MASTER

**GEOHERMAL ENERGY
FOR
AMERICAN SAMOA**

GEOHERMAL EXPLORATION & DEVELOPMENT CORPORATION

Contract No. CM-304-80
of
Territorial Energy Office
American Samoa Government 96799

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GEOHERMAL ENERGY FOR AMERICAN SAMOA

PREPARED FOR THE
TERRITORIAL ENERGY OFFICE
AMERICAN SAMOA GOVERNMENT
CONTRACT NO. CM-304-80

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ABSTRACT

The purpose of this study was to investigate the geothermal commercialization potential in American Samoa.

Presently, American Samoa, totally dependent on imported fossil fuel, is spending about 36 million dollars for 42 million gallons of oil products per year. Major island energy consumers are the tuna industry (54%), airline industry (21%), and the Electric Utilities Division (17%). Demand for fossil fuels and electrical energy (present generating capacity = 25 MW) is increasing. With fossil fuel energy becoming more expensive and unreliable, alternate energy sources need to be examined. Geothermal energy is a favorably priced near term possibility.

With geothermal energy harnessed in American Samoa, a myriad of possibilities would arise. Existing residential and business consumers would benefit from reduced electricity costs. The tuna canneries, demanding about 76 per cent of the island's process heat requirements, may be able to use process heat from a geothermal source. Potential new industries include health spas, aquaculture, wood products, large domestic and transshipment refrigerated warehouses, electric cars, ocean nodule processing, and a hydrogen economy.

With the advent of geothermal energy in American Samoa, the territory can establish a firmer industrial base and a higher

standard of living--with no attendant serious environmental impact.

There are no territorial statutory laws of American Samoa claiming or reserving any special rights (including mineral rights) to the territorial government, or other interests adverse to a land owner, for subsurface content of real property.

Technically, an investigation by Dr. Keller and Dr. Grose from the Colorado School of Mines has revealed that American Samoa does possess a geological environment conducive to geothermal energy development. Further studies and test holes are warranted.

Further geophysical studies and three test holes need to be completed. Geothermal is a major economical near term possibility and therefore should receive high priority and be pursued as fast as possible. Funds for definitive geothermal exploration need to be applied for and obtained.

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Introduction

SECTION 1

INTRODUCTION

American Samoa is completely dependent upon imported petroleum products as an energy source for generation of electricity and for direct heat purposes. In the pre-1973 era of inexpensive fuel costs, the economic drain of the negative energy balance of trade was not overly significant. However, OPEC ended the era of cheap fossil fuel energy in 1973-74 when it quadrupled prices and, for the first time, restrained supply. Now such a preponderous dependency on fossil fuels leaves American Samoa susceptible to increasingly higher energy costs and potentially unreliable fossil fuel acquisition. Should supplies of oil and petroleum products be reduced or eliminated, American Samoa will suffer proportionate energy losses, which would drastically affect its social and economic well being. Also, limited supplies of high cost imported fuel severely restricts industrial/economic island development. Therefore, obtaining some degree of energy self-sufficiency through the utilization of technically, environmentally, and economically sound alternate energy sources is critical to the Island's future.

One alternate energy source of particular promise to American Samoa is geothermal energy. Geothermal resources have

shown economic potential in Hawaii, and American Samoa, being a volcanic island in the Pacific ring-of-fire region, appears to have the good fortune of having geothermal resources also. Due to an active interest in the economic development of geothermal energy as an alternate energy source, the Government of American Samoa has obtained limited funding from the DOE for this preliminary assessment of American Samoa's geothermal energy potential.

Besides having the potential for a significant impact on American Samoa, this pursuit of geothermal energy will also impact other Pacific islands. The knowledge gleaned from exploration and development in American Samoa will be useful to other Pacific islands which lie in a similarly active geologic area and perhaps share similar geothermal resources. The efforts in American Samoa will serve as an example to other Pacific islands.

1.1 OBJECTIVES

The objective of this project is to conduct an investigation of the geothermal commercialization potential in American Samoa. The investigation is divided into three phases. Phase I covers computation of a data base detailing energy sources and demand. Phase II includes the geological, environmental, socio-economic, legal and regulatory assessments. And Phase III covers the analysis, conclusions, recommendations and plans for further action.

Phase I - Energy Sources and Demand

A) Samoa Overview

A discussion of the current dependence of Samoa on foreign oil for electrical generation, process heat, etc; volumes consumed; for what purposes; existing and potential alternatives; impact of last oil embargo; possible effects of a temporary or a permanent oil import curtailment, etc.

B) Electric Data

A description of the existing electrical power generating facilities on Samoa; MW's produced; costs in KWHRS; age and condition of existing plants; replacement and/or expansion requirements; how electricity is used; etc.

C) Process Heat Data

The scope and extent of process heat facilities on the islands; tuna packing and other uses; BTU's required for each facility; pressure and temperature requirements; how produced; fuel consumed; costs; etc.

D) Other Non-Transportation Energy Use

A summary of other energy consuming operations utilizing imported oil or other fuels; an inventory of Navy, Coast Guard and other Federal Department establishments in Samoa; their current

and future need for electricity and heat; volumes and specifications; seasonal fluctuations; source; willingness to consider alternate sources; possibilities of cooperative ventures; etc.

Phase II - Assessments

A) New Industry Potential

An assessment of industrial expansion possibilities; if an economical and dependable long-term source (geothermal) were developed on Samoa, would existing industries expand? Would new industries evolve? What types? Would they require electricity or process heat, or both? What might be their energy specifications? What would this mean to Samoa's economy? Would it save oil? Does Samoa want industrial expansion?

B) Environmental and Socio - Economic Issues

A review of environmental and socio-economic issues; what problems can be foreseen if geothermal energy is found to be present in economically and technically recoverable volumes? Are there local cultural and religious factors that might stand in the way of development and utilization? Would an expanded industrial base benefit per capita income? Are

air and water pollution problems a possibility? Are there strong environmental forces in the islands that might oppose geothermal utilization? Would such a domestic alternative energy source improve the revenue base of the islands?

C) Legal and Regulatory Factors

A description of legal and regulatory factors; Do the laws and regulations of Samoa lend themselves to geothermal exploration, development and utilization? Who owns this resource? Can private industry obtain exploration leases? What are the royalty arrangements, etc.? Is taxation on geothermal development and end-use equitable? Would new incentives be required? Are there land-use zoning laws which would make certain areas off-limits to exploration and utilization? Can foreign corporations develop geothermal resources in Samoa?

D) Technical Geothermal Potential

An assessment of the geothermal potential based on a review of existing geological/geophysical and other pertinent data by competent parties; what is the potential for geothermal energy in Samoa? Has there been recent vulcanism? Are

there hot springs? Are there water wells with elevated temperatures? Does the geology infer above average possibilities - at what locales and what depths? What do surface indications show?

Phase III - Conclusions & Recommendations

A) Further Technical Assessment Needs

Develop geothermal assessment plans; detail the process which should be followed to determine the existence of recoverable geothermal energy in Samoa. Where should exploration be conducted? What should be done? - shallow test holes, geochemical investigations, temperature probes of existing wells, geophysical surveys, etc.; estimated costs, phases, time frames, etc.

B) Analysis, Conclusions, Recommendations

Prepare an analysis and conclusions based upon the above tasks relative to technical, economic, and environmental opportunities for geothermal commercialization in Samoa. Develop preliminary recommendations for geothermal development in Samoa, assuming previous sections indicate such recommendations are warranted.

1.2 METHODOLOGY

Preparing this report required investigation into many avenues of information. The first step was to examine the relevant literature. A library of applicable studies, reports, and newspaper items was established. Then, efforts were made to collect first hand data in the field. Various GEDCO personnel spent time in American Samoa interviewing and collecting data from business and governmental agencies such as the tuna canneries, the oil companies, the Territorial Energy Office, the Electric Utilities Division, the Department of Planning and Economic Development, and The Department of Public Works. Dr. Keller and Dr. Grose from the Colorado School of Mines visited American Samoa to conduct the geothermal potential assessment. Their report is presented in section 4.4. Attorneys from American Samoa, Honolulu and California assisted in the legal aspects. Data and knowledge from all sources was then analyzed and assembled as the first major document concerning geothermal energy in American Samoa.

1.3 ACKNOWLEDGEMENTS

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Dr. D. Richard Neill, Hawaii Natural Energy Institute, University of Hawaii

Dr. Eugene M. Grabbe, Hawaii State Center for Science Policy and Technology Assessment, Department of Planning and Economic Development

2. Energy Sources and Demand:

Dependence on Foreign Oil

SECTION 2

ENERGY SOURCES AND DEMAND: DEPENDENCE ON FOREIGN OIL

This section examines fossil fuel energy in American Samoa--its present status and future possibilities. American Samoa, being totally dependent on foreign oil as its energy source, indicates the need for discussion of the origin, distribution, demand, and use of that energy source. The Island's growing reliance on imported oil as an energy source subjects it to the fluctuation of international events thousands of miles away: petroleum products being particularly susceptible to cost and supply dislocations. Examination of who uses energy, how it is used, and how much also permits a better perspective of the possible effects of these dislocations. The impact of the 1973 oil embargo is reviewed, and the possible consequences of a temporary or permanent oil import curtailment are discussed.

Because increasingly expensive fossil fuel energy stifles economic growth by feeding inflation and reducing the standard of living, an in depth assessment of alternate energy sources is important. Relevant baseline information included herein details the present costs of energy, the quantities used, and the way that it is used. Projected electrical generation requirements are also discussed. This information serves as a foundation in planning for future energy sources and systems.

2.1 OVERALL FOSSIL FUEL DEMAND: IMPORTS TO AMERICAN SAMOA

American Samoa does not have indigenous fossil fuel resources and is at present totally dependent on imported petroleum products to satisfy its energy needs. This section takes a general look at the overall fossil fuel that is imported to American Samoa. The origin, quantity, and cost of this energy source is examined here to describe American Samoa's basic dependence on, and demand for, foreign oil.

American Samoa's fossil fuels originate as crude oil from Alaska (60%), Indonesia (39%), and California (1%). Because American Samoa does not have a refinery, the crude oil from these sources is first taken to the Chevron U.S.A. refinery at Barbers Point in Honolulu, Hawaii. Every month, a fuel tanker then brings the refined products to Tutuila, the major island of American Samoa.

The fuel is pumped through a half mile of underground pipeline from the Pago Pago harbor fuel piers to a storage tank farm. Other American Samoa islands including the Manu'a Islands and Swains Island get their fuel by barge from the Tutuila tank farm.

The fuel tankers from the Honolulu refinery to Pago Pago provide the bulk of the fuel imports to American Samoa. The only additional fuel required is propane. This is obtained by the tuna canneries and oil companies in metal bottles and tanks from refineries in California.

The quantities of the various petroleum products imported to American Samoa in 1975 and 1979 are presented in Figure 2-1. The various tabulations reveal some essential information. About 42 million gallons of oil products were delivered in 1979. By comparison, the State of Hawaii consumed 1.6 billion gallons during the same period. This means that American Samoa requires approximately 3 percent of Hawaii's fuel requirements. American Samoa is spending about 36 million dollars (January, 1980 prices) per year for these products. This amounts to about 40 percent of the total (Fiscal Year 1979) imports to American Samoa according to Port Administration figures listing total imports at 90.2 million dollars.

American Samoa consumed 5.624×10^{12} BTU of energy in 1979. This is an increase of 12 percent over the energy consumed in Fiscal Year 1976 (5.019×10^{12} BTU.) The energy capacity of lube oil does not enter into the BTU calculation since lube oil is used for lubrication and not as an energy source.

Figure 2-2 is a graphical representation of the fossil fuel imports. Ninety-eight percent of the fuel imported is either diesel fuel, jet fuel, or automobile gasoline. Diesel fuel comprises the major portion, 69 percent, of the 1979 fuel imports. Jet fuel and automobile gasoline consumption amounts to 22 percent and 7 percent, respectively, of the total. The remaining 2 percent is made up of lube oil, aviation gasoline, propane, white gas, and kerosene.

2-4

Petroleum Product	<u>Imports</u>		Growth Rate 1975-79 (%)	Energy Capacity (BTU/Gal)	Total Energy 1979 (x10 ¹² BTU)	Price (\$/Gal)	Present Cost (\$/Yr)
	1975 (Gal/Yr)	1979 (Gal/Yr)					
Diesel Fuel	21,634,611	29,300,899	35.4	138,000	4.044	0.808	23,675,126
Jet Fuel	9,439,739	9,365,635	1.8	126,000	1.180	0.888	8,316,683
Automobile Gasoline	2,708,006	2,932,590	8.4	125,000	0.367	0.907	2,659,859
Propane	N/A	136,200	N/A	91,000	0.012	1.230	167,526
Aviation Gasoline	136,003	108,759	-20.0	125,000	0.014	0.958	104,191
Kerosene	0	42,000	N/A	126,000	0.005	0.981	41,202
White Gasoline	N/A	12,000	N/A	125,000	0.002	1.700	20,400
Lube Oil	N/A	<u>400,000</u>	N/A	-	<u>-</u>	2.750	<u>1,100,000</u>
Totals:		42,298,083Gal/Yr			5.624x10 ¹² BTU/Yr		36,084,987\$/Yr

IMPORTED PETROLEUM PRODUCTS
FIGURE 2-1

(Primary Source: Dept. of Port Administration Data)

100% = 42,298,083 GALLONS

ENERGY CONSUMED = 5.624×10^{12} BTU/Yr,
 PRESENT CCST BASED ON JAN. 1980 PRICES = \$36,084,987/Yr

PETROLEUM CONSUMPTION BY FUEL TYPE--1979

FIGURE 2-2

(PRIMARY SOURCE: DEPT. OF PORT ADMINISTRATION DATA)

A general comment regarding the data presented in this report is in order. The difficulties in assembling the data and graphs are numerous and complex due to the nature of the industry and the sources of data which exist. The oil companies and canneries, for example, would not reveal information that they thought might be used against them by competitors. For these reasons, some numbers are necessarily approximate and not exact. The picture taken as a whole, however, is believed to be reasonably correct and represents the best available comprehensive description of the components of energy flow in the Territory. A general view of the data nevertheless provides one with an excellent perspective on the "big picture" of energy in American Samoa.

In Figure 2-1, the data for kerosene requires some explanation. A large fraction of the Island's kerosene needs (about 240,000 gal/yr) are met by using A1 jet fuel, which is very similar to kerosene and is relabelled as such. The listed actual kerosene imports, therefore, should not be interpreted as total kerosene consumption.

The prices listed and used in calculations are the posted Chevron U.S.A. open market price in American Samoa for January 1980. The EUD and hospital enjoy a small fuel cost allowance as long as they purchase fuel in truckload increments. Union Oil Company prices are slightly different. The price listed for gasoline is simply the average of the prices for unleaded, regular, and supreme gasoline. There are many types

of lube oil at various costs. The price listed is the price of the most popular lube oil.

2.2 ENERGY STORAGE AND RESERVE CAPACITY

The potential energy in the form of petroleum products is delivered to American Samoa monthly. The fuels are stored and used in the interim. Two characteristics of the American Samoan dependence on foreign oil are the quantities of fuel that can be stored and the length of time that a given supply will last.

The major petroleum storage facility on Tutuila is the oil tank farm in Punaoa Valley leased by Chevron U.S.A. from the American Samoa Government. This facility consists of nine storage tanks which contain diesel fuel, jet fuel, aviation gasoline, unleaded gasoline, regular gasoline and supreme gasoline. These fuels are pumped to the facility from the Pago Pago Harbor fuel pier via an underground pipeline. White gasoline and lube oil arrives and is stored in 55 gallon drums. Propane is handled in metal pressurized bottles.

Two fossil fuel distributors, Chevron U.S.A. and Union Oil Company, operate in American Samoa. Before distribution to customers, all of the fuel is stored in the tank farm. A mutually agreed upon amount is distributed to Union by an exchange agreement. Chevron claims about 70 percent of the island petroleum product business.

Fuel from the tank farm goes to the consumer either directly via an oil truck or indirectly via a gasoline station. The four major fuel consumers are the tuna fishing fleet, the planes at Pago Pago International Airport, the Electric Utilities Division (EUD), and the tuna canneries. The latter three have storage tanks of their own. Figure 2-3 lists the major fuel storage facilities on Tutuila. Using the number of gallons of each fuel used per day, the number of days that initially full storage tanks will last has been computed. Barring an emergency, fuel from tankers is used to refill the tank farm, and fuel from the tank farm is used to refill the end user tanks. The canneries, for example, top off their fuel tanks every other day or every third day.

The storage reserve capacity changes over time as the demand or the storage capacity changes. The storage reserve capacity for diesel, for example, will diminish as the demand for it increases.

Note that diesel fuel has the most limited storage capacity in relation to its demand with a 57-day storage reserve capacity. This reserve is shrinking because the island demand for diesel fuel is rapidly increasing, thereby reducing the reserve capacity. In 1979, diesel fuel imports were up 35 percent from their 1975 level. A 2.27 million gallon tank, currently being proposed for construction at the tank farm, would increase the diesel reserve capacity by 28 days.

Major Storage Facilities	Capacity (Gal)	Demand (Gal/Day)	Reserve Capacity (Days)
Chevron Tank Farm			
Diesel	4,536,000	80,276	57
Jet Fuel	1,701,000	25,659	66
Unleaded Gas	512,400	3,899	131
Regular Gas	411,600	3,249	127
Supreme Gas	100,800	886	113
Aviation Gas	100,800	298	338
Satala Electric Plant			
Diesel	48,000	12,600	4
Tafuna Electric Plant			
Diesel	200,000	9,366	21
Airport			
Jet Fuel	110,000	25,659	4
Aviation Gas	25,200	298	85
Canneries			
Diesel	39,000	4,600	8

FOSSIL FUEL STORAGE CAPACITY AND DEMAND -- 1979
FIGURE 2-3

Jet Fuel has about the same reserve capacity as diesel fuel--two months. The present reserve may actually be less due to the new Continental Airlines flights through Pago Pago International Airport.

Gasoline storage tank capacity appears to be less critical: full storage tanks will last between three and four months. The kerosene supply is adequate as long as reasonable levels of jet fuel are present, because jet fuel is simply relabelled as kerosene.

In practice, although some fuels, like automobile gasoline, have a large potential reserve storage capacity, the storage tanks for these fuels are not necessarily kept full. Chevron U.S.A. tries to maintain only a 45 day supply of propane, white gas, lube oil, and all of the other fuels. Thus, all of the petroleum products presently have about the same actual reserve storage capacity. This means that if, because of some political event or physical mishap, a scheduled fuel tanker is somehow delayed from its monthly rendezvous, American Samoa has a period of about 45 days, from the date of the last tanker, within which it must obtain petroleum products (assuming unmitigated consumption) before the fuel storage levels run low.

2.3 CONSUMER UTILIZATION OF ENERGY

2.3.1 FOSSIL FUEL CONSUMPTION BY ECONOMIC SECTOR

Who uses the energy rich fossil fuels in American Samoa? This section seeks the answer by examination of the major economic sectors--transportation, residential, industrial, and commercial--in order to present the magnitude and relationship of each sector's dependence on petroleum products. These sectors consume all of the energy imported to American Samoa. The major components of each sector are described.

Figure 2-4 presents the various fuels and their usage by each economic sector. Figure 2-5 summarizes the information graphically. The transportation sector is the major energy sink in American Samoa, utilizing 77 percent of the energy imported in 1979. The water transportation subsector consumes 50 percent of the imported energy. Ninety-three percent of the diesel fuel used for water transportation is used by the tuna fishing fleet. Six percent is used for Navy ships--one or two arrive in Pago Pago Harbor for refueling each quarter. The remaining one percent is used by the three government tugboats and the coast guard boats.

The air transportation subsector utilizes 21 percent of the imported energy. Virtually all of the fuel is for aircraft commuting to Hawaii, Australia, and other distant airports. The aviation gas is used by some smaller prop planes for inter-island excursions.

Major Sector	Fuel Type	Consumption		Fraction of Total Energy Consumption (%)
		(Gal/Yr)	1979 (x10 ¹² BTU)	
<u>TRANSPORTATION</u>				
Air	Jet Fuel	9,167,635	1.155	21.0
	Aviation Gas	108,759	0.014	
		9,276,394	1.169	
Ground	Unleaded	1,423,063	0.178	
	Regular	1,186,026	0.148	
	Supreme	323,501	0.040	
	Diesel	4,800	0.001	
		2,937,390	0.367	6.5
Water	Diesel	20,342,452	2.805	50.0
Sector Total		32,556,236	4.341	77.2
<u>RESIDENTIAL</u>				
	Propane	70,560	0.006	0.7
	Kerosene	240,000	0.030	
	White Gas	12,000	0.002	
	Sector Total	322,560	0.038	
<u>INDUSTRIAL/COMMERCIAL/OTHER</u>				
EUD-Tutuila	Diesel	6,898,000	0.952	16.9
EUD-Outer Islands	Diesel	60,000	0.008	0.1
Canneries	Diesel	1,680,000	0.232	4.1
Small Users	Diesel	315,647	0.043	0.8
		8,953,647	1.235	0.1
	Propane	65,640	0.006	
	Sector Total	9,019,287	1.241	22.1
Grand Total		41,898,083	5.620	100.0

PETROLEUM CONSUMPTION BY ECONOMIC SECTOR

FIGURE 2-4

100% = 5.624×10^{12} BTU

= TOTAL 1979 ENERGY CONSUMPTION

PETROLEUM CONSUMPTION BY ECONOMIC SECTOR--1979

FIGURE 2-5

In the ground transportation subsector, some 3,300 vehicles consume over 8,000 gallons of gasoline each day, amounting to 6 percent of the island energy consumption.

Residential consumers use propane and kerosene in their stoves for cooking. White gas is used for lighting. Residential users directly consume only a small fraction (1 percent) of the island fossil fuel energy. This fraction is small for several reasons. First, the large energy intensive airline and fishing industries tend to overshadow the residential sector. Second, the indirect use of fossil fuel energy as electricity has not yet been taken into account. American Samoa does not have natural gas pipelines, so water heaters and many stoves are electric. Finally, the resident population is not as energy hungry as their mainland counterparts--this results from low wages, high electricity costs, and their Polynesian lifestyle.

