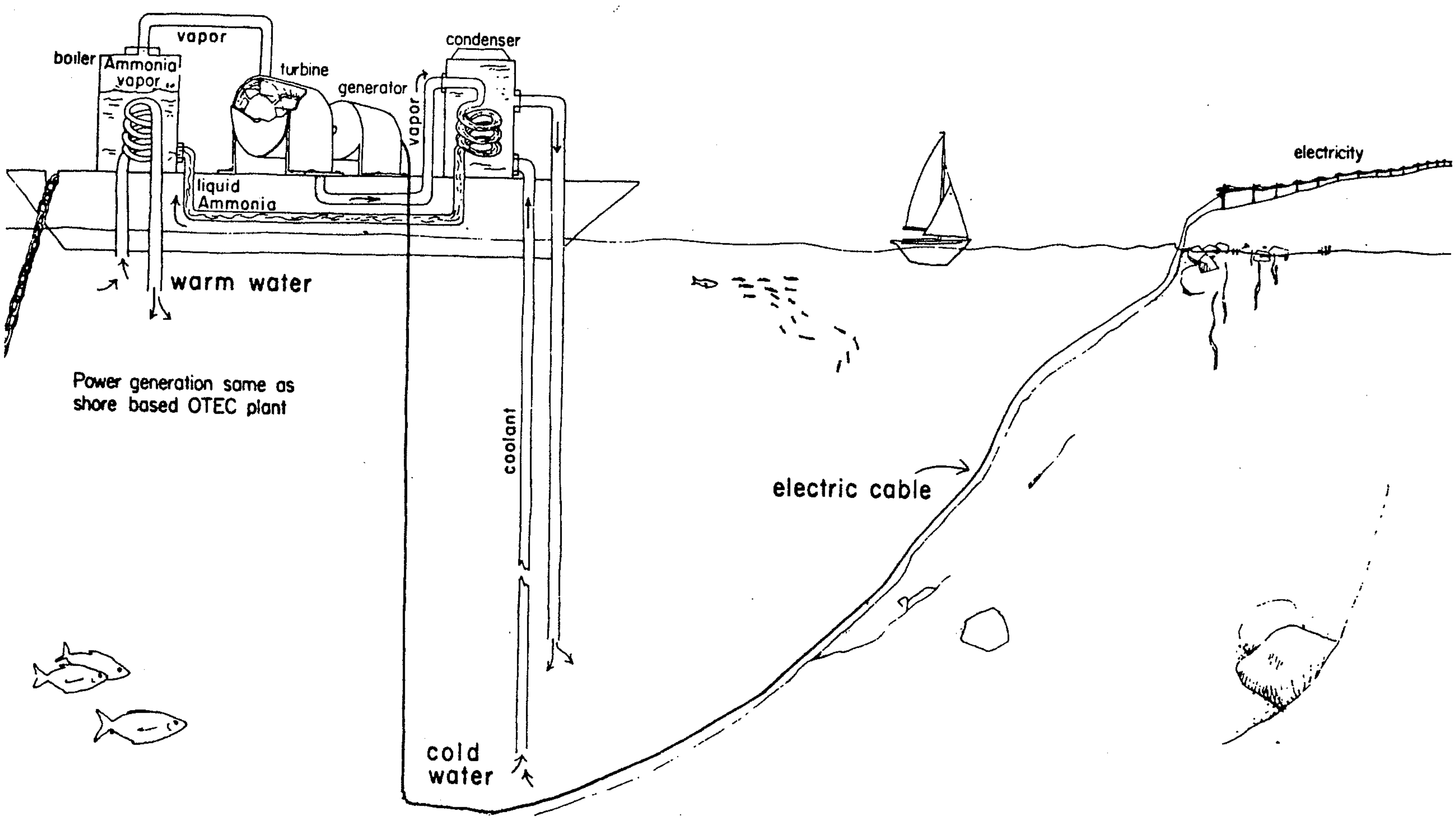


Figure 4-4. Schematic of Floating OTEC Power Generating Plant
Source [4-1]

Currently, there is relatively little interest in wave energy research and development as a major energy alternative in the United States. Britain and Japan, on the other hand, are conducting extensive research in this area.

