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TITLE: THE ECONOMICS AND APPLICATIONS OF GEOTHERMAL ENERGY IN ST. LUCIA

AUTHOR(S): J. H. Altseimer, S-4
A. E. Burris, S-2
F. J. Edeskuty, S-4
L. K. Trocki, S-2
K. D. Williamson, Jr., S-4

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Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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The Economics and Applications of
Geothermal Energy in St. Lucia

J. Altseimer, A. Burris, F. Edeskuty, L. Trocki, K. Williamson Jr.

I. INTRODUCTION

St. Lucia, an independent country of the Eastern Caribbean Commonwealth, is a volcanic island of the Lesser Antilles arc. It has a population of 125,000 and an area of 616 km^2. The terrain is largely mountainous (Fig. 1) with the highest point (967 m) being Mt. Canaries. The island is covered with tropical vegetation and cut with fertile valleys which provide the area for the principal industry--agriculture. Among the striking natural features are the twin peaks known as the Pitons which rise abruptly from the sea south of the town of Soufrière. To the northeast of these peaks is the Qualibou caldera. This area is dominated by steam fumaroles and boiling pools which attest to its volcanic origin. Although the last large eruption occurred about 20,000 years ago, past geologic and geophysical studies indicated a significant residual geothermal resource in the Qualibou caldera. The U.K. Ministry of Overseas development explored this geothermal resource by drilling seven shallow exploratory wells. Steam was found in four of the seven boreholes. Results of the overall project suggested a need for further studies, but also indicated a feasible economic basis for geothermal development.

The assessment reported here was funded by the Trade and Development program (TDP) of the US Government. It consisted of three major tasks: first, a field geologic assessment of the physical extent of the Qualibou caldera geothermal resource; second, an engineering evaluation of the potential development of the geothermal resource; and third, a study of the potential economic impact upon St. Lucia associated with the development of the geothermal resource.

The first task, the geologic assessment, will not be discussed in detail. To summarize this portion of the study--from the geologic evaluation, deep resistivity measurements and the evaluation of hyrogeochemical samples it was concluded that:

- The Qualibou Caldera has excellent geothermal potential and deep drilling should result in the discovery of a high-temperature (240 - 280°C) brine reservoir.

- Geothermal fluids and vapors should be found at a depth of 1-2 km under the central and southern caldera area and in abundance where permeable rocks and faults allow greater fluid movement.

In addition, three locations were recommended as sites for the first production wells.

Details and results of the latter two tasks will be the focus of this paper.

II. CURRENT STATUS AND PROJECTED DEMAND FOR ENERGY

Two power grids--the northern and southern grids--supply electricity on St. Lucia. The total installed capacity is 16 MWe with a peak power consumption of 12 MWe and average power consumption of 8 MWe. All power is supplied by diesel generators at an average consumer cost of $0.192/kWh US (busbar cost = $0.102/kWh US). In 1980 imports amounted to $115 million and exports $26 million--the large import bill being largely due to oil.

St. Lucia Electricity Services Limited (LUCELEC) has predicted an annual electrical demand increase of 5% in the northern grid and 4% in the southern grid. A base-load demand of 10 MWe is projected by St. Lucia planners for 1987. This is projected to rise to 30 MWe by the year 2016. Most of the diesel generator sets are aged and are being overhauled to increase their generating life. At some point in the near future they will have to be replaced and new capacity added in order to meet the expected growth in electrical demand.

Currently, thermal requirements on the island are small but the availability of low cost gas thermal heat could lead to the introduction of several new industries. The cost of this energy if supplied by oil is about $8.00 US per million BTU ($7.59 US/$10^9$ joules).

III. DESCRIPTION OF POWER AND HEAT GENERATING SYSTEMS

According to the Los Alamos estimates, a hot water reservoir exists at depths of 1,000 to 2,000 meters. Temperatures range from 240 to 280°C (464 to 536° F). Pressures should be comparable to those in other high-quality reservoirs and be capable of providing the usual geothermal steam turbine inlet pressures of 50 to 115 psia. Total capacity and effective reservoir lifetime will be known with some accuracy only after flow data from the new wells are accumulated and analyzed. The assumption was made that for every two geothermal wells drilled, sufficient energy will be available to provide 2.5 MW of electric power. This assumption and the predicted increase in demand can be used to select the desired rate for the introduction of geothermal electric power generation. This rate should maximize the geothermal electric power generation while operating the geothermal units so as to remain as close as possible to being base-loaded, an efficient scheme because the major cost of geothermal power is the investment for capital equipment.