The Electric Utilities Division uses 17 percent of the island energy to generate electricity on Tutuila. Less than one percent of the diesel fuel used by the EUD is sent to the outer islands, the Manu'a Islands and Swain's Island, for electricity generation.

The tuna industry is a major island energy consumer. The tuna industry in American Samoa consumes 54 percent of the island energy! This includes the fuel used for the tuna fishing fleet, the fuel used by the canneries, and the fuel

used to make electricity consumed by the canneries. In the canneries, diesel fuel is used in boilers to make steam for cooking tuna. Diesel is also used for backup electricity generation. Propane is used to heat solder to make a lead seal on the tuna cans.

Smaller users of petroleum products are also very important to the island economy. Figure 2-6 presents some of the major small fossil fuel consumers. The asphalt plant operates intermittently. The figure used is based on continuous road paving. There are at least three construction companies on the island using heavy equipment such as backhoes, earthmovers, and cranes. Some fuel requirements depend on EUD reliability. If the electric power is cutoff for some reason, then the establishments with backup generators will use diesel fuel to generate their own power.

2.3.2 ENERGY CONSUMPTION BY USAGE: ELECTRICAL ENERGY AND PROCESS HEAT

The previous section was concerned with who (what economic sector or entity) consumes fossil fuels. This section takes a slightly different focus. Here, we are concerned with how the energy is ultimately used. This is a very important way to characterize energy demand because, by focusing on how the energy is ultimately used, one can see how alternate sources of

SMALL NON-RESIDENTIAL FUEL CONSUMERS

FIGURE 2-6

energy might apply. Electrical energy and process heat are two major energy consumption categories. Parts (a) and (b) focus on electrical energy. The present Electric Utilities Division generation and distribution facilities are described. Various aspects of electrical energy consumption are then presented including a tabulation of where, who, how, and how much electricity is used. Part (c) considers the energy that is consumed for process heat uses. Process heat refers to the direct use of heat for making steam to cook tuna, making hot water for bathing, making hot soup,... Process heat energy includes non-transportation direct fossil fuel usage as well as some electrical energy usage.

(a) ELECTRICAL ENERGY GENERATION AND DISTRIBUTION

The purpose of this section is to describe the electric generation and distribution facilities of the Electric Utilities Division--a significant component in the island energy flow scheme. The EUD plays an important role in terms of consuming fossil fuels as well as in supplying electrical energy to American Samoa. Seventeen percent of the imported fossil fuel energy is used to generate electricity. The generators, being 28 ± 3 percent efficient, transmit as electrical energy about 28 percent of the fossil fuel energy consumed. The following baseline description will be used in discussions of

energy usage, energy cost, energy supply (plant expansion requirements), and alternate energy possibilities.

Electrical power is generated by two power stations; one located in Satala and the other in Tafuna. The stations are about 12 road miles apart. Satala is the older of the two stations. It is located on the shore of Pago Pago Bay, in the midst of the commercial and industrial center of the island. The Tafuna station went into operation in 1974. Located in an area designated as industrial park, the station serves the western half of the island which is primarily residential. The only large non-residential Tafuna subscriber is the airport which is a mile away. Layouts of the existing Satala Power Station and Tafuna Power Station are presented on Figure 2-7 and Figure 2-8. An inventory of the existing generator units is presented on Figure 2-9.

Satala units nos. 1 through 6 operate 450 RPM and no. 7 at 900 RPM. Unit no. 7 generates at 4.16 KV which is transformed to 13.2 KV for connection to the system. Tafuna units nos. 1 and 2 operate at 514 RPM and no. 3 at 900 RPM.

The condition of the EUD facilities reflects their age, the amount of usage, capital improvements, and current maintenance programs. Although deterioration has affected the appearances of some of the buildings at the Satala Power Station, all EUD buildings appear to be suitable for continued use. The condition of the generators is a function of maintenance.

FIGURE 2-7

SATALA POWER STATION SITE PLAN

(Source: Reference 2-4)

FIGURE 2-8

TAFUNA POWER STATION SITE PLAN

(Source: Reference 2-4)

STATION	UNIT NO.	POWER CAPACITY (KW)	MANUFACTURER	YEAR INSTALLED	STATUS/ CONDITION
<u>SATALA</u>	1	1,000	Nordberg-Electro Products	1962	
	2	1,000	"	1962	
	3	2,000	"	1964	
	4	2,000	"	1964	
	5	3,000	"	1966	
	6	3,000	"	1971	Down until 2/80
	7	<u>2,500</u>	General Motors EMD	1977	
		14,500			
	B1	1,500	These units are portable units leased from the U.S. Army. Plant "B" is currently in use.		
	B2	1,500			
	B3	1,500	Plant "A" is being prepared to be shipped out.		
	A1	1,500			
	A2	1,500			
	A3	<u>1,500</u>			
<u>TAFUNA</u>		9,000			
	1	3,500	Nordberg-Ideal	1974	
	2	3,500	"	1974	Down until 6/80
	3	<u>2,500</u>	General Motors EMD	1978	
		9,500			
	C1	1,500	These portable Army units are currently in use.		
	C2	1,500			
	C3	<u>1,500</u>			
		4,500			

Total Available Generating Capacity: January 1980 = 26.5 MW

Electric Utilities Division Generator Units

FIGURE 2-9

The distribution system complements the generator facilities. Figure 2-10 is a map of the existing power distribution system on Tutuila. Power is distributed by 13.2 KV feeders from each power station. Feeders from Satala serve the eastern half of the island and those from Tafuna the western half.

The distribution system of each power station is a simple radial type which is not generally used by most utilities today. But, due to the topography and configuration of the island, and the economic and social aspects, more reliable systems such as loop or multiple circuit type would not be justified. Some small loops are, however, being incorporated into the system.

Distribution throughout the island is overhead by copper conductors supported on wood poles. Overhead transformers serve all the residential users of electricity and most of the commercial users. Pad-mounted transformers are installed for the larger commercial users. The existing island power system single-line diagram is displayed on Figure 2-10.

The tie line provides for the transmission of power between the two power stations in the event that either one is unable to carry the demand on its portion of the system. The line has been installed with a rating of 34.5 KV along the coast road on the same pole line as the 13.2 KV distribution feeder.

FIGURE 2-10

MAP OF EXISTING DISTRIBUTION SYSTEM

(Source: Reference 2-4)

The distribution system is in good condition. Pole top growth is minimal. There are no damaged or unreasonably tilted poles. There are no missing or damaged insulators. The old ones are being replaced with the latest types.

(b) ELECTRICAL ENERGY CONSUMPTION

Electrical energy is a very convenient and popular energy form which can be easily put to a myriad of uses. This section presents where, who, how, and how much electrical energy is used. Figure 2-11 presents the three major sectors which make up the total island electrical energy usage. Each of the three sectors, Commercial, Government, and Residential, are detailed in Figures 2-12, 2-13, and 2-14, respectively.

The commercial sector is the dominant electrical energy consumer. The canneries play a large role in this sector with 38 percent of the commercial load and 17 percent of the total EUD load. Electricity is put to many uses in the canneries. A large fraction of electricity is used to refrigerate fish until cooking time. The canning machines are electric powered. Motors for presses and cooking dryers consume additional electricity. Boiler water pumps, lights, and air conditioning account for the remainder of the canneries' demand.

100% = 5,880,000 KWHR/MO

ALL ELECTRICAL ENERGY USERS

FIGURE 2-11

(SOURCE: BILL KEENER, ARI, AVERAGE OF 12 MONTHS: APRIL 1978 - APRIL 1979)

COMMERCIAL ELECTRICAL ENERGY CONSUMPTION

FIGURE 2-12

(SOURCE: BILL KEENER, JOHN READER)

GOVERNMENT ELECTRICAL ENERGY CONSUMPTION

FIGURE 2-13

<u>RESIDENCE TYPE</u>	<u>DESCRIPTION</u>	<u>PER RESIDENCE KWHR/MO</u>	<u>FRACTION OF OF TOTAL RESIDENTIAL CONSUMERS (%)</u>	<u>NUMBER OF RESIDENTIAL CONSUMERS</u>	<u>PER. RES. TYPE (KWHR/MO)</u>	<u>COST PER RESIDENCE (\$)</u>
Samoan Style	Refrigerator Lights Television	250	88	3800	950,000	22.50
Palagi Style without Air Conditioning	Above plus water heater, electric stove freezer fans washer dryer garbage disposal	750	7	310	232,500	67.50
Palage style with air conditioning	Above plus Air condi- tioning	2150	<u>5</u>	<u>190</u>	<u>418,000</u>	193.50
Residential Subscriber Totals:			100%	4300	1,590,000 KWHR/MO	

RESIDENTIAL ELECTRICAL ENERGY CONSUMPTION

FIGURE 2-14

Other commercial users are dwarfed by the canneries. The major hotel, a large retail store and a large office building are the next three major consumers, with air conditioning making up the bulk of their load.

Government users comprise 28 percent of the EUD load. The hospital is the number one government user. Air conditioning, lights, medical equipment, some cooking facilities, and laundry machines use electricity at the hospital. The Pacific Missile Range (NASA) uses 43,000 KWHR per month for equipment, lights, and air conditioning. It uses its own 100 KW generator to supply its electrical needs and is therefore not included in the tabulation of EUD electric consumption.

The residential sector uses about the same amount of electricity as the government sector. There are three general classes of residences that are characterized by the electric utilities (and therefore the electrical energy) used by each type. About 88 percent of the residential consumers have relatively small homes with a refrigerator, lights and a television generating a 22 dollar average electric bill each month. Palagi style residences use much more electricity. Water heaters, electric stoves, freezers, fans, washers and dryers boost the electric bill to approximately 67 dollars per month. Adding air conditioning means adding a large number to the monthly electric bill, totalling roughly 193 dollars in this three residential class analysis.

In the three economic sectors, air conditioning requires significant quantities of electrical energy. Conversations with John Reader have indicated that more than fifty percent of the electrical load for the major hotel, hospital, and Government buildings is used for air conditioning. Roughly thirty percent of the total EUD load is used for air conditioning.

(c) PROCESS HEAT

Process heat applications comprise a major category of energy utilization. Process heat refers to energy used for the purpose of heating or cooking. Isolating this ultimate use of energy is important when one considers alternate energy sources, especially geothermal energy, which may be directly applicable to process heat requirements. This section examines the major users of process heat.

Figure 2-15 lists 9 major process heat users in American Samoa. Energy used as process heat amounts to 5.5 percent of the total island fossil fuel energy consumed in 1979. Electrical energy was used to generate only 6 percent of the process heat consumed.

The tuna canneries are the major consumers of process heat, using 76 percent of the total top 9 categories of process heat consumption. Diesel boilers produce saturated steam at 214°F and 125 PSI. 72,000 pounds per hour of this steam

<u>USER</u>	<u>USE</u>		<u>ENERGY REQUIRED PER YEAR</u>		<u>TOTAL BTU PER USER</u>	<u>PERCENT OF TOTAL BTU FOR ALL USERS</u>
			(Gal) (KWHR)	(X10 ¹² BTU)	(X10 ¹² BTU)	(%)
Tuna Canneries	Cooking Tuna	Propane	48,000	0.00436		
	Cafeteria	Diesel	1,680,000	0.23184	0.23661	76.52
	Heating Solder	Electric	120,000	0.00041		
Hospital	Hot Water	Diesel	72,000	0.00994	0.01303	4.21
	Cooking	Propane	240	0.00002		
	Laundry	Electric	900,000	0.00307		
Large Hotel	Cooking	Diesel	9,600	0.00132	0.00398	1.29
	Laundry	Electric	780,000	0.00266		
	Hot Water					
Beef Processor	Cooking Beef	Diesel	24,000	0.00331	0.00331	1.07
Bottling Company	Cleaning	Diesel	12,000	0.00166	0.00166	0.54
Large Bakery	Cooking	Diesel	6,000	0.00082	0.00164	0.53
	Hot Water	Electric	240,000	0.00082		
Large Restaurant	Cooking	Electric	180,000	0.00061	0.00130	0.42
		Propane	7,560	0.00069		
Laundromat	Hot Water Drying	Electric	60,000	0.00020	0.00020	0.06
Residential	Hot Water	Electric	3,253,192	0.01110		
	Cooking	Kerosene	240,000	0.03024	0.04776	15.45
	Laundry	Propane	70,560	0.00642		
					0.3092	100.00

SUMMARY

	(X10 ¹² BTU)	(%)
Electric Process Heat	0.0189	6
Petroleum Process Heat	0.2903	94
Total Process Heat	0.3092	100
Percent of Total 1979 Energy Consumption = 5.5%		

MAJOR USERS OF PROCESS HEAT

FIGURE 2-15

is required for twelve hours each day. 48,000 pounds per hour of steam is required for the remaining 12 hours. The canneries operate six days per week. The canneries use the steam for many tasks. Steam is used to warm ocean water for thawing the stored frozen fish. Steam is used to precook the tuna while it is still on the bone. The final steam cooking, the retort process, takes place after the tuna is put in the can. The cans are washed with steam before and after packing. In another process, fish scraps are cooked to make fish meal. Steam and hot water are used to wash down and clean up the plant facilities. Besides diesel fuel, the canneries consume electricity and propane for their heat content. The employee cafeteria uses electricity for cooking. Propane is used to heat solder to make a lead seal on the seam of newly made tuna cans.

The hospital, consuming 4 percent of the top 9 process heat requirements, is another major user of process heat. A diesel boiler produces hot water at 180°F for showers and sinks. Steam at 214°F and 60 PSI is also produced. Kitchen facilities which utilize this steam include a soupmaker, steam oven, and a dishwasher. Laundry facilities also use steam which is piped to ironing and pressing equipment. The especially dirty laundry is put into a steam bath before being included with the regular laundry. The dental lab and other labs use a small amount of propane to suit their needs.

Electricity is used for cooking and for the heating element in clothes dryers.

A beef processor uses steam to make canned corned beef and cube beef which is imported in bulk from Australia. The steam at 250°F and 50 PSI is used for a precook and retort operation similar to that of the tuna canneries. Electricity is used for canning machines and conveyor belts, but not for process heat.

The major hotel in American Samoa has a boiler for hot water at 180°F which is used by hotel guests in showers and sinks. Clothes dryers and all cooking facilities are electric.

The bottling company in American Samoa uses saturated steam to heat a cleaning compound to 140°F. This cleaning compound is then used to sterilize glass soda bottles so that they can be refilled. The company makes its own carbon dioxide which is used to carbonate the bottled beverages. About 300 gallons of diesel fuel are used each month in a burner to heat chemicals in one stage of the carbon dioxide synthesis process.

A large bakery has two diesel ovens for baking. Electricity is used for hot water and for other cooking equipment.

A milk company produces steam in a boiler at 90 PSI and 214°F. This steam is used to pasteurize recombined milk for island consumption. Some hot water is used to wash down the equipment for sanitary reasons.

The largest restaurant on the island uses propane and electricity for cooking.

A large laundromat uses electricity for heating water for clothes washers and for the drying element in dryers.

In the residential sector, 15 percent of the top 9 process heat consumption is utilized in electric hot water heaters, clothes dryers, and dishwashers. Stoves use either electricity, kerosene or propane. It is reasonable to assume that about 20 percent of the total electrical energy used by residents is used for process heat. The other 80 percent is for air conditioning, lights, televisions,... Almost all of the process heat generated by electricity was consumed by the residential sector. The electric process heat amounts to about one quarter of the residential process heat requirements. Propane and kerosene supply the rest.

Figure 2-16 summarizes the energy flow in American Samoa. The large role of process heat in the residential and industrial/commercial sectors is noteable. Process heat represents 57 percent of industrial/commercial energy use and 47 percent of residential use. One third of the residential energy comes from the direct use of petroleum products, the remaining energy being electric. The industrial/commercial sector is just the opposite, with one third of this energy being electric. 75 percent of the fossil fuel energy used to generate electricity is lost due to generation and power transmission losses.

2-35

FLOW DIAGRAM OF ENERGY CONSUMPTION -- 1979
FIGURE 2-16

2.4 PROJECTED ENERGY DEMAND

The previous sections, describing the present status of energy in American Samoa, provide baseline information in planning for future energy sources and systems. The quantities of energy consumed and the way energy is used have been well defined. Bearing in mind the objective of meeting the total (near and long term) energy demand of American Samoa with the most favorable energy sources and systems, we must now consider how the energy requirements are changing with time.

2.4.1. FOSSIL FUELS AND ELECTRICAL ENERGY

With increasing exposure to the outside world, modernization is taking place, one evidence being an increased appetite for energy. Televisions, air conditioners, and cars are growing in popularity. This change in lifestyle, coupled with an increasing population results in an increasing demand for electrical energy and fossil fuels. Tuna cannery expansion will, over a three-year period, need 50 percent more energy than at present in order to double their present output as planned. New harbor development projects and other island construction projects will require additional fossil fuels. Diesel fuel imports in 1979 were up 35 percent from their 1975 level. The airport is undergoing a significant expansion. Tourism is growing.

A study has been made on the island projected electrical energy demand. A peak projected demand curve for electrical energy has been computed and is presented in Figure 2-17. Data points, the maximum power load on the EUD for each of the last eight years, were collected and plotted. A least squares linear regression line was computed and drawn through the points. Finally, a goals oriented peak projected demand curve was drawn based on a 15 percent conservation of energy in the year 2000. This curve is taken to represent the projected electrical demand on Tutuila.

2.4.2 ELECTRICAL SYSTEM CAPACITY: REPLACEMENT / EXPANSION REQUIREMENTS

The installed generating capacity of an electrical generating system should always exceed the peak power demanded. This is because some equipment must be shut down for servicing at various times and is thus not available to generate power during those times. Also, there must be some leeway allowed for various systems breaking down. According to a study of relatively small and isolated electrical generating systems, it has been found that the installed generating capacity at any point in time should be in the range of 1.66 to two times peak demand for such a system. This means, for example, that in 1985 (see graph) the required system

FIGURE 2-17

PEAK PROJECTED DEMAND CURVE

(Source: Reference 2-4)

generating capacity should be between 28 and 34 MW. The desired installed generating capacity of the generation system on Tutuila is readily derived from the goals oriented peak projected demand curve.

The costs and capacity of the existing electrical generation system serve as a baseline for discussing the pros and cons of various energy source and system alternatives. The existing electrical generator system can be expanded, phased out, or partially used as a peaking unit or a backup system. System capacity is discussed below. System costs are presented in the following section.

The electrical system capacity has been studied by Parsons Company of Hawaii. Using the existing generating system as the initial point, the magnitude and timing of generating capacity expansion was established. The peak projected demand curve was used as the projected electrical demand on Tutuila. The required installed capacity of the generation system was derived from this and used as a demand curve. The magnitude and timing of system expansions depends on this demand curve and also on the amount of energy that the existing system can supply. The supply curve of the existing system depends on the present system capacity and the times of retiring older generating equipment. Low speed units were assumed to have a life of 25 years and high speed units 20 years. The combined effects of demand growth and equipment retirement on

requirements for generation capacity increases are portrayed in Figure 2-18. The significant results of the peak demand analysis are the size and point in time of future expansions. These are:

- 6 MW before the end of 1982
- an additional 15 MW before the end of 1987
- an additional 8 MW before the end of 1992
- an additional 17 MW before the end of 1997.

A word about generator retirement and replacement is in order. As can be seen in Figure 2-18, many of the diesel generators are approaching retirement. The retirement ages used are really rough estimates. In fact, diesel generators can run for many additional years. The catch is that the cost of running them may skyrocket, much to the dismay of electricity subscribers. Diesel generators require lots of maintenance, spare parts, and fuel. As parts wear out, new parts can be bought or made. As the generator ages, more parts are susceptible to required replacement, so the maintenance cost increases with time. In addition to the quantity of replacement parts required, the cost of the replacement parts has been soaring in recent years, along with the rising costs of fuel and lube oil.

FIGURE 2-18

PLANT EXPANSION REQUIREMENTS

(Source: Reference 2-4)

So we can see that generators don't have a death and a burial. Instead they are usually replaced because they become obsolete. Generators are obsolete if they are inefficient compared to a new system. Generators are scrapped because it PAYS to install a new generator or alternate energy system. This decision is made based on scrapping costs, capital investment, lifetime, payback, and, especially cost per KWHR. Note that the Parsons study has assumed that the generators have a definite lifetime and that they are not replaced by more efficient systems before their lifetime ends.

The same cost-benefit reasoning applies on a system level. Choosing to generate power by the EUD versus some alternate system versus some combination of the two systems is a function of the cost of the system. The cost of the present energy sources and systems are presented in the next section.

2.5 ELECTRICAL AND FOSSIL FUEL ENERGY COSTS

The previous section establishes that energy demand is increasing in American Samoa. In order to meet the increasing demand, additional energy facilities must be developed. Even if the demand for energy were not increasing, American Samoa would be in a bind--it is dangerous to be so dependent on fossil fuels given the fact that the cost and availability of fossil fuel is highly unpredictable. This is certain to stifle economic development in American Samoa. The cost of fossil fuel is highly unpredictable. This is certain to stifle economic development in American Samoa.

growth and be detrimental to the island consumers. It may be preferable to replace the present electric generation system with an alternative system providing the costs and benefits warrant such a changeover.

2.5.1 FOSSIL FUELS

Fossil fuels are expensive and are certain to cost even more in the future. Prices have been rising rapidly. Diesel fuel which cost 12.5 cents per gallon in 1973 is now selling for 79 cents per gallon (January 1980). As fuel costs rise, the number of dollars spent for imported oil will rise, increasing the balance of payments deficit. Increasing fuel costs are passed on to the consumer in the form of more expensive airfare, automobile gasoline, electricity, tuna fish, etc., all of which depress the standard of living. Depending on energy intensive air and sea transportation from the mainland for a large part of its needs, American Samoa is being subjected to greater inflation than the mainland, due to cost increases in transportation fuels.