Several problems will have to be solved before wave energy becomes a reality: 1) a system would have to be designed that would work in both large and small wave conditions; and 2) wave energy is so diffuse that it is impractical and uneconomical to use—a very large system would cover an excessively large shoreline. Recently Venezian [4-17] discussed wave energy as a resource for Hawaii. On a modest scale, a 5-kilometer receptor would be needed to supply approximately 600 million KWH/yr.

Wave machines are practical only for small-scale operations, and the future depends on interest and research. The basic technology exists, but research and development activity is low in Hawaii and the rest of the United States.

Geothermal

Geothermal energy is derived from the natural heat of the earth's interior. In Hawaii, the source of heat is magma, or molten rock. The magma heats underground water, which exists under pressure, to an extremely high temperature much above the water's surface boiling point. The reservoir water boils ("flashes") when the pressure is removed, such as by drilling a well from the surface to the reservoir. The resulting steam can run a turbine generator, producing electricity. Figure 4-5 shows the schematic of a geothermal power plant.

Kauai is the oldest island in the Hawaiian chain and therefore is unlikely to have much residual subsurface heat. However, recent investigations have uncovered anomalies in the Mana and Wailua area. These discoveries will be further explored in the field in the near future [4-18].

Hydrogen

Hydrogen is potentially an important replacement for gaseous or liquid fuels presently derived from petroleum. The most abundant source of hydrogen is water, and the most common method at this time for separating hydrogen from water is electrolysis. This is accomplished by forcing an electric current through water to break the bond between the hydrogen and oxygen molecules, a process which requires energy which must be provided by some other source.

Hydrogen, called the fuel of the future, is the subject of much research today. Its primary use to date has been as rocket fuel. The potential uses are many, however: airplane fuel,