If wellhead generating modules are installed, it should be possible to generate power while the field is also being evaluated. If well drilling can be started by late 1984, we assume that by the end of 1987, four wellhead modules could be installed to provide 10 MWe. This production level would satisfy the base-load power demand projected by St. Lucia planners, and higher levels would not be required until about 1993. Therefore, 5 years would be available to learn more about (1) the geothermal reservoir, (2) the maintenance requirements, (3) the operation and control of the generator system, and (4) the possible environmental problems. A more centralized system could also be planned and constructed. According to St. Lucia's projections, base-load power requirements will rise to 30 MWe by the year 2012; a central power station would be appropriate for this level of power production. A centralized system would include above ground piping for the geothermal fluid, and both older and newer wells and steam generators would be interconnected. The availability and reliability of the system would be improved by an integrated gathering system. An artist's sketch of the surface components of the geothermal system is shown in Fig. 2.

Preliminary engineering estimates have been made of the design and performance characteristics of a representative generating system that would use well-established technology. An objective was to select the simplest technical approach consistent with reasonable generation efficiency, reliability, and minimum environmental impacts. The selections were guided by numerous conversations with industrial experts in the field. First, the arbitrary assumption was made that each production well would supply enough fluid and energy to produce 2,500 kWe net power. This assumption is conservative compared with other wells at various locations around the world. It was assumed that steam produced in a single flash steam-water separator would be used to drive turbo-generators. Hydrogen sulfide and particulate removal subsystems should be included upstream of the turbines. Because the turbine performance is very sensitive to back pressure, the existence of a low-pressure steam condenser was assumed. The noncondensable gases that would probably be encountered in the geothermal fluid will be removed by a steam-driven ejector subsystem. The residual geothermal fluid will be reinjected underground into permeable or naturally fractured strata so as to avoid interference with aquifers that might be tapped for potable domestic water.

The wellhead fluid temperature selected for the design-point case is 250°C (482°F). The fluid will pump itself out of the well by forming a steam-water mixture in the upper sections of the well. The flashing process will be completed in a steam-water separator operating at the selected design-point pressure of 90 psia. Twenty per cent by weight of the fluid will become steam and the remaining 80% will be hot water at 160°C (320°F). Some steam pressure is lost enroute to the turbine thus reducing the design-point turbine entry pressure to 75 psia. The estimated optimum turbine back-pressure is 3 in. of mercury (1.5 psia). The total well flow rate was calculated as 122,900 kilograms/hour (270,900 pounds/hour). The above design-point conditions will vary as the technical and economic system optimization process progresses into more definitive detail.

Among the many design considerations, one of the most important is the cooling method used in the steam condenser subsystem. Cooling can be performed with air flowing in a forced-draft tower. In the warm climate of St. Lucia, cooling will put a significant parasitic power load on the system, and the condensing temperature and pressure may still be somewhat higher than desired. Local water could be used, but such water supplies may not be readily available. Therefore, it is recommended that ocean water be considered for use in the follow-on systems that will be built after the initial wellhead generator phase of the development. Cold water pumped from the ocean depths offshore Soufrière could be a valuable asset. A study of a representative design of an ocean water pumping system for cooling a condenser located at a possible power plant site like Cresslands found the power consumption and costs to be reasonable. In the case studied, the inlet line was 4 kilometers long with 1.6 kilometers deployed offshore to a 500 meter depth. The inlet water temperature was estimated as

13.3°C (56°F). Even colder water would be available if greater depths can be tapped.

A large quantity of thermal energy is contained in the residual water flowing from the steam-water separator. The 160°C (320°F) temperature is suitable for many industrial process heat applications. For example, about 35% of the process heat in the US is between 65 and 175°C (149 to 346°F). A number of possible applications of the above heat were investigated.

The heat can be transferred from the geothermal fluid to the clean and chemically controlled water flowing in closed loops between the power generator and the industrial facilities. The possible arrangement is illustrated in Fig. 2 where one loop is shown supplying industrial plants in Soufrière near the Copra Manufacturers, Ltd., plant. An extension is shown as running out to possible new tourist hotels in the Anse Chastanet Hotel vicinity. Another loop is directed toward Choiseul and Vieux Fort.