On the happier side, gas in American Samoa is slightly cheaper than gas in the mainland and in Hawaii. This is primarily because there are fewer fuel taxes in American Samoa. There is a local tax, but not a Federal, County, or State tax. Also, since labor is cheaper, smaller handling costs are reflected in the fuel costs. The January 1980 fossil fuel costs are listed in Figure 2-1.

Besides the direct dollar cost, a dependence on fossil fuels implies other, less tangible costs. Air pollution, results from petroleum consumption in cars, planes, boats, boilers,... Another cost is that incurred in the event of a temporary or permanent oil import curtailment. Such an occurrence would cripple the economy. The probability of oil supply problems is difficult to assess, but the impact would certainly be significant. (See Section 2.6).

2.5.2 ELECTRICAL ENERGY

Electricity costs are a very important component of island energy costs. The electricity consumer pays for electricity according to the rate structure established in 1964. Basically, one pays a base charge according to the amount of energy (KWHR) he consumes (on a sliding block scale) plus a surcharge (4.9 cents, January 1980) to cover cost increases due to increased diesel fuel costs. Based on the rate schedules in January 1980, various users were paying approximately the following costs for electricity:

<u>USER</u>	<u>COST. (¢ / KWHR)</u>
SMALL RESIDENTIAL	9.7
MEDIUM RESIDENTIAL	8.5
LARGE RESIDENTIAL	8.2
SMALL COMMERCIAL	10.4
MEDIUM COMMERCIAL	9.2
LARGE POWER	<u>7.7</u>
AVERAGE =	8.95

Rapidly increasing electricity costs are apparently affecting the usage. In Fiscal Year 1979, the EUD added 12 percent more residential customers, but usage increased only 2 percent. This indicates a high elasticity of demand for electricity with respect to price.

The present electric rates do not represent the total cost of electricity to consumers. The electric bills paid by subscribers do not cover the total cost of generating electricity. The bills do not cover operating costs and do not take into account any capital improvement costs.

The rate structure does not take into account increasing personnel, materials, lube oil, and spare parts costs--all of which have risen dramatically in the past few years. As a result, the EUD reported a net operating loss of \$677,000 in Fiscal Year 1979. The EUD is now running a deficit of about \$100,000 per month. Presently, this deficit is made up with general funds. An additional charge to subscribers of 1.5¢ per KWHR would cover this deficit.

Operating costs do not include capital costs, which are an additional and significant factor in the total cost of electricity in American Samoa. The capital improvement money comes from the Department of Interior. Since the beginning of Fiscal Year 1976, 4-1/2 million dollars have been spent on two new generators, one used engine, overhauling and rebuilding engines, and distribution system upgrading. In the near term, 1-1/2 million dollars will be spent to renovate three army

generating units before returning them. Six million dollars has been requested for a cogeneration system and peripheral modifications such as fuel storage tank and fuel line construction. Assuming a rough average of 1-1/2 million dollars of capital improvement money per year, one can compute that an additional electricity charge of 1.9¢ per KWHR would generate these funds.

To compute the true total cost of electrical energy, simply add the average present cost per KWHR to the additional charges to cover operating losses and capital costs. The resulting figure is 12.35¢ per KWHR. This cost is tied directly to fuel costs, representing 70 percent of the EUD operating costs in Fiscal Year 1979 (per John Reader). Further increases in diesel fuel costs will be heavily felt in electric rates.

There is another cost indirectly associated with electrical energy. This cost is proportional to the reliability of the EUD. Whenever power is shut off due to a system breakdown, users of electricity are inconvenienced physically and financially. Power outages are commonplace in American Samoa. Many large businesses have obtained their own backup generators to supplement the EUD provisions.

Since consumers, including the canneries, are being subsidized for electricity, the electric rates in American Samoa seem less expensive than rates on other Pacific islands. The cost figure presented above, however, is more in line with other island rates.

Electric rates in the mainland are generally less expensive for several reasons. Large 50 to 100 megawatt plants provide economies of large scale production, partly offset by the higher cost of labor and diesel fuel there. Hydro, nuclear, and coal systems provide favorable electric rates. Geothermal energy is harnessed on the mainland also, and is producing approximately 1000 MW of power on the West coast.

2.6 OIL SUPPLY PROBLEMS

If fossil fuel is not regularly supplied to American Samoa, serious consequences may be expected. This is especially true in light of the limited island fuel reserves, which are diminishing as the demand for fuel increases. The economy of American Samoa is very vulnerable to and sensitive to fossil fuel cost and quantity disruptions. This section recounts the effect of the 1973-74 oil embargo and describes possible consequences of a temporary or permanent oil import curtailment.

2.6.1. IMPACT OF LAST OIL EMBARGO

In 1973 when OPEC raised prices and restrained supply of oil, everyone became aware of their dependence on fossil fuel energy. The Federal Government reacted by instituting a fuel rationing scheme. This scheme, which varied with time, determined how much oil American Samoa would receive in general, and how much fuel consumers would receive in particular. At the beginning of the embargo, American Samoa was getting 100 percent of the previous year's demand. At one point, the percentage was as low as 90 percent. All fuels were controlled and closely monitored.

The embargo affected all automobile owners. Gas lines proved to be a serious inconvenience to car drivers for about one and a half months in 1974.

At first, people panicked and tended to load up on gas--keeping their tanks full and storing gas in cans at home. This aggravated the problem. There was no odd-even rationing plan. Instead, gas stations restricted their hours of operation so that they wouldn't run out of their month's supply of gas. Gasoline allocations are still in effect and stations still maintain restricted hours. Tension and hot tempers were evident for a few weeks until drivers realized that the supply situation did not warrant desperation.

Some businesses experienced another kind of inconvenience due to the embargo. All users were allotted monthly quotas by the oil companies in accordance with the Federal regulations. Any increases in demand had to be justified before additional fuel was released to the consumer. Clearance for more fuel was obtained by applying to the oil company Product Supply Office which in turn went to the DOE for final approval. Desiring more fuel than they received during the same month of the previous year, some steady customers, new construction contractors, large planes, and boats had to apply for allocation clearance. In order to bypass gas lines, some steady customers opted to obtain their fuel directly from the oil depot. In both cases, paperwork was required to make this possible. Some red tape delays involved up to two months! Most delays, however, were for a few days or a few weeks. Clearance was given in all cases.

Several important entities were allowed to receive 100 percent of their fuel needs. These high priority users included: the hospital, the electric utilities, public transportation (buses and taxis), inter-island airlines, tuna canneries, and fishing boats.

Everyone became more fuel conscious and there were efforts made to conserve. The Government asked electrical users to turn off their air conditioning and unnecessary lights. The oil companies never ran out of any fuels. Generally, everyone

satisfied their oil needs, but not without some inconvenience of paperwork and gas line delays.

The most significant effect of the embargo was the fact that oil could no longer be touted as inexpensive and reliable energy. Prices soared and have continued to rise steadily.

2.6.2. TEMPORARY OR PERMANENT OIL IMPORT CURTAILMENTS

American Samoa is vulnerable to temporary or permanent oil import curtailments. Whenever fuel demand exceeds supply, one can expect rationing and rising prices. Oil companies must follow all Federal regulations--including a Federal rationing scheme. If rationing is necessary, the allocation scheme of priorities and percentages will be determined in a joint effort by the DOE and the oil companies. Gasoline rationing plans and other emergency programs will be instituted by the Federal Government or the American Samoa Government. The oil company plant managers in American Samoa will have virtually no power regarding fuel allocations; their role is to see that the allocation scheme is properly carried out. Three scenarios and their implications are discussed below: a small fuel deficit, a large fuel deficit, and a war.

A reasonably small fuel deficit will make island life more uncomfortable and inconvenient. In any rationing scheme, users

with the lowest fuel allocation priority are the automobile drivers. Car owners will probably feel the pinch more quickly and more severely than other users of fuel. Car drivers will become irritable and gas lines will grow. Carpooling will be encouraged. Gasoline may be rationed in a plan featuring, for example, odd-even-day gas purchase restrictions geared to license plate numbers. Other plans may include minimum purchase requirements or restricted gas station hours. A sticker system preventing motorists from driving their car one day a week may be instituted. Joyrides and Sunday car trips will diminish in frequency. The American Samoa Government may be the initiator of the rationing plan.

American Samoa has some emergency plans already developed for distribution of short supplies. Shortages of gasoline would bring about restricted hours of stations and an odd-even system of distribution, with weekend and holiday closings of service stations. Shortages of diesel would bring about emergency restrictions on air conditioning, lighting, and hot water heating.

With a reasonably small deficit, companies receiving, for instance, 80 percent of their fuel needs may have to restrict their hours of operation. As prices rise and fuel supplies shrink, people and businesses will be forced to make do with the limited fuel supplies and the resulting reduced output. A 4-day, 32-hour work week may be instituted to balance output

with fuel supplies. Everyone will be urged to conserve energy by turning off air conditioners, unnecessary lights, etc...

The tuna canneries, as well as other food related businesses, would probably receive the bulk of their fuel needs. The electric utilities, hospital, taxis and buses, and airlines would probably not be directly affected by restrictions due to a 20 percent deficit. Buses will become more popular and will require additional fuel.

A major fuel deficit will have a larger impact on the island. A major fuel deficit may result in the case of a very serious international political event or, in the longer term, depletion of existing reserves. Other possibilities include the loss of a scheduled tanker delivery or the loss of a storage facility. The probability of a major fuel deficit is much lower than the probability of a small fuel deficit which can be triggered by a more minor event. Although a major fuel deficit is improbable in the foreseeable future, it is, however, a possibility and is therefore worth examining. The upper limit for a major fuel deficit can be taken as the fraction of the total United States consumption that is being provided by foreign sources. This fraction is about 47 percent. One can imagine a very restricted supply of fuel (40 percent deficit) with a commensurately severe allocation scheme whereby only high priority users can obtain a large fraction of their fuel needs. The hospital, canneries, EUD, and public transportation will retain a high priority for fuel

acquisitions. But even high priority users may have to take conservation steps and justify fuel consumption at regular intervals. Non-essential users, car drivers and pleasure boat users, will be cut off from a significant amount of their fuel needs. Gasoline will become scarce and severely rationed to drivers. Airplanes to other parts of the world may be somewhat limited. Tourism will decline.

The EUD may have to ration electricity to conserve limited fuel supplies. The island consumers would be broken down into groups. Group "A" would have its power cut off for a few hours, then group 'B' would have its power cut off for a few hours, etc... With the existing radial power line network, users at the end of the distribution lines may be hurt the most--it is easiest to cut off their power. This is typical of any unlooped feeder system. The EUD has other options to consider in the rare event of a major supply deficit. One option is to cut off power to specific users such as the canneries and other businesses or districts in a group interval scheme like the one mentioned above.

Many employees may lose their jobs, or perhaps a three or four day work week will be put into effect. Bartering for goods and services will become more popular. Unable to adjust to the change, a few people may resort to theft and violence to vent their frustration or to meet their needs. Opportunists might steal fuel and sell it on the black market. Confusion and chaos may result in some cases. In this situation the

possibility of developing an alternate energy source would have great significance.

Another significant import curtailment scenario concerns the effect on oil supplies in the event of a war. Like the major fuel deficit scenario described above, this scenario is improbable but possible. In the event of a war, the number of tankers to American Samoa may be a function of the military utility of the island. Navy ships and Air Force planes would receive the highest priority in terms of fuel allocation. This may affect the fuel allocation to island residents. During a war lasting more than several months, the relatively small fuel storage tanks are certain to be drained if imports are curtailed.

In summary, in any import curtailment scenario where rationing is necessary, American Samoa is treated just like any of the states. The only exception to this rule has to do with the island's military utility. The Federal Government will play a large role in terms of fuel allocations and emergency activities in the event of a war or a substantial fuel shortage. American Samoa is more vulnerable than any of the states only in the sense of its remoteness. Being isolated in the mid-Pacific, American Samoa is extremely dependent on fuel tankers, barges and airplanes to maintain its status quo. Any disruption of these carriers by fuel limitations or by enemy initiatives will take its toll on the welfare of the people.

Based on a 47 percent U.S. dependence on foreign sources for fossil fuels, it is unlikely that fuel shortages will be so severe that air and sea transportation of basic goods (food) to American Samoa from the mainland will be seriously impaired. The economics of American Samoa are more sensitive than on the mainland insofar as the cost of imported goods rises with transportation fuel. Unless prices are controlled, a severe fuel shortage will take a heavy economic toll on American Samoa.

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3. Existing and Potential

Alternatives to ~~Oil~~ Fuels

SECTION 3

EXISTING AND POTENTIAL ALTERNATIVES TO FOSSIL FUELS

Previous Sections have described American Samoa's total dependence on fossil fuels. Faced with high costs and an unreliable supply of petroleum products along with a growing economy, American Samoa needs to look for a more satisfactory energy alternative. Various fossil fuel independent energy sources may be able to provide reliable energy at a favorable cost. The major possibilities include geothermal, solar, biomass, windpower, and ocean thermal energy conversion. Another "source" of energy, i.e., conservation, is also an important means of mitigating oil dependence problems. The selection of optimal alternate energy systems requires a close evaluation of costs, benefits, technological feasibility and applicability.

Figure 3-1 presents the major alternate energy system possibilities for American Samoa. The island energy consumption can be divided into three energy categories: electricity, process heat or cooling, and transportation fuels. The applicability of the alternate energy systems to each energy regime is noted in the Figure. Note that all alternate energy sources providing electricity can provide process heat indirectly through electric hot water heaters, electric stoves, etc:

<u>ALTERNATE ENERGY SYSTEMS</u>	<u>DIRECT ENERGY REGIME</u>		
	<u>ELECTRICAL GENERATION</u>	<u>PROCESS HEAT OR COOLING</u>	<u>TRANSPORTA- TION FUEL</u>
1. Conservation	X	X	X
2. Biomass Combustion or conversion to fuel	X	X	X
3. Solar Air Conditioning		X	
4. Decentralized Solar Thermal water heating		X	
5. Wind Energy electrical generation	X		
6. Centralized Solar Thermal electrical generation	X		
7. Solar Photovoltaic energy	X		
8. Ocean Thermal energy conversion	X		
9. Geothermal Energy	X	X	

ALTERNATE ENERGY SYSTEMS

FIGURE 3-1

In the transportation fuel category, some interesting observations can be made. There are three major ways to replace fossil fuels for transportation purposes. One way is to convert biomass to liquid fuels to be used in engines. Another way is to power vehicles by batteries. This way applies only to light duty ground transportation vehicles such as cars and buses. Heavy duty vehicles, machinery, and boats will require liquid fuel for the foreseeable future. Electrifying vehicles becomes much more economical if an alternate energy source can provide electric rates that are more favorable than those derived from American Samoa's present oil fired generation equipment. Therefore, all of the alternate energy systems that provide electricity have relevance to electric car feasibility. Electric cars are discussed as geothermal new industry potential in Section 4.1.2.

The third way to replace fossil fuels is to use hydrogen. There is general agreement within the aviation industry that liquid hydrogen is their future fuel, and that conversion to it should be well along by the year 2000.

It is often said that hydrogen is the fuel of the future, being able to replace fossil fuels in every way (as a transportation fuel, process heat fuel,...). This may be true. A catalyst may be discovered that splits water by the direct application of heat. Biologists may also perfect an algae or bacterium that gives off hydrogen when activated by

sunlight. But hydrogen will not be the fuel of the present until such breakthroughs have been made. When these will occur is perhaps the greatest imponderable of the entire energy problem. A hydrogen economy may emerge in American Samoa if geothermal energy can provide inexpensive energy and if improvements are made in electrolysis efficiencies. A hydrogen economy is discussed as geothermal new industry potential in Section 4.1.3.

3.1 CONSERVATION

One way to avoid increased dependence on oil is to conserve--to cut waste and get more from each unit of energy used. In a sense, conservation is the best, cheapest, and quickest "source" of energy. Conserving energy is the primary way to ease the "energy crunch" burden until alternate energy sources can be found and made available. Energy can be conserved in three ways: by improving the energy efficiency of buildings, vehicles, and industrial equipment, by substituting energy-efficient goods and services for energy-intensive ones, and by curbing the need for energy services.

The Territorial Energy Office has a variety of energy conservation programs stemming from five major categories. The categories are:

- building efficiencies
- power efficiencies
- transportation efficiencies
- procurement practices
- coordination and awareness activities.

As an example, in the "building efficiency" category, under a DOE approved "state plan", energy conservation measures for schools and hospitals will be examined. Engineers and energy specialists are auditing and redesigning these buildings in order to reduce costs connected with lighting, hot water heating, and cooling systems.

Dollars spent on conservation programs will have a beneficial and significant impact on the island fossil fuel consumption. Conservation alone will ease, but not eliminate, the cost and supply burdens associated with fossil fuel dependence. In order to obtain a more favorable energy situation, alternate energy sources are needed to complement conservation.

3.2 BIOMASS COMBUSTION OR CONVERSION TO FUEL

Organic matter such as crop and forestry residues, marine plant life, and municipal and animal wastes have great potential as an energy source. This organic matter is collectively known as biomass.

Burning or direct combustion is an efficient way to obtain heat energy from biomass. Other techniques to produce fuels from biomass include: gasification and liquefaction to make natural gas- and petroleum-like products; anaerobic digestion, or treating biomass by certain bacteria to produce a synthetic gas; and fermentation to produce gasoline substitutes.

One technique is being actively pursued in American Samoa where a study is underway to assess the possibility of converting 20,000 gallons of tuna sludge waste from the canneries into methane, feedstock, and fertilizer.

Of all the techniques, direct burning of biomass appears to be the cheapest and quickest way for a community to exploit biomass energy potential and is therefore the focus of this section.

Biomass combustion is being actively pursued in Hawaii where several projects are underway. Biomass, in the form of bagasse, is already supplying one tenth of Hawaii's gross energy requirements. Each ton of bagasse (at 4,100 BTU per pound) has an oil equivalent heating value, after combustion efficiencies are accounted for, of a barrel of residual fuel oil.

On the Island of Oahu, the City and County of Honolulu is presently soliciting bids for the design, construction and operation of a municipal refuse-to-energy plant. The project is called Honolulu Program of Waste Energy Recovery (HPOWER). Two possible plant variations are described below.

A typical 1,200 TPD plant which processes the refuse to separate the combustible portion for fuel and ferrous metals for salvage and which would generate 23.4 MW of power would cost approximately \$60,000,000 to construct. After deducting internal power requirements for plant auxiliaries and fuel processing, the net salable power would be about 20 MW.

Another version of the plant would not incorporate refuse processing. In this case, the refuse would be discharged as received onto traveling grates to be burned within the furnace. This approach is less efficient in that heat available for steam production is less than in a boiler fired with only the combustible portion of the refuse. On the other hand, there is a lower requirement for internal power due to the elimination of fuel processing equipment. However, it can be assumed that the net salable energy might be somewhat less than 20 MW. The capital cost of this type of biomass plant would be less than the capital cost of the processed fuel type due to elimination of the fuel processing facilities. The resultant capital cost would be roughly \$49,000,000 in 1979 dollars.

Another example of current biomass developments in Hawaii is a bagasse, municipal refuse and oil-fired plant under construction at Lihue Plantation, Island of Kauai. This plant, with a projected cost of \$27,500,000, is rated at 21.75 MW. It will also produce steam for sugar processing. Oil will be used as a supplementary fuel to insure firm power generation.

It should be noted that all of the foregoing example plants are sophisticated, high-pressure designs requiring experienced operating and maintenance personnel for successful, reliable performance. Less complex, lower pressure plants with fewer trouble points have been built and successfully operated. Such a plant would be more suitable for use in American Samoa than the Hawaiian plants described above.

The biomass material required for a combustion system in American Samoa would have two major sources, crop residue and municipal waste. Presently, the ASG collects and landfills solid waste materials generated on Tutuila. The collection amount averaged 142 tons per day (TPD) in 1978 and is forecasted to be 192 TPD in 1983 and 278 TPD in 1993. Combusting this waste would result in less than one fifth of the original volume of waste, thereby significantly affecting costs and amount of land for landfilling.

The recycling of metals from this waste can further enhance a biomass combustion scheme. Recycling a pound of aluminum, for example, uses only 5 percent as much energy as would be required to produce it from raw ore. With regards to recycling and conversion of waste to usable (electrical or steam process heat) energy, the important role of conservation should be noted. By conservation practiced at the source, by using less plastic and paper in packaging, for instance, or getting more use from fabrics and furniture, we could save more energy than

we would save by combusting the "waste" to reclaim energy. A styrofoam cup reused, for instance, saves more energy than can be obtained by burning it for fuel if the energy cost of replacing it is considered.

Paper in municipal waste poses an interesting dilemma. Although it makes up about one half of the weight of an average load of garbage, it provides more than two-thirds of the total heat value of the load. We would, in the long run, save more energy by recycling the paper, but removing it from the trash will significantly lower the heat value of the remaining material. Paper separation and transportation costs must be figured into an economic study of recycling versus combustion.

Returning to the topic of biomass sources for American Samoa, the municipal waste for biomass combustion could be supplemented by coconut husks and shells, herbaceous plants, and trees and tree parts. As with municipal waste, crop biomass use implies several considerations. One of the major problems in growing plants for energy is that photosynthesis is a relatively inefficient process, seldom exceeding 3 percent efficiency. This means that 97 percent of the solar energy falling on the plant is not converted into stored energy, but is reflected away or dissipated into the atmosphere. Therefore, a large amount of land and a lot of biomass are required to produce significant amounts of energy. Based on yields of 10 to 30 tons of biomass per acre per year, the land

required for a 10 MW organic-fired plant would be at least 1,600 acres (2.5 square miles) and it could be twice that. Two thoughts are in order concerning land used for biomass crops. First, one must consider whether the land could be better used for food production or for residences or businesses. One solution is to grow tree farms on land that is too hilly for crops and homes. But, even in this case, we have a dilemma--perhaps tree farming would be better applied to satisfy the world's growing appetite for paper products or synthetic motor fuels rather than for biomass combustion. A second thought is that, perhaps land for biomass combustion crops could be better used for solar conversion systems. With solar technologies, efficiencies of 10 to 20 percent can be attained instead of the 1 to 3 percent photosynthetic efficiency. Solar systems have the additional benefit of not requiring lots of water, as biomass crops do. The economic and physical possibilities of collecting and drying (by solar radiation or waste heat) suitable quantities of biomass crops needs to be studied. Shipping agricultural material to American Samoa from Western Samoa is a possibility--although transporting it would require a lot of fuel.