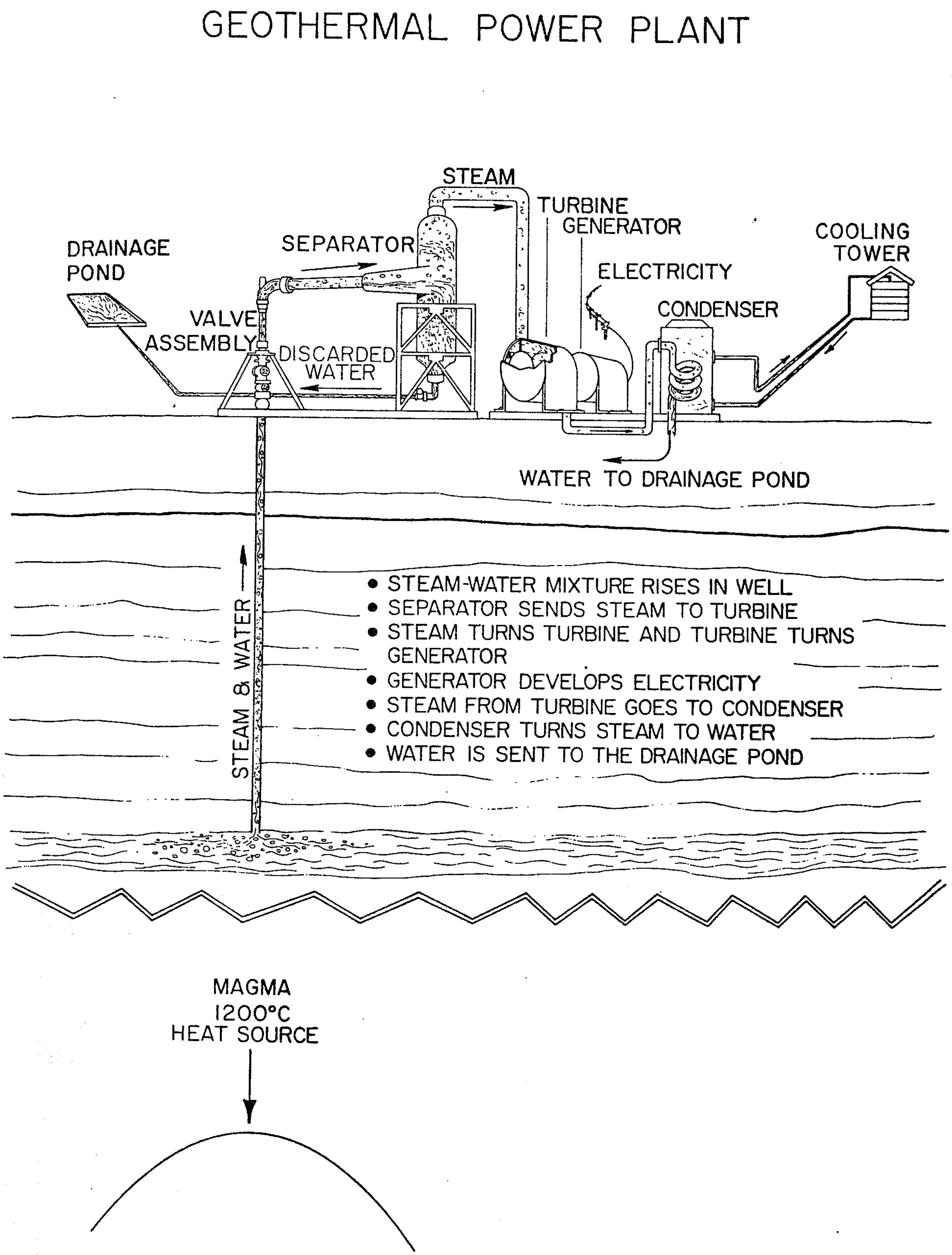


Figure 4-5. Schematic of Geothermal Power Generating Plant
Source [4-1]

automobile fuel, utility gas, space heating, and other [4-13]. However, the technologies for storage, distribution, and utilization have yet to be developed before commercial application can be realized.

C. Economic Considerations

The economic aspect of these energy resources is the primary factor determining the development of energy self-sufficiency. Reduction of imported petroleum into the State will, among other things, improve the balance of trade and decrease unemployment. The impact of substituting petroleum imports with alternative resources will be discussed in a later section.

The economics of these natural resources are determined by a number of factors:

- Type of technology and fuel.
- Economy of scale.
- Location of supply and utilization modes.
- Availability and cost of resources, labor, and collateral technology.
- Load factors.
- Plant life.
- Interest rates.
- Financing.
- Breakthroughs in technology.

Tables 4-6 and 4-7 give data pertaining to summaries of electricity-producing natural energy technologies, including costs, availability, and general comments. Biomass combustion and community and utility-scale wind turbines are competitive with conventional diesel units. Hydropower may also fall into this category.

Tables 4-8 and 4-9 are similar summaries of liquid and gaseous fuel-producing natural energy technologies. Thermochemical gasification of wood to obtain low and intermediate BTU gas are competitive with conventional refining plants.

Tables 4-10 and 4-11 present summaries for heat-producing natural energy technologies. Solar water heating, biomass combustion, and geothermal energy are well within the range of conventional water heating.

TABLE 4-6. Summary of Electricity-Producing Alternative Energy Technologies for Kauai

Alternative Technology	Commercially Available	Economic Outlook	Environmental Acceptability	Other Important: Incentives	Other Important: Disincentives
Hydropower	Current	Unfavorable	Favorable	Well-Understood Technology	Limited Potential
Biomass (Direct Combustion)	Current	Favorable	Some Minor Difficulties	Well-Understood Technology	Possible Land Use Problems
Geothermal Energy	Long-Term	Indeterminate	Some Difficulties	Continuously Available	Resource Availability Is Uncertain
Wind Energy (Large-Scale)	Near and Mid-Term	Favorable	Some Minor Difficulties	Well-Understood Technology	Requires Stabilization
Solar-Thermal Elec.	Long-Term	Indeterminate	Favorable	Centralized Applications	Possible Land Use Problems
Photovoltaics	Long-Term	Favorable	Favorable	Decentralized Applications	
Ocean Energy	Long-Term	Indeterminate	Probably Favorable	Continuously Available	Inappropriate Scale for Kauai