A study of a plant which would use a mixture of municipal refuse and agricultural waste as fuels has been made. A plant of this type would have a minimum acquisition time of four years and is therefore not a short term solution to meeting

Tutuila's growing power demand. Initial assumptions for the plant include:

- o An average of 200 TPD of biomass fuel will be collected and delivered to the plant six days per week.
- o The biomass fuel will have an average heat value of 4,100 BTU per pound.
- o The plant will be designed to produce both electrical power and steam for industrial consumption.
- o Steam will be required by the industrial consumer 24 hours per day, seven days per week to enable the plant to operate as a base load plant.
- o The refuse portion of the fuel will be hand sorted or controlled to preclude the introduction of large incombustible items that would damage the furnace grate.

The plant would burn 14,285 pounds of biomass fuel per hour to produce steam at 450 psia and 600°F. A vertical boiler with a traveling grate and super-heater would be used for steam generation. The steam would be used to drive a turbine-generator producing 1,400 KW and 35,877 pounds per hour of saturated exhaust steam at 105 psia for sale to industrial users. Boiler flue gases would be cleaned of fly ash by an electrostatic precipitator before discharge through a stack.

Flue gas heat would be used to improve efficiency by preheating feed water and combustion air. Ash residue would be collected in a bin below the boiler where it would be quenched and dampened with boiler blowdown water and water treatment equipment backwash prior to its being landfilled.

The ventilation air for the receiving/storage area would be used as boiler combustion air to eliminate outside odors. Elimination of water discharges, removal of particulates from the fly ash, and odor control would make this an environmentally acceptable plant at most any location.

The economics of the biomass plant are presented in Figure 3-2. In the analysis of the biomass plant, credit has not been taken for the saving of landfill costs due to the greatly reduced volume of waste and reduced cover requirements. The assumed limitation on the amount of available biomass material results in a small plant from the standpoint of power production, conservatively computed to be 1,400 KW. About 400 KW of this would be required to operate auxiliary equipment leaving a net output to the utility grid of 1,000 KW. This is about 8 percent of the present EUD peak load and 10 percent of the base load requirements. Steam production for industrial consumption would amount to about 35,877 pounds per hour. The value of this steam is computed to be \$6.79 per 1,000 pounds. This price is based on a cost of diesel fuel for steam production of \$0.75 per gallon, adjusted for 80 percent boiler efficiency.

Available installed capacity (KW)	1,000
Installed cost (\$)	7,806,000
\$/KW installed	7,806
Lifetime (yrs)	25
Capacity factor (%)	72
Lifetime output (KWHR)	157,680,000

Annual costs:	
Fixed charges	731,266
Repair, replacement and supplies	348,457
Labor	197,472
Diesel fuel	86,468
Total Annual Cost	1,363,663
Total Lifetime Cost	41,897,575
Annual Credit for Steam	1,824,113
Lifetime Credit for Steam	45,602,825
Net Lifetime Cost	(3,705,250)
Energy Cost (¢/KWHR)	--0--
Lifetime Electrical Revenues @ 9¢/KWHR	14,191,200
Total Revenue/Cost Ratio	1.43

Not incl. Higher fuel costs due to increased diesel costs
 Not incl. Higher steam revenues due to increased diesel costs

Not incl. Savings due to reduced waste disposal costs
 Not incl. Pipeline hookup to canneries

Not incl. Land acquisition and site preparation (existing structures may have to be demolished or relocated).

Assumption: Location near canneries, canneries buy steam
 No adjustment for the return of clean condensate.

ECONOMICS OF BIOMASS COMBUSTION

FIGURE 3-2

The capacity factor of 72 percent is based upon estimated downtime for scheduled and unscheduled maintenance amounting to an average of six weeks per year, and the assumption of 82 percent average load factor when the plant is in operation.

Supplementary diesel fuel oil may be supplied to the plant for boiler warm-up on cold starts and to supplement the refuse fuel in the event its supply is temporarily interrupted or if it has excessive moisture content. Fuel oil consumption is estimated to be 115,290 gallons per year.

An alternate design of this plant would produce electric power only using a condensing turbine-generator. Generator output would be on the order of 3,659 KW; however, a considerable additional capital investment would be required for the condensing system. The power available to consumers would be about 1/4 of the present EUD peakload.

The design and construction of a plant using biomass fuel should be predicated on future expansion by addition of a unit of like capacity when sufficient biomass fuel is available. While the best route for the first unit might be sale of steam plus power production, the second unit might well be for power production only.

3.3 SOLAR AIR CONDITIONING

Being in a tropical environment, American Samoa is in a favorable position to exploit solar energy air conditioning

systems. These systems produce high temperature hot water or low-pressure steam to operate absorption refrigeration equipment for cooling. In a popular system, heat is transferred by exposing an expanded and, therefore cold, gas to the cool interior, compressing it so that its temperature increases and allowing it to discharge this heat outside. In an electrical refrigerator, pumps and compressors are used. In a heat-activated refrigerator, the heat drives a vapor out of a liquid which expands, cools, picks up heat, and is then re-absorbed in the liquid to carry the heat away. The major difficulty with solar cooling units of this type is that temperatures of 200°F or higher are needed. Since flat plate collectors cannot easily produce temperatures higher than 150°F, some kind of concentrating collectors are employed.

Concentrating collectors can heat water to around 265°F. The water is normally at about 200°F when it reaches the generator. One system--by Northrup--requires 150 square feet of concentrating collectors to run one ton of air conditioning. Newer systems may be more efficient and may require smaller collectors.

Solar air conditioning systems have been installed on a number of buildings on the Mainland; one demonstration has been considered in Hawaii. Three companies have received Federal grants to develop economic residential solar air conditioning systems by 1980. Its major competition being expensive electricity, solar air conditioning units could result in

diminished electrical generation requirements and fossil fuel demands. Air conditioning, used year round in American Samoa's tropical environment (primarily in government buildings, the hospital, and the hotel), consumes 30 percent of the island electricity. To generate this much electricity, 156,000 gallons of diesel fuel are needed each month.

There are two ways that solar air conditioning units can be introduced to American Samoa--by being installed with new buildings or by being retrofitted into existing buildings. The economics are different in each case, the former being most favorable. Hybrid solar systems which provide hot water and air conditioning should be considered, as they can be more cost effective than a system providing heating or cooling only.

3.4 DECENTRALIZED SOLAR THERMAL WATER HEATING.

The radiant energy of sunlight is a potential alternate energy source for American Samoa. Using heat from the sun to produce hot water represents the simplest and most practical application of solar technology. A blackened surface can absorb 85 to 90 percent of the energy striking it.

The collector is basically a flat rectangular box containing a black absorption plate fitted with water passageways which are connected by manifold pipes or tubing. The absorption plate is backed by several inches of insulation,

and the entire box is covered with a transparent glazing material such as glass. The sun's radiation, trapped by the glazing, warms the absorption plate and the waterways. Heat transfer to the water is enhanced by the use of heat-conduction materials. The hot water leaves the collector via the outlet manifold pipe and is piped through insulated piping to an insulated storage tank. Water from the tank is recirculated for additional heating by other insulated pipes connected to the collector's inlet manifold.

There are two major types of solar water heating systems: forced circulation, and thermosiphon. The forced circulation system uses a small electric pump to circulate the heated water; it is activated by solar sensors and a differential temperature controller. The thermosiphon system is passive, relying upon thermal convection to circulate the water, and requires the storage tank be located higher than the collector. Temperatures above 200°F are possible using concentrating collectors, tracking devices and related techniques.

With a properly designed and insulated system, water hot enough for domestic use will be available even after several days of heavy overcast. Backup conventional heaters can be used in case of extended periods of inclement weather.

Solar water heating systems are on the market now and many have been installed in Hawaii and in California. Good quality

equipment is initially expensive, but the capital investment is recovered from savings on utility bills-usually in five to ten years, depending on the amount of the initial investment, the availability of incentives such as tax credits, the lifetime of the equipment, and consumer utility rates.

With a high cost of electricity and an average incidence of direct clear day solar radiation in American Samoa of 3,007 BTU per square foot per day (one and a half times the amount in Hawaii), the territory is particularly well-suited for solar water heating. There are approximately 1200 water heaters in American Samoa. A large fraction of these are in government buildings. Solar water heaters may be used in American Samoa as replacements for, or additions to, conventional electric heaters for residences and businesses. Presently there are 36 solar water heaters in American Samoa. With the addition of a solar water heater, one family of four was able to cut its monthly electric bill by one third.

If 1200 solar heaters were installed in American Samoa and each heater saved 400 KWHR/month in electricity, then American Samoa would save 42,000 gallons of diesel fuel per month. This is about 8 percent of the EUD load. Much larger savings can be realized if businesses using boilers for making hot water or steam would install solar heaters to preheat water before entering the boiler.

3.5 WIND ENERGY ELECTRICAL GENERATION

Wind energy is a potential alternative power source for American Samoa. Presently available wind machines are of two basic designs (see Figure 3-3). One is a horizontal axis with propellor-like blades. The other has a vertical axis with (eggbeater) blades that are not affected by changes in wind direction. The blades turn a generator which produces electricity.

The energy that can be harnessed from wind in American Samoa depends on the nature of the wind: speed, variability, and location. It is reported that prevailing easterly winds average 8 to 13 miles per hour; however, this is not necessarily an indication of the extent of wind power potential on the island. The effects of surface heating could produce more favorable winds at certain locations which would have to be identified by a comprehensive program of wind speed measurement. Wind variability has a large effect on wind machine output. Even though a wind machine may be rated at, for example, 500 KW, the power that the wind machine can deliver diminishes (as a cubic function of wind speed!) whenever the wind relents. Therefore, unless wind speed is continuously present at a reasonable velocity, wind machines cannot provide reliable power and can be used only as a supplemental energy source to a more reliable primary source.

FIGURE 3-3

WIND TURBINE GENERATOR TYPES

Perhaps, by strategically locating many wind machines over a wide area, reliable firm power may be generated.

Wind inconsistencies could be smoothed out if wind machines are coupled with an energy storage medium. Batteries such as sodium-sulfur cells could be charged while the wind is blowing and then used to maintain a required output when the wind dies down. Presently, battery storage systems are expensive, and batteries last only a few years. A five megawatt hour utility battery will consist of about 15,000 cells and will fill a large, high room. Problems of heating, cooling, fault detection and fault isolation, reliability, cycle life, and safety need to be addressed. Large scale production is 15 years away. In the long term, superbatteries may be used for wind and solar energy smoothing, utility load leveling and electric cars.

Another energy storage scheme is to build a pumped-hydroelectric plant to store surplus energy for later use. This storage medium may be coupled with wind and solar energy systems. When surplus energy is available, water is pumped into an upper reservoir. When power is needed from the storage reservoir, water is allowed to fall through a turbine into a lower reservoir, thereby generating electricity. Pumped hydro capital costs are high (\$1,500 per KW for a 5 MW system) but considering its long life and comparing it to the alternatives it may provide the most economical energy storage

medium in the near and long term. American Samoa's steep terrain greatly favors pumped hydro by permitting a very high head to be developed over a short distance. A head of several thousand feet should be feasible at some locations.

In considering windpower, the system economics need to be examined. A popular vertical axis wind machine made by Alcoa has a generating range of 10-30 mph, height of 135 feet and a power rating of 300 KW (based on a power capacity of 311 KW at 30 mph). Mean annual wind speeds of 12 mph and 18 mph will yield 287,700 KWHR/YR and 866,800 KWHRS/YR, the average output power being 33 KW and 99 KW respectively. The installed cost would be the sum of the base cost, shipping cost, site preparation and erection, and connection to the existing power grid. There may be some phasing and synchronization problems associated with hooking the wind machine to the existing EUD power grid. Additional costs would be incurred for land acquisition, engineering and supervision, and modification of wind machine to withstand typhoon winds and salt corrosion. Wind machines have the advantage of being non-polluting with no fuel costs and low maintenance requirements. Annual maintenance and operating costs could be about 2 percent of installed cost. The lifetime of the wind machine is hard to predict due to lack of sufficient operating data. A conservative estimate of 15 years seems reasonable. Some tabulations of wind power economics are presented in Figure 3-4.

WIND MACHINE: Alcoa 300 KW Vertical Axis Wind Turbine

Installed Cost:	
Base Cost	\$185,000.
Shipping	15,000.
Site Preparation and Erection	40,000.
High Wind and Corrosion Modification	40,000.
Power Grid Hookup	<u>20,000.</u>
TOTAL INSTALLED COST:	\$300,000.
ESTIMATED LIFETIME (Years):	15.
ANNUAL MAINTENANCE AND OPERATING COSTS:	\$ 10,000.
LIFETIME MAINTENANCE AND OPERATING COSTS:	\$150,000.
TOTAL LIFETIME COSTS:	\$450,000.

	MEAN ANNUAL WIND SPEED (MPH)		
	12	14	18
Output Energy per year (KWHR)	287,700	475,300	866,800
Average Output Power (KW)	33	54	99
Lifetime Energy Generation (KWHR)	4,315,500	7,129,500	13,002,000
Installed Cost per KW (\$/KW)	9,091	5,556	3,030
Energy Cost per KWHR (¢/KWHR)	10.4	6.3	3.5
Revenues at 9¢/KWHR	388,395	641,655	1,170,180
Revenue/Cost Ratio	0.86	1.43	2.60

Not incl. Land Acquisition Costs.

WIND POWER ECONOMICS

FIGURE 3-4

With a mean annual wind speed of 14 mph, the average output power for the wind machine is only 54 KW, costing 6.3 cents per KWHR. This is a small output compared to American Samoa's electrical energy demands. In order to supply 3 megawatts of power (25% of the EUD load) at 14 mph, 56 wind machines need to be installed.

Larger wind machines with a 2 or 3 MW capacity are being developed. Their costs and wind regimes should be studied. Wind machines may become more practical with mass production and technological improvements.

The tabulation of wind energy economics, indicates that wind energy may be an economically feasible near term alternate energy source for American Samoa. Wind power economics is a strong function of wind speed. American Samoa apparently does not have wind regimes comparable in magnitude and extent to those in Hawaii (where one wind site has a mean annual wind speed of 19 mph), meaning that wind machines in American Samoa may be less cost effective. Wind data needs to be collected to determine the magnitude and the economic feasibility of the wind resource. Since wind over American Samoa probably fluctuates significantly, wind energy is only valuable (in the near term) as a supplemental energy source and not a reliable base load energy prospect. Other alternate energy sources need to be examined for base load application.

3.6 CENTRALIZED SOLAR THERMAL ELECTRICAL GENERATION

Heat from the sun can be converted to electricity by solar thermal systems. The most promising system consists of a large field of mirrors which track the sun and focus on a boiler mounted on a tower. Fluid in the boiler is vaporized to run a turbine coupled to an electric generator. A major advantage of the system is its high overall efficiency: concentrating the sun's energy in the boiler fluid is 85 percent efficient, and the turbine efficiency is 40 percent. Other advantages include free fuel and no pollution. The deterrent to immediate reliance on the sun is the cost of the plants and the land needed for energy collection. The problems and expense lie in providing for the power and control of tracking and in the cost of mirror materials.

Technology advancements and mass production will enhance system economics. The first commercial units could be on line in a decade. Estimates for a plant with enough thermal storage to provide for 12 hours of daily operation, range from \$1,000 to \$2,500 per KW. Economies of scale favor very large plants.

Because the sun doesn't always shine, solar thermal systems must be considered as supplementary energy sources and not base load energy sources unless coupled with a storage system to smooth out sun fluctuations. One approach is to store hot fluid in huge supplementary tanks.

Steam cannot be stored successfully and so steam plants require a separate storage system, with crushed rock for instance, and considerable energy is lost in the exchange. The technology of heat storage is not well developed and continued research may produce new solutions.

It may also, of course, prove attractive to store energy in electrical form (in batteries), as gravitational potential energy in pumped water or compressed air, as chemical energy in hydrogen, or as mechanical energy in flywheels.

A 10 MW plant to demonstrate engineering feasibility is now under construction at Barstow, in the California desert, and scheduled for completion before 1982. At Barstow, the heliostats (sun tracking mirrors) alone will cost \$3,000 per KW. The total system costs \$10,000 per KW.

In a related recent proposal the installation of a solar steam generator at Port Allen, Kauai is discussed. This steam generator would produce steam to operate an existing 10 MW power plant turbine. Solar energy would be concentrated by a 200-acre field of 2,400 concave, parabolic mirrors, each about 15 feet in diameter, to provide the heat source for steam production. Projected cost of the project is \$61,100,000, equating to an installed cost of \$6,110 per KW, excluding the cost of the existing plant equipment.

Solar thermal electric generation is well-suited for American Samoa's sunny climate. These systems provide unfirm

power as a function of sunlight unless coupled with a storage system. The systems are most suitable for intermediate and peaking applications--that is, to provide additional electricity during heavy use, daytime hours. The systems will probably not be commercially available for 10 years.

3.7 SOLAR PHOTOVOLTAIC ENERGY

Solar radiation can be converted directly to electricity with solar cells. Photovoltaic cells are semiconductor materials such as doped silicon crystals. Virtually any power output can be supplied by combining the cells into a larger solar array. Solar cells may be used by utility networks or by individual home owners. Advantages include free fuel, no pollution, and long lifetimes. Deterrents to widespread commercial use are the land area needed and, more importantly, the cost of the system.

Silicon cells currently cost \$10,000 to \$15,000/KW, delivered and ready to be installed. This is a very high price that must be brought down to more like \$350 to \$500/KW before it will be possible to build plants that are economically competitive in power applications. It is estimated that the cost could drop to \$500/KW with mass production in 1986. Power plant costs, exclusive of the cells, are estimated to be about \$750/KW. This includes some battery storage, regulation, and DC to AC conversion.

Achievement of these goals requires a considerable improvement in semi-conductor manufacturing technology, further reduction of array cost, reduction of other system costs, and mass production.

The intermittent nature of sunlight implies that solar cells are best suited for supplementary, and not base load, power. There is the possibility of using solar energy in conjunction with a storage medium as has been discussed earlier.

Despite the high installation cost per unit of power produced, solar cells are in demand for a variety of remote applications. For example, the space industry and the boating industry require solar cells to charge batteries and power communication systems.

Wilcox Memorial Hospital, Lihue, Kauai, is the site for a DOE funded solar voltaic energy demonstration project. The project, having a projected cost of \$1,800,000 will be designed to produce 85 KW peak electrical power to be used for air conditioning and hot water heating. This equates to an installed cost of \$21,176 per KW. This is partially offset by the fact that the system is a hybrid solar heating/photovoltaic system which provides hot water as well as electricity.

In summary, solar cells, providing additional electricity while the sun shines, are most suitable for intermediate and peaking applications. Solar cells will probably not be economically feasible for American Samoa until 1986. When and

if they become economical, solar cells can provide large amounts of clean centralized or decentralized power for residences and businesses.

3.8 OCEAN THERMAL ENERGY CONVERSION

Ocean thermal energy conversion is a promising alternate energy possibility. Just as a conventional power plant requires the heating of a working fluid--usually water--and its subsequent condensation, OTEC uses a low-boiling-point fluid such as ammonia, which is boiled using the heat from warm surface water. The ammonia steam turns a turbine, generating electricity, and is then condensed by cold sea water for reuse. The difference in the temperatures of the surface and deep cold water should be at least 40°F making the tropical seas a preferred location. Such a system has a theoretical efficiency of approximately 7 percent, but an actual efficiency of 2 percent. Therefore, large heat exchangers and pumps are required to produce significant quantities of power.

Cold water is brought to the surface from depths of several thousand feet in huge pipes, and the heat exchange takes place either in floating or land based plants. A working OTEC plant will require a large initial capital investment and continuing maintenance, but the "fuel"--temperature differences--is free. The deep ocean water is also rich in nutrients which can be used by an aquaculture industry.

A major advantage of OTEC is that the energy stored in water as heat is continuously available. Thus, the difficulty of the intermittence of most solar conversion systems is avoided. OTEC can provide firm base load power. An OTEC plant situated offshore will have to transmit power through submerged cables to the land. Or perhaps the plant could electrolyze sea water and pipe hydrogen fuel to shore.

OTEC systems are in the developmental stages. Milestones for OTEC development are considered to be: (Reference 3-2)

--A 1 MW floating OTEC plant in 1980 off the Big Island of Hawaii.

--A 40 MW plant in 1986 (actually a cluster of four 10MW modules on a single barge) to demonstrate engineering feasibility.

--A 100 MW plant in 1990 to demonstrate commercial feasibility.

--The first commercial 100 MW plant in 1992.

The OTEC program has yet to answer basic questions of approach, such as closed-cycle versus open-cycle (that is, condensing or non-condensing).

Heat transfer rates, biofouling, corrosion, and cleaning methods have yet to be adequately explored. Such conceptual concerns, together with the enormous amount of hardware development, could lead to program slippage. Hawaii is very active in OTEC development, with several major projects currently underway.

A recent full-scale review of OTEC technology has concluded that, after some experience has been gained, the capital cost in today's dollars should come down to about \$4,000 per kilowatt. Clearly, OTEC will never in the foreseeable future compete with geothermal, costing about \$1,200 per KW.

American Samoa appears to have conditions favorable to OTEC development. The OTEC resource (depths and temperature differentials) needs to be confirmed.

3.9 GEOTHERMAL ENERGY

Geothermal energy is an alternative energy source worthy of careful consideration for American Samoa. The following subsections will discuss technical and historical aspects of geothermal energy, and then describe a potential plant for American Samoa. Providing a geothermal resource exists on American Samoa, the technology is sound and the economics are favorable for the production of electricity and, for process heat purposes, steam. Geothermal energy may be able to provide firm power in the near term to American Samoa.

3.9.1. HISTORY

Geothermal energy is primarily the product of a few elements in the Earth's core which release energy as they radioactively decay. This energy is then converted to heat

energy that keeps the core molten. In certain places, geological forces thrust large pools of this molten rock relatively near the Earth's crust and these form the so-called geothermal "hot spots". If the hot rocks are fissured or porous and contain water, a "geothermal well" is in the making. Drilling a hole several thousand feet into the ground is required to tap the geothermal energy as hot water or steam.

In the early use of geothermal sources, health rather than energy was the goal and hot springs were popular gathering places. Italy was the first country to generate electric power with natural steam by opening the Lardarello Field in 1904. This dry steam field now has 396 MW of generating capacity. Other developed fields exist in New Zealand (where wet steam fields produce not only 170 MW of electric power, but heat for homes and industry as well); in Japan (50 MW); in Mexico, which has just installed a 75 MW generator at Cerro Prieto; and in Russia and Iceland.

In Iceland geothermal heat has been used for a long time in buildings; it provides almost all of the heat for the 100,000 people in the capital, Reykjavik. Several hundred American homes and businesses are heated in this way in Klamath Falls, Oregon and Boise, Idaho.

The largest geothermal power generating complex now in operation is Pacific Gas and Electric Company's field at the Geysers, some 90 miles northeast of San Francisco. At the

present time, 900 MW of electric power are generated by 11 turbine generators (the largest has a capacity of 106 MW). The Pacific Gas and Electric Company's complex at the Geysers produces more than one-third of San Francisco's electricity. Plans call for an additional 110 MW per year, bringing the total to 1,450 MW by 1985.

Production wells at the geyser field average 150,000 lbs/hr of dry steam, and about 13 wells can supply the standard 110 MW generator station with the required 2 million pounds of dry steam per hour. The reservoir pressure is 500 PSI and the turbine intake pressure is 100 PSI.

Of particular relevance to American Samoa are examples of small geothermal plants in operation or being implemented. The geothermal exploration and development in Hawaii is one such example. Following various investigations and initial attempts under the sponsorship of the University of Hawaii, a very promising geothermal well was completed in the Puna area of the Island of Hawaii. The well site is in the east rift zone of still active Kilauea Volcano. Steam production rate has been measured at 54,000 pounds per hour, 165 psig and 372°F. when throttled with a 3-inch orifice. The completion cost of the well to a depth of 6,435 feet was approximately \$1,500,000.

A 3.5 MW wellhead generator plant will soon be completed to produce electrical power for supply to the local utility system. The plant is to be a demonstration of the feasibility of power production and to ascertain the peculiarities of

operating and maintaining a geothermal power source. The total cost is projected at \$6,400,000, with close to \$200,000 of this cost being for a visitor's center.

3.9.2. A GEOTHERMAL PLANT FOR TUTUILA

The initial geothermal power plants on Tutuila may consist of two geothermal wells supplying a total of 10 MW. This estimate is based on a generating capacity of 5 MW per well. Expansion to 20 MW would occur with increasing confidence and power demand. The first 5 MW power plant could be installed, shaken down, and on line within 18 to 24 months after the first successful exploratory well has been drilled and evaluated. Turbines International, Inc. has indicated that a complete 5 MW plant turnkey installation could be finished 18 months after notification of purchase.

A flow diagram of a possible type of geothermal plant (similar to the design in Hawaii) is shown on Figure 3-5. A phase separator is provided to separate the majority of the liquid from the geothermal fluid. The liquid, which is routed to a percolation basin for disposal, carries most of the dissolved solids. The steam portion, which contains noncondensable gases, is further cleaned of excess water in a scrubber to protect the turbine from erosion. A muffler is provided for noise abatement of released steam during system warmup and on the occasion of a sudden shutdown of the turbine.

FIGURE 3-5

GEOTHERMAL POWER PLANT FLOW DIAGRAM

The turbine is a multi-stage condensing type which exhausts to a shell and tube condenser. Condenser water is the condensed geothermal steam which is recirculated through a mechanical draft cooling tower. Noncondensable gases are drawn off the condenser by a two-stage condensing ejector which discharges the gases to a scrubber for absorption of hydrogen sulfide and returns condensed water vapor to the condenser water system. There are various options available for condensing system arrangements, the best of which can be determined for a given situation only by a comprehensive analysis.

Geothermal steam and fluid characteristics are highly variable and have a primary influence on the design and cost of a geothermal power plant. Some of the variables include the total dissolved solids in the fluid and their scaling, corrosive, and precipitation characteristics; the dissolved gas content, including hydrogen sulfide, an air pollutant; and the presence of mercury which constitutes a health hazard. Environmental protection measures may include noise and odor abatement equipment.

The capacity factor of 82 percent is based on the average annual load factor achieved by five Japanese geothermal plants during 1977 having outputs in the range of 8 to 24 MW. This capacity factor is higher than that of a wind power plant, a biomass plant, or an oil-fired generator.

The economics of such a system need to be examined. Figure 3-6 presents the economics of a geothermal energy system for American Samoa. The costs for preliminary geothermal exploration are presented in the recommendations (Section 5.2) and are not included in this plant analysis. The economics for geothermal exploration overlaps with the plant economics presented below in that a successful temperature test well may be designed and used as a production well.

Geothermal wells cost about \$450/KW. This is based on obtaining two 5 MW wells for every 3 holes drilled at a cost of \$1,500,000 per hole. Replacement of wells (one every ten years) during the 30 year plant life is estimated to cost \$6,000,000. The power plant itself costs approximately \$950/KW to \$1,500/KW for a total geothermal system cost of \$1,400/KW to \$1,950/KW. The power plant consists of a turbine, generator, condensers, and various peripheral equipment such as an H_2S scrubber. Turbines International, Inc. has indicated that a complete plant can be installed with a turnkey installation cost of \$950/KW which equates to about \$4,750,000 for a 5 MW system. Geothermal energy would cost about 2.5 cents per KWHR delivered at the busbar. This figure may be further reduced by as much as 1 cent per KWHR if the heat discharged from the wellhead generator is recovered and sold to the canneries. By way of comparison, modern oil generating plants and associated equipment now cost about \$800 to \$1000 per KW and produce electricity at about 6 to 8 cents per KWHR delivered at the busbar based on a diesel fuel cost of \$0.75 per gallon.

1. Plant and well field capacity 10 megawatts.
2. Sale of steam to plant 30 mills per KW hour about 80% of oil equivalent at \$22.00/bbl.
3. Plant operating 82% of capacity.
4. Well drilling one dry well for every 3 successful at average well cost of \$1,500,000.
5. Average well capacity 5 megawatts.
6. Three wells drilled, total cost \$4,500,000.
7. Cost of two 5 MW plants complete with turbine, generator, and peripherals: \$9,500,000. (excluding wells)
8. Total well, plant and collecting system for two 5 MW capacity \$14,500,000, including contingency of \$500,000.
9. Estimated direct yearly operating cost for two 5 MW plants in American Samoa is \$800,000. This is based on an extrapolation of HECO's estimated operating cost of \$600,000 for the University of Hawaii 3.5 MW plant at Kapoho. Indirect cost for royalties and overrides are estimated at \$323,000. Total operating expense: \$1,123,000.
10. Total gross sales per year 10 MW at 82% capacity if sold at 90 mills/KWHR ----- \$6,457,500.

NET OPERATING COSTS/YEAR

Operating expense (direct and indirect costs)	\$1,123,000
Depreciation (30 years)	483,333
Reserve for well replacement (one every 10 years)	<u>200,000</u>
	\$1,806,333

Cost/KWHR: 25 mills/KWHR

All price are calculated in 1980 dollars.

GEOHERMAL ECONOMICS

FIGURE 3-6

3.10 SUMMARY

With the goal of fossil fuel independence in mind, the nine major alternative energy systems are listed below along with their highlights. The systems are listed according to their importance to American Samoa based on costs, benefits, technological feasibility, and applicability.

Geothermal energy appears to be a very high priority alternate energy system. If a significant resource is located promptly, then a geothermal power plant should be the highest priority and could contribute significant power to American Samoa in as little as 18 months after successful exploratory drilling. A geothermal plant could provide firm power with the EUD generators functioning as peaking and backup units. Presently harnessed in many locations such as Hawaii and California, geothermal is technically feasible, non-polluting, economically favorable, and predictable, costing \$1,400 per installed KW and generating power at 2.5 cents per KWHR at the busbar. With the advent of geothermal energy in American Samoa, lower priced electricity and steam will spur industrial development, make electric vehicles more economical, and perhaps sometime in the future begin a transition to a hydrogen economy. Geothermal energy can

create a higher standard of living for the people of American Samoa.

Wind energy is ranked second in importance. If a good location providing a favorable wind speed is found, then wind machines are economical near term partial solutions to the energy problem. They are partial solutions because they provide intermittent power as a function of wind speed and hence can be used only as supplemental power to another base load source. Besides large capital costs per installed KW considerations, there may be some phasing and synchronization problems in hooking wind machines to the existing EUD power grid. American Samoa apparently does not have high wind regimes comparable in magnitude or extent to those in Hawaii, meaning that wind machines in American Samoa are less cost effective. Many wind machines are needed to make a large contribution: at 14 mph mean wind speeds, 56 machines need to be installed to supply 25 percent of the present EUD peak load. American Samoa is obtaining a wind machine thanks to the DOE. This wind machine merits careful attention as the future of wind machines in American Samoa will depend on this example. Wind data needs to be collected and an optimal location chosen.

Third in importance to American Samoa is a biomass combustion plant. Technically feasible and with an acquisition time of four years, the plant offers some favorable

economics. The plant capital and operating costs are more than paid for by steam sales to the canneries. Electrical sales of about \$14 million over 25 years will further increase revenues. Effective revenues are enhanced even more when one considers increases in steam revenues (as diesel costs rise) and savings due to reduced waste disposal requirements. However, although the biomass plant can provide fairly reliable firm power, the available electrical output is restricted (to 1000 KW) due to the limited amount of island biomass available. The plant could provide only 10 percent of the present EUD base load or 8 percent of the EUD peak capacity. A large capital cost (\$8 million) is required to do this.

The major biomass plant energy consumers are the canneries, and the impact on them is very marginal. The canneries would not save much money since they would be charged for steam according to its fossil fuel equivalent value. And, because of reliability concerns, the canneries may have to be coerced to buy steam from the plant! A related issue is whether the plant can be situated near the canneries (for efficient steam distribution) without extreme costs for land or for demolition or relocation of existing structures. Geothermal and wind energy are given a higher priority because they have the potential for satisfying a larger fraction of the island's energy needs, thereby directly and positively impacting all businesses and residences. It should not be inferred that the

biomass plant is more trouble than it is worth, because 1 MW of very economical electricity and economical waste disposal are not to be lightly disregarded. The biomass plant merits further study.

Conservation deserves to be mentioned as an immediately important alternate energy source. While not a total solution to the energy situation, conservation can impact all energy regimes (electricity, process heat, transportation fuels,...) in the near term and provide a large contribution to energy self-sufficiency and diminished fossil fuel demand.

Next on the list are solar water heating and solar air conditioning systems. Solar cooling and water heaters appear to be near term and feasible for homes, government buildings, and businesses which are presently using 100% electric cooling and water heaters and diesel boilers for hot water and steam. The potential contribution to energy self-sufficiency is significant, but not large. Solar air conditioning may be able to make a contribution to energy independence if installed in government buildings and in businesses, although economic feasibility has yet to be confirmed. Combined heating and cooling units can be more cost effective than a system that provides heating or cooling only.

The remaining alternate energy systems are mid to long term. Economic and/or technical feasibility considerations indicate that solar thermal electrical generation,

photovoltaic energy, and OTEC are at least five to ten years away. In that time, better ways may be available to generate and process biomass for liquid fuels. With all of these systems, a range of issues such as intermittency, energy storage, large land requirements, and massive high technology equipment maintenance need to be addressed. An outstanding factor in their favor is that the energy for these systems is from the sun and is therefore reliable and, considering American Samoa's geographic location, relatively intense. Intermittency is a consideration for all solar systems except OTEC.

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4. Geothermal Assessments

SECTION 4

GEOHERMAL ASSESSMENTS

Previous sections have established a need to look for more reliable sources of energy. Geothermal energy appears to be the best alternate energy source potentially capable of providing large amounts of near term firm power to American Samoa if the resource is confirmed promptly. This section is an assessment of various aspects of geothermal energy. These assessments include:

- impact on existing industry
- potential for new industries
- impact on residents: environmental and socio-economic issues
- legal and regulatory issues concerning geothermal development
- technical geothermal potential: extent of the geothermal resources in American Samoa.

4.1 IMPACT ON INDUSTRY

If an economical and dependable long-term geothermal energy source were developed in American Samoa, the industrial sector would be significantly impacted. If geothermal energy can provide inexpensive electricity and process heat, dependence on imported fossil fuel could be substantially reduced or eliminated. A reasonably priced

and reliable source of electricity and process heat would be greatly welcomed by business. Many new industries may emerge including health spas, large domestic and transshipment refrigerated warehouses, aquaculture, wood products, and ocean mineral processing. Electric vehicles could replace present gas consuming cars in 5-10 years, thereby significantly reducing the island's fossil fuel dependence. In the long term, a hydrogen economy may emerge in which airplanes and fishing boats use hydrogen as a transportation fuel.

4.1.1. INDUSTRIAL POSSIBILITIES

Geothermal energy could have a very beneficial impact on existing commercial establishments. A geothermal energy source will decouple the present energy cost and fossil fuel cost relationship, probably resulting in reduced energy costs which are certain to encourage commercial expansion and growth. Reliable and reasonably priced electricity will be enthusiastically welcomed by all commercial consumers, especially the large users such as the canneries, the hotel, and large retail stores.

In addition to electrical benefits, large savings are possible if the geothermal by products of steam or hot water is used as direct heat source. The tuna canneries, using steam for thawing, cooking, and cleaning, presently require 72,000

pounds of steam per hour, and will require even more in the near future in order to double the tuna fish output as planned. For most of the cannery steam usage (in which steam directly contacts food), steam without impurities is required. Steam directly from the geothermal well could be filtered and used directly, or a binary system could be used in which geothermal steam is the heat source. Based on diesel fuel cost of \$0.75/gallon, the canneries spend \$1,260,000 per year on fuel to generate steam. The geothermal developer could make arrangements for sale of steam to the canneries at a rate which is less than what they are presently paying for diesel, and at a rate which is not subject to the unpredictable price and availability of fossil fuel.

Other commercial establishments may benefit from geothermal process heat. These include the beef processing company, the major hotel, the bottling company, and the milk company.

If a geothermal source can replace fossil fuels, the awareness that the island has a reliable energy source providing reasonably priced electricity and process heat will encourage existing businesses to expand and new businesses to develop. The obvious and most transient new activity resulting from geothermal development would be the construction of the production facilities at the wellsite. In addition, there would be many potential new businesses, the number being limited only by one's imagination.

With lower electricity costs, large refrigerated warehouses become more feasible. These can be used for wholesale food and fish storage for island consumption. Refrigerated warehouses may also be used as temporary storage for transshipment. This will make Pago Pago Harbor a more important transshipment point for Pacific traders.

Geothermal waters offer a potential touristic attraction to American Samoa. Generally the waters contain minerals thought to be beneficial for various ailments (and this seems to be a wide range, judging from the many geothermal clinics in Europe, mainland United States, and Japan) and the essential ingredient for establishing a spa would be present. Around a spa, inventive management could, as it has for many centuries and in many parts of the world, construct facilities to attract and accommodate visitors seeking health treatment.

Most spas have hotels for their guests near the thermal waters. As an alternative to a hotel, it may be feasible to provide cabanas for the day-time use of visitors to the geothermal spa, along with restaurants and other service facilities, while at night the visitors would return to the existing American Samoa hotels.

Skillful landscaping and design, including adequate muffling of sound from the wells, might make it possible to combine operation of a spa with the generating of electricity and even a geothermal industrial park. Filters and chemical

treatment of the thermal waters should be able to handle bacteriological and aesthetic problems for such use. Various users would be subject to the constraint that the application needing highest temperatures and steam pressures (presumably electricity generation) would receive the flow first, out of the well, while applications using lower temperatures are made downstream.

A geothermal production plant would itself be a touristic attraction. The experience of other islands--Japan, New Zealand, and Iceland--has confirmed that tourists are interested in witnessing a geothermal field in operation. The geothermal well in Hawaii has already attracted significant numbers of tour buses and casual visitors. Hawaii is constructing a \$200,000 tourist accommodation facility at the Puna well site.

An aquaculture industry may be spurred by geothermal development. Hot geothermal fluid or steam could be used in a heat exchanger to maintain a stable elevated temperature in a fish farm. One type of fish with economic aquaculture potential is the Malaysian prawn, which thrives in water with temperatures of 95-98°F. Geothermal heat could be used to obtain such a temperature.

It is possible to recover and sell various minerals, salts, and trace elements from the geothermal fluid (brine) such as salt, sulfur, and potassium chloride. Perhaps the geothermal waters could even be bottled and sold as mineral water.

Geothermal heat can be used to desalinate the abundant brackish water existing as ground water in American Samoa. This is presently done in the Imperial Valley, California and in Chile.

Another business idea concerns bringing forest products from Western Samoa to American Samoa. Geothermal heat can be used to season and dry the timber. The power plant could then power a sawmill, with the products being used for pulp and paper manufacturing and furniture construction.

Other possibilities include drying fish meal, bananas, and other agricultural products.

Geothermal possibilities range from superficial applications to large scale industrial enterprises. The development of substantial geothermal power would enhance the possibility that American Samoa could become the site of a major manganese nodule processing industry. The objective of such an enterprise would be to extract nickel, copper, cobalt, and manganese from nodules mined from the Pacific Ocean floor. Mineral processing in American Samoa would have an important technical and social impact. A three product manganese nodule plant requires 150 MW of power--this is six times more power than the present generating system on American Samoa can provide.

4.1.2 ELECTRIC VEHICLES

Electric Vehicles (EVs) may assist American Samoa to decrease its dependence on fossil fuel--EVs use electrical energy that can be provided by resources other than imported oil. With the advent of geothermal energy in American Samoa, it may be possible to replace gasoline powered internal combustion engines with EVs in the near future.

What is an EV? An electric vehicle differs from a gasoline vehicle in that it uses traction batteries, a controller, an electric traction motor, and a charger. The batteries store energy and provide electricity to the motor. A controller controls the flow of energy from the battery to the motor so the driver can adjust the speed. The motor converts electrical energy to mechanical energy and transmits it to the wheels of the vehicle. A charger converts and regulates electricity from a regular wall outlet to recharge the batteries.

Hybrid vehicles use a combination of an electric motor powered by batteries and an internal combustion engine or other power source. The addition of the second power source adds range and acceleration when needed. Hybrid vehicles are still in the experimental stage. Many more electric vehicles other than hybrid vehicles are now on the road.

Compared to the internal combustion engine, EVs offer many advantages. EVs use energy that can be provided by resources

other than imported oil. Thus, the transportation sector may obtain a reliable energy source at a favorable cost. The energy consumption of an electric vehicle is less than that of a gasoline-powered internal combustion engine vehicle. The EV equivalent of gasoline at 90¢ per gallon is electricity at 7.5¢ per KWHR. Recent EVs require .4 KWHR per mile. The net energy required for EVs is less than that of gas cars even if oil-fired electrical generation is used, as currently in American Samoa. EVs create very little environmental pollution compared with gasoline engines. Lower maintenance costs and shorter repair or "down" times are necessary for EVs because of lower vibration, fewer moving parts, and overall simpler design.

Electric Vehicles have some disadvantages, too. EVs cost about 1-1/2 times as much as conventional vehicles, primarily because they are not yet in mass production and probably will not be for at least several years. At present, most EVs are conversions of existing petroleum-fueled vehicles. Battery replacement, which is a major cost, is required every 20,000-30,000 miles.

EVs have a range of 20 to 60 miles with limited acceleration, hill climbing ability, and top speed. This condition is due primarily to the limitations of the present lead-acid batteries. New batteries that are under development could increase EV capabilities fourfold, and when in production could reduce the EV cost to that of conventionally-powered

vehicles. General Motors recently announced their new EV and battery system that should cost about \$7,000 in 1985 and get up to 100 miles per charge.

Since there are a limited number of EVs presently on the road, availability of parts and experienced labor could be a problem.

Presently over 3,000 EVs are on U.S. roads. Many of these EVs are part of a DOE EV Demonstration Program in which local governments or companies share the cost of buying, using, and monitoring a fleet of EVs. The purpose of the program is to demonstrate the economic and technical practicality of electric vehicles. The public exposure resulting from the program will result in additional demand which will help the new industry get its start.

Hawaiian Telephone Company is taking part in a three-year EV program. The company has 3 converted Dodge Omni coupes, with 2 more coupes and 20 pickup trucks scheduled to arrive from Jet Industries in Texas. These vehicles will be used to provide maintenance and installation services for telephone systems of business customers. The maximum range is about 40-50 miles between charges. Eight hours is required to fully recharge the batteries, which are good for 10-20,000 miles. The maximum speed is between 45 and 55 mph, but their acceleration rate is less than 13 seconds to achieve 30 mph. The recharge capacity is .4 KWHR per mile. The coupes cost

\$12,000 plus \$1,000 for shipping to Hawaii. Figure 4-1 is a picture of one of the electric cars.

The Hawaii Natural Energy Institute presently with 2 EVs is waiting for the arrival of 23 electric vehicles to be used as an integral part of the University of Hawaii Transportation Services fleet of vehicles. Hawaii County has submitted a proposal in which 10 EVs are to be acquired.

The DOE expects dramatic increases in the number of EVs during the 1980s with possibly over eight million vehicles on the road by the year 2000.

Electric Vehicles may be of great value to American Samoa. The island has many of the conditions that optimize the potential of electric vehicles to make a near term contribution to the fossil fuel energy problem. Year-round warm weather in the 70° to 90°F range is most favorable for maximum electric battery output and vehicle range. The island of Tutuila is small. With fifty miles of paved roads, the average car trip is short distance. Short trips will not strain the range limitations of EVs. The major road skirts the ocean and crosses level (non-hilly) terrain. Traveling on level ground extends the effective range of EVs. The low existing demand for electricity between midnight and 7:00 A.M. enables the EVs to be recharged during non-peak nighttime periods, thereby levelling out the load on the EUD. The major potential renewable natural energy source in American Samoa, geothermal,

Electric Car Photograph
Figure 4-1

could produce electricity at a reasonable cost. This would be ideal for recharging EVs.