Adapted from [4-19]

TABLE 4-7. 1977 Cost Summary of Electricity-Producing Alternative Energy Technologies for Kauai

Alternative Technology	Capacity Factor	Capital Cost [$/KW]	Oper. & Maint. Cost [MILLS/KWH]	Total Cost [MILLS/KWH]
Biomass (Dir. Combustion of Wood)	70%	1690	36	66
Hydropower, Storage Run-of-River	appears promising; requires further study			
Wind Energy				
. Small-Scale	30%	3130	12	
. Community-Scale	35%	1800	10	115
. Utility-Scale	40%	1220	7	70
Geothermal Energy	70%	1800	17	70
Solar Thermal Electric	50%	3100	6	133
Photovoltaics	20%	1950	2	204
Ocean Thermal Energy Conversion	70%	UNAVAILABLE IN MID-1980'S		
Conventional Diesel				73
Electric				
. Small Peaking	15%	330	43	71
. Large-Scale	80%	542	33	43

Adapted from [4-19]

TABLE 4-8. Summary of Liquid and Gaseous Fuel-Producing Alternative Energy Technologies for Kauai

Alternative Technology	Feedstock	Product	Commercially Available	Economic Outlook	Environmental Acceptability	Other Important	
						Incentives	Disincentives
Fermantation	Molasses	Ethanol	Near-term	Favorable	Some Difficulties	Well-Understood Technology	Feedstock quantity is limited
Hydrolysis/ Fermentation	Cane Trash	Ethanol	Mid-term	Indeterminate	Favorable	Product is useful gasoline substitute	Feedstock quantity is limited
Thermochemical Gasification	Wood	LBG	Near-term	Indeterminate	Favorable		Product cannot be transported economically
Thermochemical Gasification	Wood	IBG (High Pressure)	Mid-term	Indeterminate	Favorable		
Thermochemical Gasification	Wood	IBG (Low Pressure)	Mid-term	Indeterminate	Favorable		Product cannot be transported
Thermochemical Gasification	Wood	Methanol	Mid-term	Indeterminate	Favorable	Product is useful gasoline substitute	Some conversion problems
Pyrolysis	Wood	Oil	Mid-term	Indeterminate	Favorable	Well-Understood Technology	Product may require upgrading
Anaerobic Digestion	Bagasse or Cane Trash	IBG	Near-term	Indeterminate	Favorable	Well-Understood Technology	Product cannot be transported economically
Hydrocarbon Extraction	Euphorbia	Oil	Long-term	Unfavorable	Favorable		Product may require upgrading

IBG = Low BTU gas; IBG = Intermediate BTU gas

Adapted from [4-19]

TABLE 4-9. 1977 Cost Summary of Liquid and Gaseous Fuel-Producing Alternative Energy Technologies for Kauai

Alternative Technology	Feedstock	Product	Capital Cost [$/MMBTU/YR]	Oper. & Maint. Cost [$/MMBTU]	Total Cost [$/MMBTU]
Fermentation	Molasses	Ethanol	20.0	14.9	18.5 [$1.45/gal]
Hydrolysis/ Fermentation	Cane Trash	Ethanol	50.8	.23	21.4 [$1.70/gal]
Thermochemical Gasification	Wood	LBG	14.0	3.0	5.5
Thermochemical Gasification	Wood	IBG [High-Press.]	27.6	3.1	8.1
Thermochemical Gasification	Wood	IBG [Low-Press.]	22.1	2.6	6.6
Thermochemical Gasification	Wood	Methanol	52.2	6.4	15.8 [$1/gal]
Pyrolysis	Wood	Oil	18.0	6.4	8.5 [$41/BBL]
Anaerobic Digestion	Bagasse or Cane Trash	IBG	42.7	17.5	25.2
Hydrocarbon Extraction	Euphorbia	Oil	54.7	4.8	14.7 [$74.5/BBL
Conventional Refining	Crude Oil	Gasoline			5.6 [$.70/gal
Conventional Production	--	LPG			7.7 [$.70/gal