Electric vehicles in American Samoa are feasible only if electricity can be produced more cheaply than the present fossil fuel generators which are about 28 percent efficient. With the present utilities system, it is cheaper to put gas directly into a car (where it is converted to mechanical energy with a 15 percent efficiency) instead of converting the given fossil fuel energy twice (from fossil fuel to electric to mechanical energy). American Samoa has 3,300 vehicles which travel about 60 million miles and consume 3 million gallons of fuel costing about \$2.8 million per year (and rising). Rated at .4 KWHR/mile, 3300 EVs would consume 24 million KWHRS/year costing \$2.2 million if electricity costs 9¢ per KWHR. With electricity at 9¢/KWHR, car travel would cost 3.6¢ per mile. With gas at \$1.00/gallon, car travel costs 5¢/mile. A generating system of 2.74 MW would be needed to supply the power needed to recharge 3,300 EVs. If all of the vehicles were charged during the same 12 hour period (at night), then 5.48 MW would be needed during those 12 hours.

4.1.3 HYDROGEN

As fossil fuels become increasingly expensive and scarce, it may be advantageous to switch to other energy sources and

fuels. Hydrogen--plentiful, clean, high in energy content, adaptable to power generation and to industrial, residential, and transportation uses--could be the perfect fuel in the long run.

A hydrogen fuel economy in American Samoa would imply energy self-sufficiency. In the following scenario, hydrogen is produced, stored, distributed and utilized in American Samoa, thereby making the island independent of fossil fuels. A primary energy source such as geothermal, solar, or OTEC would be used to produce hydrogen from water. This hydrogen would be stored as a gas, liquid, or hydride. It could be piped to residences and businesses where it would satisfy all process heat requirements. Moreover, as fuel for fuel cells, hydrogen could provide decentralized electric power for residences and businesses. Airplanes, fishing boats, and cars would use hydrogen as fuel. Since hydrogen is clean-burning, air pollution would be non-existent. A hydrogen engine and a generator could easily convert hydrogen energy to electrical energy if desired. Various aspects of hydrogen production, storage, distribution, and utilization are discussed below. Hydrogen, H_2 , is not found naturally in the free state. Though abundant, hydrogen is almost invariably locked (bonded) into chemical compounds such as water and organic matter. Releasing the hydrogen stored in these materials requires expending energy. Since energy must be invested in hydrogen

before energy can be released as a useful fuel hydrogen can therefore be regarded as a means of storing energy. The heat or electrical energy required to separate it from the elements to which it is bonded is in effect stored in hydrogen until that fuel is burned.

Most hydrogen is produced by the reaction of natural gas or light oil with steam at a high temperature. In the future, other methods may become more popular. Coal gasification and thermochemical processes have possibilities; however, the simplest and most fundamental form of hydrogen production is via the electrolysis of water. When a small, direct current is fed into an electrolysis cell via the electrode, hydrogen collects at the cathode, and oxygen collects at the anode. Making hydrogen electrolytically is presently one of the more expensive methods of production. As other (fossil fuel) methods become more expensive, and as the technology is improved, electrolysis may become an economic and popular method. The cost of hydrogen production by electrolysis is tied directly to electricity costs. If electricity costs 4 cents per KWHR, it would cost two dollars to produce hydrogen with the same energy content as a gallon of gasoline. This figure does not include capital costs, labor costs, or the market value of the by-product oxygen.

Hydrogen may be stored as a compressed gas, as a supercold liquid, or as a metal hydride. Hydrogen's low energy content

per cubic foot as a gas makes the gaseous storage option, although simple, infeasible for many applications due to the large volumes involved. Liquid hydrogen, taking up less than 1/700 as much space as gaseous hydrogen, has an energy density of about one third that of gasoline. To remain a liquid, hydrogen must be kept at -423°F . in a heavily insulated tank. Converting hydrogen gas to a liquid and keeping it refrigerated is expensive, consuming the equivalent of 25 percent of hydrogen's energy value. Another consideration is that some liquid hydrogen is always evaporating and must be bled off by being vented or burned. Safe and inexpensive ways of cooling and maintaining liquid hydrogen need to be developed before liquid hydrogen storage is commercially feasible and available to the public.

A new and promising means of storing hydrogen is in hydride compounds. Certain metals and their alloys, like magnesium-nickel, magnesium-copper, and iron-titanium, can absorb hydrogen gas to form chemical compounds referred to as hydrides. When heated, these compounds release the hydrogen again. This storage method avoids having to contain large volumes of hydrogen as a gas or to maintain the special pressures and temperatures needed to store hydrogen as a compressed gas or as a liquid. Hydrogen stored in the solid hydride is safer than gasoline since most of the hydrogen is bound in the lattice and is not free to combust. Though they

can store twice the hydrogen in the same space required by liquid hydrogen tanks and more than half of the energy in a similar volume of gasoline, hydrides are presently heavy and expensive.

Hydrogen can be used as a heating fuel and as a transportaton fuel. The beauty of hydrogen being used as a fuel is that, when it is combusted in air, the only combustion product is water vapor and a miniscule amount of oxides of nitrogen. There are no pollutants such as hydrocarbons, carbon monoxide, lead oxides, and sulphur.

It is likely that the first major use of hydrogen as an energy source for motive power (besides rocket propulsion) will be jet aircraft. Liquid hydrogen, with much more energy per unit volume than gaseous hydrogen, would be used. (Hydrides are too heavy.) Liquid hydrogen would require about four times the storage space that jet fuel requires for equivalent amounts of energy. However, since hydrogen weighs much less than jet fuel (pounds/gallon) the hydrogen aircraft could be 200,000 pounds lighter than contemporary planes. This reduced weight would reduce fuel requirements (liquid hydrogen storage volume) by about one third. Since the liquid hydrogen requires refrigeration and more volume, it would probably be stored in the fuselage rather than in the wings. A smaller wingspan could be used due to the lighter aircraft weight and fuel storage in the fuselage. An 800 passenger aircraft with a

5,000 mile range and a cruising speed of 4,000 miles per hour is technically feasible. Lockheed-California Company has a \$270,000 Federal contract to study the design of a liquid hydrogen aircraft. The study is strictly preliminary design work. A hydrogen aircraft design-from-scratch effort could begin by 1982 or 1983. Willis Hawkins, Lockheed President, said U.S. airlines should be flying hydrogen planes by the end of the century. A hydrogen plane built new is more than a decade away, but it would be possible to retrofit an existing plane in three or four years.

Hydrogen may be used for ground transportation as well as for air transportation. A conventional automobile engine can operate on hydrogen with relatively simple changes in the carburetor, although better engines must be custom built. There are about 100 hydrogen powered vehicles in the world today. Present engines are about 80 percent as powerful as a gasoline engine and fifty percent more efficient. This means that a hydrogen vehicle may not be able to accelerate as fast but it would travel further per BTU equivalent, and do so without polluting. Assuming favorably priced hydrogen, the major problem in ground transportation usage is the storage medium. Even when highly pressurized, hydrogen in the gas phase requires entirely too much volume to provide a vehicle with adequate range. Liquid hydrogen storage requires three times the space of BTU equivalent gasoline storage. Given that

hydrogen vehicles are 50 percent more efficient than gas cars, a hydrogen storage tank with 1-1/2 times the volume of a gas tank will give a hydrogen vehicle the same range as a gas car. Inexpensive and safe bottles and cooling systems must be developed to make liquid hydrogen in cars more attractive.

Hydride storage is the other automotive alternative. In some hydride storage systems, the concentration of hydrogen per unit volume is actually greater than in liquid hydrogen. Similar fuel tank sizes would give hydrogen (hydride) vehicles the same range as gas cars. Since hydrides release their hydrogen slowly when heated, there is little risk of explosion from damage to a hydride storage tank. A disadvantage is that hydride storage tanks presently weigh too much and cost too much. In a hydrogen bus in Riverside, California, the iron-titanium on board weighs 2,400 pounds and cost \$5,000. Another \$5,000 was spent on the tanks and connections. Hydrides may become a safer and more convenient alternative for transportation when costs and weights diminish due to mass production and technological improvements.

Hydrogen may be used as fuel for fishing boats. As with automobiles, a ready source of favorably priced hydrogen and an appropriate storage system must be present before fishermen become hooked on hydrogen.

Hydrogen can be used to satisfy residential and industrial process heat requirements and can be an excellent fuel for

almost any cooking and heating applications in the home and in industry. Compared with natural gas, hydrogen burns with a faster, hotter flame. Hydrogen-air mixtures are flammable over wider limits of mixtures. Hydrogen burns without producing noxious exhaust products; therefore, in many applications, unvented appliances can be used, resulting in large energy savings. In the gaseous phase, hydrogen has a low energy density. This means that huge tanks would be needed to transport gaseous hydrogen to users. Better methods of distribution include pipelines, hydride fuel trucks or liquid hydrogen fuel trucks.

In summary, hydrogen offers a potential way for American Samoa to become independent of fossil fuels in the long run. Hydrogen could replace fossil fuel in planes, boats, cars, and process heat equipment provided that a feasible alternate energy source such as geothermal can be developed. Taking advantage of hydrogen's versatility will require developing less expensive, more efficient production, storage, and distribution methods, for at present the hydrogen system is much more expensive than the fossil fuel system that it would seek to replace. Costs can be expected to decrease considerably when demand merits mass production of hydrogen, storage facilities, engines, etc.... If new technology is developed and fossil fuel prices continue to increase--and both are likely--then hydrogen may become a practical and affordable solution to part of American Samoa's energy problems.

4.2 ENVIRONMENTAL AND SOCIO-ECONOMIC ISSUES

The socio-economic reason for developing geothermal energy in American Samoa is to increase the comfort and welfare of the people. It is therefore important to assess geothermal energy as it relates to the individual. Environmental and socio-economic issues are addressed below.

4.2.1. ENVIRONMENTAL IMPACT

Samoan residents are becoming increasingly aware of their environment and jealously guard their natural island beauty. Even today lawsuits have been threatened to correct the air pollution problems attributed to the tuna factories. Therefore one must expect that Samoans will watch carefully any development which would further endanger their environment.

The environmental impact of utilizing a geothermal resource should remain within acceptable and safe limitations that now exist in the natural environment. Proper engineering and construction of geothermal development can preclude any pollution problems. The chemistry of the geothermal product will be a dominant factor in determining the degree of environmental impact. For this reason environmental baseline monitoring is planned as a parallel operation with the exploratory drilling program. (See recommendations in Section

5.2). Environmentally related activities include chemical monitoring of both fluids and gases at the well head; the effect on groundwater level and water chemistry in observation wells in the adjacent area; seismicity and noise levels.

In Larderello, Italy, where geothermal power has been produced for 70 years, vineyards and fields of grain grow right up to the plant where electricity is being produced. The area where the Geysers (California) geothermal plant is located was originally wilderness and used as a forest and game preserve which use has not been affected except for the actual land that is occupied by the plant. (Reference 3-1)

Although in a steam-dominated system noise during drilling can be excessive when clearing the hole with air, this is temporary and can be muffled. Once a hole is completed and tied into steam lines, noise is no greater than that of a conventional power plant and is certainly less than the noise associated with the present EUD facilities. Any noise problems are very localized and can be satisfactorially suppressed.

Ground subsidence which occurs in connection with water or other fluid withdrawal in many places is not anticipated to be a problem in American Samoa. This is because such subsidence is a function of geology, the conditions for which do not exist in American Samoa.

Any effect on water quality due to reinjection is regarded as negligible in American Samoa because of the high

permeability of the islands and the fresh water supply floating as a Ghyben-Herzberg lens on underlying salt water. If reinjection is below the Ghyben-Herzberg lens level, it is not likely to migrate laterally against the hydraulic gradient toward the producing well.

Inducing seismicity (or causing an earthquake) in a basaltic terrain by either removing steam or water or reinjecting water into the ground is also highly unlikely since with highly permeable and porous basalts the effect on hydrostatic pressure will either be negligible or tend to hold constant. It should be noted that this has not been a factor in other geothermal areas--even in those with a low level of natural seismicity like American Samoa.

Although low level radioactivity does characterize some thermal springs which are exploited for therapeutic purposes, this is not regarded as a health hazard, and radioactive monitoring at the Geysers has shown the alpha count to be well below that permissible for drinking water as specified by the U.S. Public Health Service.

Air pollution from a geothermal plant, while a matter of concern, is not apt to exceed that of the visual impact of condensing steam. At the Geysers, for example, the condensing steam consists of 99.5 percent water. Of the small remaining non-condensing fraction, 80 percent is carbon dioxide with only the 4.5 percent portion represented by hydrogen sulfide which

smells like rotten eggs and is potentially injurious to plants. While this amount of hydrogen sulfide cannot be totally discounted with a large geothermal plant, the production of hydrogen sulfide at the Geysers is only about one-third that which would be produced using fossil fuel to generate the same amount of electricity. Similarly, an equivalent fossil fuel power plant would produce 20 times as much carbon dioxide for the same electrical output as with a geothermal power plant utilizing steam as at the Geysers.

In Hawaii, based on tests for mercury, arsenic, sulfur dioxide, sulphuric acid, and hydrogen sulfide, the geothermal well is amongst the cleanest in the world: its impact on air and water quality is clearly not harmful.

Until exploration of American Samoa's geothermal potential is accomplished, the pollution potential cannot be completely defined. It is clear, however, that air and water pollution problems can be very adequately provided for with existing technology.

Harnessing geothermal energy will actually decrease air pollution in American Samoa! First, the geothermal power plant is likely to emit less pollutants than the present fossil fuel generators that it may replace. Secondly, if geothermal energy provides favorably priced electric power, then, non-polluting electric cars may become widespread, resulting in a large air pollution reduction.

In general, therefore, utilizing geothermal energy in American Samoa can be said to have negligible environmentally negative impact and some positive impact.

4.2.2 SOCIO-ECONOMIC IMPACT

Development of geothermal energy can be viewed as development of a natural resource equal or superior to an oil field, coal mine, gold mine, etc. American Samoa could save millions of dollars yearly by reducing the outflow of cash for the purchase of fossil fuel. The money would be retained in the economy and the savings would be reflected as decreased energy costs and a broader economic base.

A successful geothermal development could produce energy that costs less than the energy presently produced in American Samoa. Present businesses would expand and new ones would be created, generating new job opportunities. As an example, a geothermal plant might increase the number of tourists to American Samoa (to visit the plant itself or to visit a health spa). This would positively impact island employment and lower the government sector versus private sector employment ratio. Another example, the furniture manufacturing company, would require skilled people thereby enhancing the island pay scale as well as the island employment rate.

Comparatively low energy costs provide financial advantages to the Government of American Samoa by growth of the economic base. Direct savings in energy costs would be realized by the hospital, the water pumping system, schools, government buildings, and the airport. The hospital, a significant process heat user, may be able to use geothermal process heat for cooking, laundry, and washing. The geothermal wells of the Queen Elizabeth Hospital in Rotorua, New Zealand are used for sterilizing steam, kitchen steam, domestic hot water, and hydrotherapy.

The Government tax revenues would be increased by geothermal induced industrial growth and increased productivity. The multiplier effect will be seen as income streams created by the increased productivity, would feed into the overall economy of the Territory, generating additional tax revenues.

For residences, low cost power will cut present electric bills and make household conveniences such as air conditioning, electric stoves, and washing machines more economical and therefore within the reach of more families. Increased productivity and employment will result in modernization and increased consumption, thereby increasing the standard of living.

Changing the perspective somewhat, geothermal development in American Samoa can be viewed as preventing things from

getting worse instead of being viewed as making things better. Geothermal energy may be able to prevent the increasing burden and stifling effect of fossil fuel cost and its unreliability. In fact, decoupling energy costs from fossil fuel costs and supplies may avert a serious economic disaster. Ultimately, high priced or unavailable fossil fuels could cripple the island. Geothermal energy has the potential of producing abundant and favorably priced power for American Samoa. In the near term, this could alleviate fossil fuel energy cost shocks to the economy. Electric cars may become economically competitive in a few years with car mass production and with geothermal electricity. In the long term, geothermal energy may make possible a transition to a hydrogen economy where planes, boats and process heat applications will require hydrogen fuel. Other technologies such as solar or OTEC will probably not be able to compete economically with geothermal.

It appears that American Samoa has an immediate need for an energy source such as geothermal in order to reduce its fossil fuel dependency and to develop a broader and more secure industrial base. Presently, the island economic base is dominated by, and sensitive to, fluctuations of the two major employers, i.e., the American Samoa Government and the tuna canneries.

It is difficult to envision any problems either culturally or religiously arising from the development and utilization of an environmentally clean geothermal resource. There is nothing in the Samoan culture which would impede a rise in the standard of living and enjoyment of modern comforts and conveniences. American Samoa has TV and its share of luxury cars which have not adversely affected the Samoan way of life.

Geothermal energy development would result in a higher standard of living and a potential for industrial expansion that might not otherwise be attainable. American Samoa would then enjoy the luxury of a choice between remaining an isolated island economy with its attendant simple Polynesian lifestyle, as opposed to more involvement in the mainstream of world affairs, and modern attitudes.

4.3 LEGAL AND REGULATORY FACTORS

An examination of legal and regulatory factors relevant to geothermal energy is important as they can either hinder or facilitate geothermal exploration and development on American Samoa. Questions of ownership rights, taxation, incentives, and permits are discussed in this section. First a collection of relevant federal legislation, state legislation, and court decisions are presented as background information. Then, this information is used as a foundation in discussing legal and regulatory factors specifically relating to American Samoa.

4.3.1 BACKGROUND INFORMATION

Prior to 1978 the term "geothermal energy" was unknown to the general populus of American Samoa. Now it is talked about daily because geothermal may be the only alternate energy source capable of providing large amounts of near term base load power, thereby substantially reducing American Samoa's dependence on imported fossil fuels.

In order to expedite Federal and/or private participation in orderly development of American Samoa's potential geothermal resource the term "geothermal energy" must be defined and based on this definition, the question of "who owns the geothermal resource" must be addressed.

Since the development and exploitation of geothermal resources is a phenomenon of comparatively recent origin in the U.S., there is a paucity of legal precedent concerning the nature of ownership and property rights in the energy resource.

This section presents a collection of federal legislation, state regulation, and court decisions which attempt to define and regulate geothermal resources:

I. The Geothermal Steam Act , 1970 (84 Stat. 1566 Pub. Law 91-581, 30 O-S.C 1020 (b) and Fed. Reg. Title 30, Part 270, P. 35068, states:

(g) "Geothermal resources" means (1) all products of geothermal processes, embracing indigenous steam, hot

water, and hot brines; (2) steam and other gases, hot water, and hot brines, resulting from water, gas, or other fluids artificially introduced into geothermal formations; (3) heat or other associated energy found in geothermal formations; and (4) any byproduct derived therefrom.

(h) "Byproduct" means (1) any mineral or minerals (exclusive of oil, hydrocarbon gas, and helium), which are found in solution or developed in association with geothermal steam and which have a value of less than 70 per centum of the value of the geothermal steam or are not, because of quantity, quality, or technical difficulties in extraction and production by themselves, and (2) commercially demineralized water.

II. Letter of Opinion from the Solicitor General, December 16, 1965

"Geothermal Steam" is essentially just subterranean water heated to a high temperature. In Solicitor's Opinion M-36625 (August 28, 1961) it was stated that "from an examination of the pertinent sections of a report prepared for a United Nations Conference by the Geological Survey entitled "Preliminary Evaluation of Geothermal Areas by Geochemistry, Geology, and Shallow Drilling," we conclude that geothermal steam is developed from hot spring systems and that the greatly dominant component in these systems is meteoric water, i.e., of atmospheric origin."

Water, particularly subterranean water, is normally classified as a mineral. See article on "Minerology" in Encyclopedia Britannica, XV 501 (1965); "Water" 93 C.J.S. 580; "Mines and Minerals," Sec. 2(b) (7), 58 C.J.S. 24; Hathorn v. Natural Carbonic Gas Co., 87 N.E. 504, 508 (N.Y. 1909). However, it is recognized that water differs from other minerals and must be treated differently from a legal point of view. Erickson v. Crookston Water, Power & Light Co., 111 N.W. 391, 393 (Minn. 1907). Courts have held that a reservation of minerals does not reserve water. Fleming Foundation v. Texaco, 337 S.W. 2d 846, 850 (Tex. 1960); Mack Oil Co., v. Laurence, 389 P. 2d 955, 961 (Okla. 1964); see charge of the court in Estate of Geneva O'Brien v. United States, 8 Oil and Gas Reporter 845, 846 (U.S.D.C., N.D. Tex. 1957).

Water has not been treated as a mineral in the public land laws. The Congress has enacted special statutes about water, and to the best of our knowledge there is no statute in which water is treated as a mineral.

III. United States v. Union Oil Co., supra, Judge Harris' opinion depended heavily on the reasoning that since the main component of geothermal energy was water or superheated steam, and since water was not generally considered a mineral for legal and commercial purposes, that therefrom geothermal resources were not classifiable as minerals. However, there

exists authority in some states, especially those where the "mineral estate" has been severed from the "surface estate" to permit exploitation of oil and gas resources, that the question of whether or not groundwater is a mineral depends on its source, its mineral content, or the purpose for which it is being employed. Many of the decisions which have held that groundwaters are not minerals have been concerned with protecting the surface owner's use of groundwaters incident to the beneficial enjoyment of his land against interference from mining interests. But if it should appear that development of geothermal resources is not likely to interfere with those groundwater supplies utilized for domestic purposes (drinking water, irrigation, etc.) and if the public interest in ownership of geothermal resources is strongly pressed by the State, a court might well draw a distinction that classified certain groundwater as mineral and others as not.

IV. Arizona Revised Statutes Title 27, Chapter 4, Article 4, Section 1. Legislative Intent.

It is hereby found and determined that the people of this state have a direct and primary interest in the development of geothermal resources and that this state should exercise its power and jurisdiction through the Oil and Gas Conservation Commission to require that wells drilled in search of, development of, or incident to the production of geothermal

resources be drilled, operated, maintained and abandoned in such manner as to safeguard the life, health, property, natural resources and the public welfare and to encourage maximum economic recovery.

Section 2. Title 27, Chapter 4, Arizona Revised Statutes, is amended by adding Article 4, Sections 27-651 through 27-666 to read:

ARTICLE 4, GEOTHERMAL RESOURCES

27-651. Definitions:

In this Article, unless the context other requires:

"Geothermal resources" means:

- (a) All products of geothermal processes embracing indigenous steam, hot water and hot brines.
- (b) Steam and other gases, hot water and hot brines resulting from water, other fluids or gas artificially introduced into geothermal formations.
- (c) Heat or other associated energy found in geothermal formations, including any artificial stimulation or induction thereof.
- (d) Any mineral or minerals, exclusive of fossil fuels and helium gas, which may be present in solution or in association with geothermal steam, water or brines.

V. IDAHO: Legislature of the State of Idaho

(Second Regular Session)

(Forty-first Legislature)

IN THE HOUSE OF REPRESENTATIVES

HOUSE BILL NO. 732

BY STATE AFFAIRS COMMITTEE

AN ACT

TO REGULATE THE DEVELOPMENT AND USE OF GEOTHERMAL RESOURCES:
MAKING LEGISLATIVE FINDINGS AND STATING LEGISLATIVE PURPOSE AND
POLICY: PROVIDING A SHORT TITLE: DEFINING TERMS: ...

Be It Enacted by the Legislature of the State of Idaho

SECTION 1. It is hereby declared that the State of Idaho claims the right to regulate the development and use of all of the geothermal resources within this state and that geothermal resources are natural resources of limited quantity and of a unique value to all of the people of the state.

The legislature of the State of Idaho further declares that the geothermal resources of this State may provide an outstanding opportunity for enhancement of our economy and quality of life with a minimum of environmental degradation through utilization of this energy source. It is also recognized that the process of utilization and development of our geothermal resources on a large scale

may be associated with risks to the maximum sustained yield from these resources, risks to our valuable groundwater resources, and risks to the environment in the immediate locality of and around the installations at which such utilization is done.

The legislature further finds that there is presently substantial interest in the geothermal resources of this state, that regulation in the public interest is imperative and, that regulation must take effect at an early date.

The legislature does therefore declare that it is the policy and purpose of this state to maximize the benefits to the entire state which may be derived from the utilization of our geothermal resources, and to minimize the detriments and costs of all kinds which could result from their utilization. This policy and purpose is embodied in this Act which provides for the immediate regulation of geothermal resource exploration and development in the public interest.

SECTION 2. This Act may be known and cited as the Idaho Geothermal Resources Act.

SECTION 3. Whenever used in this Act the term:

(c) "Geothermal resource" means the natural heat energy of the earth, the energy, in whatever form, which may be found in any position and at any depth below the surface

of the earth present in, resulting from, or created by, or which may be extracted from such natural heat, and all minerals in solution or other products obtained from the material medium of any geothermal resource. Geothermal resources are found and hereby declared to be sui generis, being neither a mineral resource nor a water resource, but they are also found and hereby declared to be closely related to and possibly affecting and affected by water and mineral resources in many instances.

VI. NEW MEXICO

LAWS OF 1973

CHAPTER 75

AN ACT

RELATING TO THE CONSERVATION, REGULATION AND PREVENTION OF WASTE OF GEOTHERMAL RESOURCES, GIVING THE OIL CONSERVATION COMMISSION AUTHORITY TO REGULATE, CONSERVE AND PREVENT WASTE OF GEOTHERMAL RESOURCES.

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF NEW MEXICO:

Section 1. The oil conservation commission is hereby vested with the authority and duty of regulating the drilling, development and production of geothermal resources and with the authority and duty of conserving and preventing waste of geothermal resources within this

state in the same manner, insofar as is practicable, as it regulates, conserves and prevents waste of natural or hydrocarbon gas. "Geothermal resources" as used herein shall mean the natural heat of the earth, or the energy, in whatever form, below the surface of the earth present in, resulting from, created by, or which may be extracted from, this natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas and other hydrocarbon substances. Nothing in this section shall be construed to supersede the authority which any state department or agency has with respect to the management, protection and utilization of the state lands and resources under its jurisdiction.

House Bill 156

Approved March 15, 1973

VII. MONTANA

CHAPTER NO. 452

MONTANA SESSION LAWS 1973

SENATE BILL NO. 444

AN ACT PROVIDING A SYSTEM FOR THE APPROPRIATION AND USE OF SURFACE AND GROUNDWATER: PROVIDING A PROCEDURE FOR THE DETERMINATION AND CONFIRMATION OF EXISTING WATER RIGHTS:...

BE IT ENACTED BY THE LEGISLATIVE ASSEMBLY OF THE STATE OF MONTANA

Section 1. Short Title. This act shall be known and may be cited as the "Montana Water Use Act."

Section 2. Declaration of policy and purpose.

(1) Pursuant to Article IX of the Montana constitution, the legislature declares that any use of water is a public use, and that the waters within the state are the property of the state for the use of its people and are subject to appropriation for beneficial uses as provided in this act.

(2) A purpose of this act is to implement Article IX, Section 3 (4) of the Montana constitution, which requires that the legislature provide for the administration, control, and regulation of water rights and establish a system of centralized records of all water rights. The legislature declares that this system of centralized records recognizing and establishing all water rights is essential for the documentation, protection, preservation and future beneficial use and development of Montana's water for the state and its citizens, and for the continued development and completion of the comprehensive state water plan.

(3) It is the policy of this state and a purpose of this act to encourage the wise use of the state's water resources by making them available for appropriation

consistant with this act, and to provide for the wise utilization, development, and conservation of the waters of the state for the maximum benefit of its people with the least possible degradation of the natural aquatic eco-systems. In pursuit of this policy, the state encourages the development of facilities which store and conserve waters for beneficial use, for the maximization of the use of those waters in Montana, for the stabilization of stream flows, and for groundwater recharge.

(4) Pursuant to article IX, section 3(1) of the Montana constitution, it is further the policy of this state and a purpose of this act to recognize and confirm all existing rights to the use of any waters for any useful or beneficial purpose.

Section 3. Definitions. Unless the context requires otherwise, in this act:

(1) "Water" means all water of the state, surface and subsurface, regardless of its character or manner of occurrence, including geothermal water.

VIII. UTAH

WATER AND IRRIGATION

CHAPTER 189

S.B. No. 64 (Passed March 8, 1973. In effect May 8, 1973)

GEOHERMAL ENERGY AND ASSOCIATED RESOURCES ACT

An Act Enacting Section 73-1-20, Utah Code Annotated 1953;
Granting to the Division of Water Rights Specific
Authority to Regulate Geothermal Energy and Associated
Resources.

Be it enacted by the Legislature of the State of Utah:

Section 1. Section enacted.

Section 73-1-20, Utah Code Annotated 1953, is enacted to
read:

73-1-20. Division of water rights authorized to regulate
geothermal energy and resources.

(1) The division of water rights is given
jurisdiction and authority to require that all wells for
the discovery and production of water to be used for

geothermal energy production in the State of Utah, be drilled, operated, maintained, and abandoned in such manner as to safeguard life, health, property, the public welfare, and to encourage maximum economic recovery.

(2) In carrying out its responsibility under this act, the division of water rights may utilize personnel, equipment, or other assistance of any division or department and may transfer funds to that division or department to reasonably compensate it for use of its personnel or facilities.

Approved March 16, 1973.

IX. HAWAII

BE IT ENACTED BY THE LEGISLATURE OF THE STATE OF HAWAII:

SECTION 1. Findings and determination. The Legislature of the State of Hawaii finds and declares that the geothermal resources of the State provide an energy potential which may be utilized to supply power economically with minimal adverse environmental effects. It is the intent of the Legislature to establish in law the definition and ownership of the geothermal resources, to encourage their development, and to provide for their administration and management in the public interest.

SECTION 2. Section 182-1, Hawaii Revised Statutes, is amended to read:

Sec. 182-1 Definitions. In this Chapter, if not inconsistent with the context:

(1) 'Minerals' means any or all of the oil, gas, coal, phosphate, sodium, sulphur, iron, titanium, gold, silver, bauxite, bauxitic clay, diaspore, boehmite, laterite, gibbsite, alumina, all ores of aluminum and, without limitation thereon, all other mineral substances and ore deposits whether solid, gaseous, or liquid, including all geothermal resources, in, on, or under any land, fast or submerged; but does not include sand, rock, gravel, and other materials suitable for use and used in road construction.

X. Summary of Characterization of Geothermal Resource for States involved in geothermal exploration.

Mineral

Alaska
Hawaii

Water

Utah
Wyoming

Neither Water or Mineral

Colorado
Idaho
Montana
Nevada
Oregon
Washington

Other Classification

Arizona - uncertain
California - not water, unclear as to mineral
Louisiana - not mineral
New Mexico - not water
Texas - none
Federal - may be mineral

4.3.2 AMERICAN SAMOA LAWS AND REGULATIONS

House Bill 247, which would provide a definition of the word "minerals" for purposes of Chapter 3, Alienation of Land, of the property code, has been disapproved.

"A statutory definition of minerals is desirable in the long run. However, the proposed inclusion of geothermal energy, in view of minerals, may unduly inhibit development of that energy source at a time when its use here is beginning to appear feasible. Additionally, the broad exclusion of sand, rock, gravel and materials suitable for road construction, the uncontrolled removal of which can cause serious environmental degradation, is open to question.

"In short, this legislation needs more careful and thorough study than it has been given to date. Meanwhile, the common law definitions of "minerals" are sufficient to fill the present void in the statutory law. (Reference Gov. Coleman letter Serial 495, 23 April 1980)

There are no territorial statutory laws of American Samoa claiming or reserving any special rights (including mineral rights) to the territorial government, or other interests adverse to a land owner, for subsurface content of real property.

As a starting point in the analysis of entitlement to land and mineral rights, reference should be made to the Treaties of Session of 1900, in the case of Tutuila & Aunu'u, and 1904, in the case of Manu'a Islands. The second numbered paragraph in the former reads:

The Government of the United States of America shall respect and protect the individual rights of all people dwelling in Tutuila to their lands and other property in said District; but if said government shall require any land or any other thing for Government uses, the Government may take the same upon payment of fair consideration for the land, or other thing, to those who may be deprived of their property on account of the desire of the Government."

The second numbered paragraph in the Manu'a lessons read:

It is intended and claimed by these Presents that....the rights of the Chiefs in each village and of all people concerning their property according to their customs shall be recognized."

Both treaties have been ratified by the Senate (See 48, USC Sections 1661 and 1662). It is interesting to note that Section 1661 (b) disqualifies any assertion or claims to reservation of interest by the Federal Government to any lands as being public lands. The enactment reads:

"The existing laws of the United States relative to public lands shall not apply to such lands in the said islands of eastern Samoa;...."

The most recent expression of Congressional policy on lands in Samoa, is contained in 95th Cong. Senate Report No. 95-1275, p. 3, wherein the Committee on Energy & Natural Resources considered the repeal of 48 USC Section 1480, which placed limits on land holdings by churches in the Territories. While the subject matter therein is irrelevant for purposes of this report, it is significant to note the following committee comment, reaffirming realization of treaty obligations.

The Committee is aware of and fully supports the current restraints on the alienation of communally owned lands in Samoa which we developed to fulfill the obligations of the treaties of cession."

Having noted that the foregoing, it will thus be seen that the relationship of the United States vis-a-vis the Samoan land owner is entrenched in treaty provisions. As such it supercedes any Congressional Law that is or may be subsequently enacted, which effects property rights of the Samoan land owner, as guaranteed in the Treaties. In the same manner, the Territorial government as an instrument of Federal government, (48 USC Section 1431a(c)) would likewise be limited by Treaty provisions, insofar as Samoan property rights may be affected by its activity.

The conclusion in essence then, is that whatever the Samoan land owner held prior to the treaties, that is exactly what he holds today, unless his holding has been taken for fair consideration, or alternatively, his property rights have been diminished with his agreement.

As to what the Samoan land owner holds today, the following submission may be made: Any territorial law not inconsistent with the spirit of the treaties, shall be upheld as the law, by the High Court of American Samoa. By local statute 1 ASC Section 1 (4), the Common Law of England as is suitable to American Samoa and not inconsistent, with statutory law, is adopted as part of the law of the territory. To determine the extent of a land owner's holdings then, resort may be had to the English Common Law for a determination thereof. The Common Law of England is that a land owner not only owns the surface of the land, but owns the airspace above it, and everything else contained in the subsurface, unless otherwise reserved.

Under present statutory laws, foreign corporations properly licensed in American Samoa could develop geothermal resources in American Samoa. The American Samoa tax laws are similar to the U.S. Federal I.R.S. tax requirements and all benefits thereunder would accrue to the developer and any savings therefrom would be passed on to the end user.

In examining legislation pertaining to the leasing of land for the working of minerals, we find the following provision in the American Samoa Code, v.i.z. 27 ASC Section 206 (a) which reads:

"Native land may, with the approval of the Governor, be leased to any person for a term not exceeding 30 years for any purpose, except for the working of minerals and cutting timber".

It is the meaning of the exception underscored that gives rise to difficulties. It is not explained anywhere else in the Code, and the mention of minerals and timber is apparently the only singular instance in the Code. Without it being further explained, the exception as it is subjects the enactment to several alternative readings:

- (I) Native lands may with the governor's approval, be leased for any purpose. It may not however be leased for the working of minerals or timber; or

(II) The leasing of native lands is permitted if the governor approves the lease. The governor's approval is not required, if the lease is for the purpose of working minerals or timber; or

(III) The leasing of native lands is permitted if the governor approves. However, in the case of minerals or timber, the government reserves the rights thereto.

More probably than not, the original intent behind the bill was the naive attempt to reserve special rights for the local government, as in (III) above. It is quite probable that the government never had prior interests in land to reserve. This is reflected by the treaties as well as the ratification statute. Further if it is the statute's intention to create special rights of government to timber and minerals, this would be a taking by government without consideration, and hence invalid by virtue of the Treaties. At the same time, if the statute was attempting to create special rights for the government, the legislative context for doing so is not appropriate. While there may be a prohibition against lessees working minerals and timber, there is no similar prohibition against the landowners. Accordingly, it may be reasoned that the statute is not sufficient to accommodate a creation of special rights to government, quite apart from the question of

whether it could do so in view of the treaties. Therefore, interpretation (III) seems to be unacceptable.

Interpretation (I) also seems to be unacceptable. It would otherwise be a blanket prohibition on use without any referable territorial interest. Any prevailing territorial interest or necessity is not apparent in the statute, and even if there was such a prevailing need, the treaties demand a fair consideration. As it stands, an unexplained blanket prohibition, would most likely be viewed as a taking by government, and such taking is not lawful.

Interpretation (II) would appear to be the only alternative which would give reading sense to the statute, but this would defy any intelligible legislative policy. Further, such an interpretation would clearly go against the legislative scheme and intendment of the statute as a whole, i.e. the prevention of improvident bargains and the securing of communal land for Samoans.

The inevitable conclusion is that the exception is contextually superfluous and probably not meaningful. The attempt to assign meaning to the exception encounters prevailing difficulties.

Based on the foregoing, the legal discussion of geothermal resources and ownership rights thereto indicate that the owners of land (whether communal or individual) own all geothermal resources and have the right to receive all royalties, in connection with any commercial exploitation of such resources.

Although the ASG does not appear to own any subsurface rights to land owned by others, it will play an important role in geothermal development by planning, observing development, and coordinating development with the EUD and the needs of the people. ASG will provide some degree of input concerning location, environmental impact, extent of development, pricing, etc. The Territorial Energy Office will play a large role in terms of the forementioned items plus the coordination of the Electric Utilities Division with a geothermal electric development. There will be close coordination and cooperation between the ASG and the geothermal developer for two major reasons.

First, the ASG may be the provider of some of the capital required for geothermal development, thereby becoming a "partner" in the venture. Incentives, in addition to any tax benefits, should be considered if private industry risks capital to develop the geothermal resource. The degree of incentive must relate to the risks, the costs of the project, and the benefits derived therefrom. The establishment of the particular roles of ASG and private industry in a geothermal development venture is the subject of ongoing discussion.

Secondly, ASG may influence development through favorable land-use zoning laws which may make available areas promising for exploration and development of a geothermal resource. However, considering the limited environmental impact and the

cooperative Samoan custom and culture, no impediments are foreseen.

4.4 TECHNICAL GEOTHERMAL POTENTIAL

It is necessary to locate and evaluate the nature and extent of the geothermal potential prior to planning its development. Dr. Keller and Dr. Grose from the Colorado School of Mines were primarily responsible for the assessment of the geothermal potential in American Samoa. Their report consists of an abstract, an analysis of geology, a review of drilling in basalt, and a recommended exploration plan. It is presented in Sections 4.4.1 through 4.4.6 below. They conclude that "the geology is locally favorable for the occurrence and development of geothermal energy at moderate or high temperatures" and "within the entire Pacific Basin (with the exception of the backarc basins...), the Samoan Islands are one of only five sites where volcanism has occurred in historic time at or near sea level..." and "the only positive approach to evaluation of geothermal potential on basalt islands appears to be the drilling of temperature tests wells...to depths beyond 3,500 feet...".

4.4.1 ABSTRACT

The Samoan chain of islands is one of only five sites in the Pacific Basin where historical eruptions of basalt have

taken place. There appear to have been extensive eruptions of basalt and ash on Tutuila, one of the Samoan chain, as recently as 2000 years ago. Historic eruptions have taken place in the last 100 years on islands both to the east and west of Tutuila in the Samoan chain.

Geothermal exploration on other active basaltic islands has been quite successful, the prime examples being Iceland and Hawaii. Of these two examples, the case in Hawaii is most directly comparable to that in Samoa. Experience in Hawaii through the drilling of geothermal test holes which were based on geological and geophysical studies has resulted in a success ratio of 2 successes on 3 prospects.

Based on geological evidence, there is significant potential for the occurrence of geothermal energy on the Island of Tutuila. However, not enough detailed information is available to permit a more quantitative estimate of the potential at this time. Therefore, we recommend that geological and geophysical surveys be carried out, followed by the drilling of several temperature test wells to determine the geothermal potential.

4.4.2 INTRODUCTION

We have attempted to carry out a review of all available geological and geophysical data bearing on the potential for

the existence of exploitable geothermal energy at moderate or high temperatures on the Island of Tutuila, American Samoa. Accordingly, we undertook such a review during December, 1979, and January, 1980, culminating in this written report.

A variety of information resources was used in the evaluation. The primary resource was the published technical literature in geology and geophysics. Because of wide scientific interests in the crustal structure of the Pacific Basin, a great deal of geological and geophysical exploration has been carried out, particularly in the last decade. Much of this interest has centered in the Tonga-Kermadec region, not far from the Samoan chain, because of the clear evidence for crustal movement processes which can be gathered there. Relatively little of this work has touched on the geology and geophysics of the Samoan chain, but what information has been published is reviewed in this report.

To supplement the published information, Professor Grose and Keller visited the Samoan Islands during the period December 27, 1979 - January 3, 1980, for an on-site inspection of geology and to discuss various aspects of the information they were gathering with local residents. Much information on waterwells and hydrology was gathered from local drillers and government officials concerned with groundwater development. The settings of Tutuila, Upolu, and Savaii were examined by low-level flights along the several coastlines. The

geophysical observatory at Apia was visited and we discussed the availability of information on local earthquakes with the personnel there. In addition, a search was carried out of the records of the World Data Center at Boulder, Colorado, to find records of seismicity on the Island of Tutuila; none was found.

A small number of soil samples was collected on Tutuila for chemical analysis for trace elements associated with hydrothermal activity.

This report summarizes the information collected and makes recommendations for further evaluation of the geothermal potential on Tutuila, American Samoa.

4.4.3 GEOLOGY

The Samoan Islands chain is comprised of five islands or island groups that extend a distance of about 400 miles in a west-northwest to east-southeast direction (Fig. 4-2). From west to east, the islands are: Savaii, the largest and most volcanically active island, Upolu, Tutuila, the Manua Group, and Rose Island, a small atoll. Our interests and preliminary investigations have centered on the Island of Tutuila, where there is need for the development of new energy supplies, and where the geology is locally favorable for the occurrence and development of geothermal energy at moderate or high temperature.

Geographic Index Map
 Scale: 1 inch $\cong$ 575 miles at equator, and
 $\cong$ 450 miles at 40°S

Map of Pacific Islands
 Figure 4-2

Regional Setting:

The Samoan Island chain is rarely mentioned in the geological and geophysical literature in comparison with the attention which has been given to other island chains in the Pacific Basin or other tectonic elements in the western Pacific (Dickinson, 1973; MacDonald, 1976; Winterer, 1976). Its tectonic setting is anomalous as a consequence of its location only 100 miles from the north, curving end of the Tonga Trench (Fig. 4-2). Several important papers dealing with the tectonics and seismology of the Fiji and Tonga region adjacent to the south (Chase, 1971; Green and Cullen, 1973; Isacks and others, 1969) simply do not relate to the Samoan Islands. The Samoan Islands are regarded as being intra-Pacific in character since their geological characteristics are so typical of other intra-Pacific islands. However, tension associated with downbending of the Pacific plate south of the Samoan chain into the north flank of the Tonga Trench has been invoked to account for slumping and presumed normal faulting on the submarine southern slope of the Samoan edifice by Lonsdale (1975), and also to account for rifting along the axis of the Fagaloa shield volcano on Upolu by Natland (1974), and the island chain axis as a whole by Hawkins and Natland (1975).