Adapted from [4-19]

TABLE 4-10. Summary of Heat-Producing Alternative Energy Technologies for Kauai

Alternative Technology	Commercailly Available	Economic Outlook	Environmental Acceptability	Other Important	
				Incentives	Disincentives
Solar Water Heating	Current	Favorable	Favorable	Well-Understood Technology	Only suitable for low temperature applications
Biomass (Direct Combustion)	Current	Favorable	Some Minor Difficulties	Well-Understood Technology	Possible land use problems
Geothermal Energy	Long-term	Indeterminate	Some Difficulties	Continuously Available	Resource availability is uncertain
Solar Process Heat (Intermediate Temperature)	Mid-term	Indeterminate	Favorable	Well-Understood Technology	Possible land use problems
Solar Air-conditioning	Long-term	Indeterminate	Favorable	Well-Understood Technology	

Adapted from [4-19]

TABLE 4-11. 1977 Cost Summary of Heat-Producing Alternative Energy Technologies for Kauai

Alternate Technology	Capital Cost ($/MMBTU/YR)	Operation and Maintenance Cost ($/MMBTU)	Total Cost ($/MMBTU)
Solar Water Heating	120	2.3	8.3
Biomass (direct combustion of wood)	9	2.4	4.0
Geothermal Energy	12	.7	2.9
Solar Process Heat (intermediate-temperature)	125	4.5	27.1
Solar Air-conditioning	29.5	2.6	17.4
Conventional Water Heating			
Electric	15.6	27.0	27.8
LPG	22.1	17.3	18.4
Petroleum Fired Process Steam	3.4	6.0	6.6
Electric-Powered Air-conditioning	38.7	10.3	12.2

Adapted from [9-19]

D. Environmental Impact

The development of natural resources is less of an environmental problem compared with fossil fuel use. Many technology-specific environmental impacts have been conducted and are available; however, specific impacts on Kauai will have to be done at the appropriate time.

Water Pollution

Water resources have played and continue to play a crucial life or supporting role on Kauai as well as the other islands. Drinking, agriculture, industrial, and recreational uses all compete for the island's limited resources. Environmental and marine biology interests in the ocean resources have pointed out the effects of water pollution on marine life.

In the past, public health was the only consideration related to water pollution control for drinking and recreational water. Now the standards have been expanded to ensure that water is free from color, turbidity, taste, odor, and excess heat.

Industrial or agricultural uses of water in energy recovery systems may affect biochemical oxygen demand (BOD) content, chemical oxygen demand (COD) content, or the amount of suspended solids (SS) in the water. Wastewater treatment that complies with established standards may be necessary before discharge. Deep ocean outfalls have been one solution in discharging wastewater. Steep geologic formation of the islands and the surrounding ocean currents have the combined effect of diminishing the impacts of deep ocean outfalls; however, federal standards may prohibit these practices in the future.

Air Pollution

Since the first wood fire, pollutants have been emitted into the air during energy generation processes, and they can be a major health hazard. Fossil fuel combustion processes have been the largest contributors to air degradation in recent years. The major combustion-generated pollutants are nitrogen oxides, sulfur oxides, unburned gasses and solids, and non-combustible solids. Secondary pollutants may be formed through reactions with natural compounds in the atmosphere.

On Kauai, the unique climate and the tradewinds disperse the pollutants away from the populated areas and out to sea. Nevertheless, industry must comply with federal and state standards for emission control unless variances are obtained.