Probably the most anomalous feature of the Samoan Island chain is the fact that the bulk of the eruptive volcanic rock comprising the high island edifice is increasingly younger and

higher in a westerly direction along the chain, whereas all other island chains in the Pacific Ocean, except the Galapagos (McBirney, 1969), appear to become younger in an easterly or southeasterly direction (Chubb, 1957, Claque and Jarrard, 1973; Norgan, 1972). However, as pointed out by Jackson (1976) and by Hawkins and Natland (1975), volcanic activity of different types and volumes occur over the entire length of Pacific island chains more or less simultaneously; this is clearly true in the Samoan chain.

Within the entire Pacific Basin (with the exception of the backarc basins such as the Phillipine Sea, the Coral Sea, and so on), the Samoan islands are one of only five sites where volcanism has occurred in historic time at or near sea level (Grose and Keller, 1975); the other sites include Hawaii, the Galapagos, Juan Fernandez and San Felix.

From the standpoint of the regional setting of Samoa, characteristics and phenomena generally favorable for the occurrence of geothermal resources include young volcanism, normal faulting and rifting, and volcanic activity at widely scattered locations along the Samoan Island chain.

Geologic Setting of Tutuila:

The general reconnaissance geology of the Island of Tutuila has been presented by Daly (1924) and by Stearns (1944). No detailed geologic mapping has yet been carried out. A generalized geologic map of Tutuila is shown on Figure 4-3.

4-57

Map of Tutuila Volcanics
 Figure 4-3

The geology and potential for the occurrence of geothermal energy can better be understood if they are considered in conjunction with the geology and potential for geothermal energy on the other islands comprising the Samoan Island chain. The general geology of the larger islands of Upolu and Savaii has been presented by Thomson (1921) and by Kear and Wood (1959). Petrologic studies have been made by Bartrum (1927) and by Hedge and others (1972); hydrologic studies are included in a paper by Kear and Wood (1959). The Manua Group of small islands lying east of Tutuila has been investigated geologically and petrologically (Stice, 1966, 1968; Stice and McCoy, 1968; Hubbard, 1971). Tutuila lies between the islands of Western Samoa and the Manua Group, and is intermediate in size and extent of erosion, and in age of the bulk of the rock comprising the various islands. The rocks and volcanic structures are generally the same in all the islands.

The Island of Tutuila is understood mainly on the basis of reconnaissance mapping by Stearns (1944), petrologically on the basis of work by MacDonald (1944, 1968) and by Natland and Claque (1975), and hydrologically on the basis of work by Davis (1963) and by Bentley (1975). The structure and ecology of Samoan reefs have been studied by Mayor (1924). Tutuila is covered by volcanic rocks which have been divided into five mappable units (Fig. 4-3) that generally decrease in age and crudely increase in volume above sea level from east to west.

These units are thought to represent separate eruptive centers and separate volcanic episodes.

Our preliminary study has been concentrated on the youngest of these units, the Leone-Tafuna volcanics, inasmuch as youthfulness of activity is considered a prime criterion for evaluating the potential for the occurrence of geothermal potential. Whereas the total volcanism represented by the buildup of the Tutuila shield from the floor of the sea is probably younger than three million years, the Leone-Tafuna flows and ash represent the latest volcanic activity on Tutuila. The age of the Leone-Tafuna extrusives is probably less than 2000 years as evidenced by freshness of flows, open cooling cracks, lack of soil development, absence of appreciable erosion of cinder cones, and the occurrence of coral beneath the flows at modern sea level elevation. The flows are mainly alkali olivine basalt. They issued from the bases of cinder cones which are aligned along a north-northwest trending rift zone (Fig. 4-3). Olotele crater supplied most of the flows toward Tafuna and Olovalu crater supplied most of the flows toward Leone. Fagatele and Fogamaa craters may be rootless twin littoral cones formed by phreatomagmatic explosions (MacDonald and Abbott, 1970, p. 44) caused by lava entering the sea from either side of the rift. The Leone-Tafuna flows and ash cover about 12 square miles and range in thickness from wedge edge to over 255 feet as

determined from water wells (Craddick, D., 1979, personal communication) drilled through the flows to coral and beach sand beneath.

Numerous intrusions and hundreds of dikes on Tutuila trend dominantly in an east-northeast to west-southwest direction (Fig. 4-3). They occur in the older (estimated to be 50,000 to two million years in age) and eroded volcanic piles.

The Leone-Tafuna eruptive rift zone appears to trend normal to the older rift zones of the island. It is on trend with an elongate north-northwest to south-southeast trending bathymetric high about 15 miles to the south (Hawkins and Natland, 1975). The rift may possibly reflect tension associated distantly with the curvature and downbending of the Pacific plate into the Tonga Trench.

Other volcanic centers on Tutuila, especially the Pago caldera and Aunuu Island (Fig. 4-3) may be young enough to have remained hot at shallow depth. Historic eruptions on Savaii (Anderson, 1910; Fraser, 1893; Jensen, 1906), a submarine eruption in the Manua Group (Friedlander, 1910), and flows no more than a few thousand years old and more than likely a few hundred years old on Upolu, on Tutuila, and on the Manua Islands provide strong evidence that high temperatures could be encountered at shallow depths in many places along the Samoan chain.

4.4.4 REVIEW OF DRILLING BASALT

Geothermal systems have been developed in widely different geologic settings, but exploration in oceanic islands that consist of basaltic volcanoes has been particularly successful (Keller and others, 1980). Geothermal energy has been developed at several dozen locations in Iceland, an island which has been built up from lava flows from many basaltic volcanoes. Much of the development in Iceland has been for space heating applications and for industrial process heat use. Several sites have been used for the generation of electric power, but in Iceland, electric power can be more easily obtained from hydropower development.

The rate of activity of Iceland has been rapid enough to build a large island, so the experience gained in drilling there may not be as comparable to the case in Samoa as would be the experience which has been gained in drilling geothermal prospect holes in Hawaii. Hawaii, the largest island in the Hawaiian chain, is also built of several basaltic volcanoes very similar to those in Iceland, but the size of the volcanic complex is closer to that of islands in the Samoan chain. Hawaii is built of five volcanoes, of which three have been active in historic time.

No geothermal development has yet taken place on Hawaii, but holes have been drilled in three geothermal prospect areas

on the island. The earliest of these was drilled in 1973 at the summit of Kilauea Volcano (Keller and others, 1974, 1979), though attempts to drill holes to investigate temperature had been carried out even as early as 1922 (Jaggard, 1930). The Kilauea test hole was drilled to a depth of 4000 feet (the bottom was a few feet below sea level), and encountered temperatures of 300°F at the bottom, as well as a thermal gradient of 15°F per 100 feet. There is a likelihood that temperatures suitable for the generation of electricity would have been found at depths between 5,000 and 6,000 feet, but drilling was not carried to that depth because the well site was located in a National Park where commercial development could not be contemplated. The most significant result of the drilling project was the recognition that the temperature regime found in the upper levels of the well, to a depth of approximately 3,500 feet, was severely affected by groundwater circulation and that no reliable estimate of deep temperatures could be made until the hole reached an area of stable heatflow beneath 3,500 feet. There was no temperature rise at all noted in the first 1,600 feet of drilling.

The second area where a geothermal test hole has been drilled on Hawaii is in the Puna district, along one of the rift zones of Kilauea Volcano. Extensive eruptive activity had occurred in the immediate vicinity of the well site in the 1950's. This well, drilled by the University of Hawaii with

support from the Energy Research and Development Administration in 1976, reached a depth of a little in excess of 6,000 feet. Bottom hole temperatures in the neighborhood of 700°F were found, and the well is capable of producing sufficient steam to generate three and a half megawatts. A turbine is being installed by the University of Hawaii as a demonstration of feasibility.

As in the case of the Kilauea summit well, the thermal profile in the Puna well is unstable. The wellhead is located at an elevation of 600 feet (approximate), but the high thermal gradient that results in the high bottom hole temperature is not established until a depth of 3,500 feet is reached. At shallower depths, the temperatures are quite moderate.

The third location at which a geothermal test well has been drilled on Hawaii is at Puu Waawaa on the north flank of Hualalai Volcano. Hualalai is located on the west side of the Island of Hawaii. Hualalai Volcano has been eruptive in historic time (shortly after 1800), but is not nearly so active as Kilauea Volcano.

In 1978 and 1979, Puu Waawaa Steam Company drilled two test wells to a depth of approximately 6,000 feet in the search for steam. Bottom hole temperatures were only 70° to 80°F. Deep circulation of groundwater was suspected of being the cause of the unusually low temperatures.

In summary, test drilling on Hawaii, which is geologically similar to the Samoan Islands, has yielded a success ratio of 2 in 3.

4.4.5 RECOMMENDED EXPLORATION PLAN

In drilling for geothermal energy both in Iceland and in Hawaii, geological and geophysical studies have played an essential role in locating well sites. Because of the effect of circulating groundwaters in the near surface rocks, surface thermal manifestations have not been found to be necessary to locate subsurface thermal reservoirs.

The only certain method of exploration consists of drilling test holes to adequate depth to determine whether or not exploitable temperatures are present at drillable depths. Experience in Hawaii suggests that the minimum depth for such test wells should be 3,500 feet; the maximum depth may be as great as 6,000 to 8,000 feet, if ultimate reservoir temperatures are to be tested. The drilling of deep temperature-test wells is an expensive undertaking, and careful choice of drilling sites is mandatory. Early geological and geophysical studies should be undertaken to provide the best locations for temperature test wells.

A wide variety of pre-drilling exploration has been evaluated in Hawaii (Furomoto, 1975). Based on this

experience, one can subdivide the pre-drilling surveys into several categories based on probable cost and effectiveness. The highest priority category includes those surveys that provide highly useful information and are relatively inexpensive to carry out. The second category includes methods that are useful, but expensive, and whose use is warranted only if methods in the first category indicate that the prospects for the occurrence of geothermal energy are good. The third category includes methods which are not always effective, but which may be needed under special circumstances to provide a comprehensive picture of subsurface structure.

Category 1 Surveys:

In our opinion, the minimum program of exploration prior to drilling temperature test wells should include detailed geologic mapping, an extensive survey of soil mercury content, a self-potential survey, and a gravity survey.

Detailed geological mapping of favorable areas on Tutuila is needed to determine what evidence is available about the age of volcanic activity and young tectonic activity, both in the Leone-Tafuna area, and in the Pago caldera. The mapping will have as its primary objectives the search for evidence of ages of volcanism and volcanotectonic deformation. More definitive information about the ages of activity will be helpful in estimating the chances for success of drilling, as well as being useful in determining the most likely sites for drilling.

Surveys of the mercury content in soil have been found to be very useful in geothermal exploration. The normal content of mercury in soil ranges from a few parts per billion (ppb) to a few tens of parts per billion. In areas where hydrothermal activity has taken place in the recent past (in geologic terms), far higher mercury contents are often found in soil. These concentrations of mercury are commonly located over fractures in the subsoil rock. Mercury surveys are useful in providing evidence for sites of thermal activity and for locating faults, which in turn provide information about subsurface structure.

During a brief reconnaissance of the Island of Tutuila, some thirty soil samples were collected for analysis for mercury content. The results are shown on Figure 4-4. High mercury contents were found in the center of the Leone-Tafuna plain, and around the margins of the Pago caldera. Normal mercury content in Hawaii is 20 to 40 ppb; values in excess of 100 ppb must be considered to be anomalous. The levels of mercury content in soil shown in Figure 4-4 are comparable to the levels mapped at the three sites drilled in Hawaii. Further detailed soil sampling should be carried out on Tutuila.

Movement of groundwater through volcanic rock produces unusually large natural voltages, which are the object of measurement in the self-potential method (Keller and Rapolla, 1974; Zablock, 1975). A survey of self-potential on a volcanic

Mercury Analysis
Figure 4-4

island provides clear indications of the direction of groundwater movement. If the groundwater is heated by only a few tens of degrees, significant distortions of the pattern of groundwater flow can develop which can easily be recognized by their effect on the self-potential field. All three locations at which holes were drilled in Hawaii were characterized by strong self-potential anomalies.

It is recommended that a self-potential survey be given first priority in evaluating various drill sites on the Island of Tutuila. Even if positive results in terms of geothermal potential are not obtained, the results should be particularly useful in the future groundwater development.

We consider that a gravity survey should be given first priority in pre-drilling studies. Furumoto (1975) has pointed out that gravity surveys are useful in locating dense dike rocks that make up the rift zones and central caldera complexes in Hawaii. The most likely location for residual heat on Tutuila is in such dike complexes.

Category 2 Surveys:

Under Category 2 Surveys, we include those techniques which are probably effective, but too expensive to apply on a broad basis. They should be used to evaluate sites which are indicated as being favorable by the surveys in Category 1. Chief among the Category 2 measurements are electrical resistivity surveys.

Electrical resistivity surveys are among the most widely used methods in geothermal exploration (Keller and others, 1980). Either direct-current methods (Keller and Rapolla, 1974) or induction methods can be used (Jackson and Keller, 1973; Keller, 1970). Both induction surveys and direct-current surveys were carried out at all three sites on Hawaii prior to drilling, with useful results. It is recommended that resistivity surveys be carried out at sites selected on the basis of Category 1 surveys on Tutuila.

Category 3 Surveys:

Category 3 Surveys include those measurements which are not always successful, but which can be very effective when they work. Two types of Category 3 Surveys might be considered for use in Samoa, depending on the results obtained with the Category 1 and 2 Surveys; these are microseismicity studies and airborne infrared imaging.

A microseismicity study consists of the deployment of a number of earthquake recording stations (from six to ten) over a small area to detect and locate very small earth tremors. In an area of active volcanism, patterns of earthquake activity can often be recognized which are associated with the movement of molten rock underground. Such surveys have been used quite successfully at the three drill sites on Hawaii, and in Iceland. Unfortunately, earthquake activity is episodic, and

so, observations may need to be carried out over a long period of time. If this time exceeds several months, the cost of a microseismicity survey is too great to warrant its use in exploration. A further difficulty is encountered on small islands; the sensitivity of the earthquake recording systems must usually be reduced to avoid interference from wave action along the coast. In this case, a fewer number of events will be detected, making application of the method more uncertain. Attempts to use microseismicity on the Island of Oahu in the State of Hawaii have been unsuccessful because of this problem, at least in part.

We recommend that a single seismograph monitor station be operated on Tutuila to determine whether or not the rate of occurrence of local earthquakes is high enough that a microseismicity survey can be successful. Normally, the approximate seismicity of an area can be estimated by making use of records at the World Data Center in Boulder, Colorado. A search of their records for the period from 1965 to 1979 revealed no reported seismicity. Inquiries at the Seismological Observatory at Apia on Upolu provided the information that local earthquake activity had been recorded, at least on the Islands of Upolu and Savaii. Several unpublished studies of these events were said to have been done by scientists from the Division of Scientific and Industrial Research (New Zealand), but the results are not available.

Airborne infrared scanning of ground surface temperatures is a method used occasionally in geothermal exploration. On land, it is unusual to find thermal manifestations which are not already known, but the method can be used effectively on Pacific islands to locate areas where warm groundwater discharge is taking place at submarine springs (Fischer and others, 1964). Consideration should be given to flying an infrared survey along coastal waters around Tutuila, if other surveys indicate it is warranted.

4.4.6 CONCLUSIONS AND RECOMMENDATIONS

We have reviewed published data on the geology and geophysics of the Samoan Chain, and particularly, on the Island of Tutuila, American Samoa. In addition, we have carried out a field examination of the Islands, and searched the World Data Bank for additional information. This information provides a reasonable picture of the geological setting of the Islands, but inasmuch as none of the earlier field work was directed towards evaluation of the potential for the presence of commercially exploitable geothermal energy, we cannot use the information to arrive at a quantitative estimate of the probability of success for a geothermal development effort on Tutuila. Instead, we can recommend what must be done before such an evaluation can be made.

The preponderance of evidence is that the most recent volcanic activity on Tutuila occurred only a few thousand years ago, forming the Leone-Tafuna plains. If the activity was indeed so recent, there is a strong probability that significant residual heat is present in the dike complex or magma chamber which supplied the eruptive activity. This complex should be located and tested.

The principal magma chamber on Tutuila was probably the one which collapsed to form Pago Harbor. This is certainly older than the chamber that supplied the Leone-Tafuna volcanics, and may be as old as one million years. If the chamber were large or rejuvenated, it would provide a reasonable target for investigation. We believe it should be given second priority in an evaluation of the geothermal potential at Tutuila, but there is some possibility that significant heat remains in the Pago Harbor area.

There is no surface evidence apparent on Tutuila in the form of steaming vents or warm springs for the presence of subsurface heat. This is not unusual in basaltic volcanoes where ample surface waters can remove anomalous heat before it reaches the earth's surface. The only positive approach to evaluation of geothermal potential on basalt islands appears to be the drilling of temperature test wells. On the Island of Hawaii, which is similar in many respects to Tutuila, such temperature test wells have had to be drilled to depths beyond 3,500 feet to provide reliable information on geothermal potential.

We recommend that several temperature test wells be drilled on Tutuila to test the Leone-Tafuna source dikes and the Pago caldera for residual heat. Because the drilling of such test holes is expensive, we must point out that it is essential to carry out detailed geophysical and geological studies in order to site these holes in the best possible locations to obtain definitive results. A three-stage geological-geophysical program has been outlined in the body of the report.

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5. Analysis, Conclusions, and Recommendations

SECTION 5

ANALYSIS, CONCLUSIONS, AND RECOMMENDATIONS

Previous sections have presented much of the current knowledge relevant to geothermal energy in American Samoa. This section presents the implications of that information. Specific action items and recommendations are detailed.

5.1 ANALYSIS

The information and data collected and presented in this report indicates a reasonable opportunity for viable commercialization of a potential indigenous geothermal resource in American Samoa. In analyzing other alternate energy source such as solar, biomass, wind, and OTEC, it has been concluded that, with the possible exception of wind and OTEC (if the resource is confirmed and a demonstration plant could be provided), none of these present any major near-term economical solution to the Island's total dependency on imported fossil fuel. The utilization of wind as an alternate energy source represents a medium range (4-8 year) possibility for generating small amounts of electricity. It will take about 3 to 4 years of wind monitoring in order to collect sufficient data upon which to make a proper assessment of the economics of wind energy applications to American Samoa.

Other alternate energy sources such as solar, biomass, and OTEC presently can have only a limited impact due to various considerations such as intermittency, small supply of biomass, high costs, or unproven technology.

American Samoa's present electrical generating system must be upgraded and expanded to meet present and projected needs. There is presently a proposal to purchase 6 to 8 MW of generation capacity at an estimated cost of six million dollars. This may well be functional by January 1982 and present a stop-gap measure until investigation and thorough evaluation is made of geothermal possibilities. A 5 MW geothermal well with a generator could be feasibly on line within two and a half to four years hence, depending on the effort expended to achieve this goal. Funds for definitive geothermal exploration need to be applied for and obtained.

5.2 CONCLUSIONS

Major conclusions are:

1. American Samoa requires an alternate energy source to offset its total dependence on imported fossil fuel.
2. Geological conditions on American Samoa reflect an excellent environment for the development of a geothermal resource.

3. Development of geothermal energy represents the best alternate energy source which is economically feasible in the near term.
4. Development of a geothermal resource would have a significant positive effect on American Samoa's economic base by inducing expansion of existing industry and creating an opportunity for new industry.
5. A medium range opportunity is to make a transition from gas-powered vehicles to electric vehicles.
6. A long-range opportunity is to manufacture hydrogen to fuel airplanes and fishing vessels.
7. With proper safeguards, development of geothermal energy would not adversely effect the environment.
8. We do not anticipate any legal, regulatory, or cultural barriers which would discourage development of geothermal energy. Traditionally, when similar problems have arisen, they have been satisfactorily handled within the framework of the Samoan culture.
9. There are no territorial statutory laws of American Samoa claiming or reserving any special rights (including mineral rights) to the territorial government, or other interests adverse to a land owner, for subsurface content of real property.
10. Tax incentives presently available to promote industry could apply to geothermal development.

11. Present statutes make it possible for foreign corporations to participate in geothermal development.
12. Private capital could be made available for geothermal development.
13. Potential sales for the geothermal steam and process heat are immediately available to any development of the geothermal resource.
14. Funds for definitive geothermal exploration need to be applied for and obtained immediately. Barring funding obstacles, the ASG should determine if geothermal energy is available in commercial quantities and proceed with the development program as outline by Drs. Keller and Grose.

5.3 RECOMMENDATIONS FOR GEOTHERMAL DEVELOPMENT

The recommendations of Dr. Keller and Dr. Grose as presented in Section 4.4.6 form the basis for a logical pursuit of geothermal energy. Definitive geophysical studies should proceed and be completed as described. Three test wells are a requisite part of the exploration. The first well should be drilled at the prospect indicating the best potential. Thirty-five hundred feet is estimated to be the minimum depth required to bypass surface and ground water effects and to make meaningful observations. If temperatures are high at a 3,500 foot depth, then the rig should be prepared to move to a second

selected site. However, if at 3,500 feet, geothermal evidence is inconclusive, it may be necessary to drill deeper on the first site before moving to the next site. Temperature holes can be designed for easy conversion to production holes if successful.

A timetable is presented in Figure 5-1. Note that the specific time scheduling of the latter two wells depends on the outcome of the first. The latter two wells are identical to the first well in all respects except location, startup time, and depth. Drilling of all three test wells can be expected to be completed within one year after the commencement of the definitive geophysical studies, provided that this program is continuous and funding is committed. A listing of the various program elements and costs is presented in Figure 5-2.

GEOTHERMAL PROJECT

FIGURE 5

1. GEOPHYSICAL STUDIES

Category 1	\$ 75,000
Geologic Mapping	
Survey of Soil Mercury Content	
Self - Potential Survey	
Gravity Survey	

Category 2	
Electrical Resistivity Surveys	25,000

2. DRILLING

Transporting Drilling Equipment and supplies to Tutuila and Return	250,000
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Drilling 3500 foot well Equipment and Crew	650,000
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Drilling 4500 foot well Equipment and Crew	850,000
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Drilling 6000 foot well Equipment and Crew	<u>1,000,000</u>
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2,850,000

Contingency	<u>150,000</u>
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3,000,000

GEOTHERMAL EXPLORATION COST ESTIMATES

FIGURE 5-2