A summary of the possible geothermal systems investigated shows that even with conservative assumptions there are no insurmountable obstacles to development of either power generation or heat delivery systems. However, a great deal of work still needs to be done on matters such as plant siting, steam condensing subsystems and coolants (ocean, indigenous water, air), single or double flash steam systems, bi-phase (water and steam) systems, binary primary or bottoming systems, the actual effluent to be expected from the well, expected demand for process heat, and location of the industrial plants using the heat.

IV. SCENARIO FOR THE INTRODUCTION OF GEOTHERMAL POWER

Curves for future average and peak electricity consumption are shown in Fig. 3. Also shown in Fig. 3 is the recommended rate for the introduction of geothermal-based electric power generation. These curves show that it is desirable to install the first 10 MW as quickly as possible (by 1987). Thereafter, the completion of additional 2.5-MW systems will be needed in intervals varying from 5 years initially to 2 years shortly after the turn of the century. To calculate the levelized life cycle cost (LLCC) for the electricity, we do not need to extend the scenario beyond the year 2016, when a geothermal capacity of 30 MW is attained. Because the geothermal system should be operated as close to its full capacity as possible, additional power generation capacity is required for peaking. We assume that peaking power will continue to be provided by the existing diesel units, which will be replaced as it becomes necessary. For this reason, a curve showing the desired total power production capacity (including reserve) is also shown in Fig. 3.

V. COST STUDIES

A. Geothermal Power Costs-Electricity

From the scenario represented in Fig. 3, estimates were made of the capital and operating expenditures over the assumed project lifetime of 30 years. Costs were itemized by year, and a discounted cash flow computer code calculated the LLCC for the system under study.

For the base case, it was assumed that the geothermal wells would have a lifetime of 20 years and that the generation equipment will require replacement after 30 years of service. Wells were assumed to cost $5.4 million EC($2 million US) each and the generation system $2,700 EC($1,000 US) per kilowatt of installed power. Contingency factors of 25% were added to both capital equipment costs and operating costs. With these costs and the other necessary expenses over the years, a LLCC of $0.170 EC($0.063 US) per kilowatt hour was obtained.

If UN funding is obtained for drilling the first three wells and repayment made according to the required consistency of UN schedule, the LLCC is slightly less, amounting to $0.167 EC($0.062 US). The cost of producing the much smaller amount of peaking power by the existing diesel method is $0.275 EC($0.102 US) per kilowatt hour. If all the future electricity were to be produced entirely by a diesel system, the generation cost per kWh would be a little less than the above diesel cost and would amount to $0.243 EC($0.090 US) per kilowatt hour; however, the lower cost of the geothermal generation, which produces most of the electricity where the combined systems are in use, results in reduced oil imports as well as a cost savings. See Table 1. For the proposed system indicated by Fig. 3 during its 30-year operation, a 231-million-gallon reduction of diesel oil use results, corresponding to a decrease in expenditure for imported oil of $783 million EC($209 million US). The difference in total cost between all diesel generation and geothermal base-load plus diesel peaking would save $264 million EC($98 million US) over the 30-year period, if the UN funds drilling of the first three wells.

B. Sensitivity Studies-Electricity

Sensitivity studies were made for variations in the cost of drilling the wells, the cost of the generating equipment, interest rate, inflation rate, insurance rate, and capacity factor. The cost of well drilling and of the generation equipment are two factors that affect only the geothermal costs, whereas the other factors have effects on all of the generation systems considered. The results of the sensitivity studies for these two factors are presented in Figure 4. This figure shows that the cost of the electricity generated from geothermal power can be even less than predicted above with conservative assumptions. When the exploratory wells have been drilled, closer estimates will be possible. With a favorable combination of several of the parameters used in the sensitivity studies or with more productive wells than those assumed here, the cost of the electricity could be as much as 40 to 50% lower than estimated here.

C. Power Cost from Alternative Technologies-Electricity

For comparison the generation cost was also estimated for coal-fired and oil-fired steam power plants. Provided that these plants can be base-loaded, they are less expensive than diesel generation but more expensive than the geothermal system. In addition, these plants must be added in larger increments, which consequently makes it more difficult to contribute as much to the total power demand while remaining close to the base-load condition. A summary of the cost estimates for each of the above-mentioned generation systems is given in Table 1 and Fig. 5.

D. Geothermal Power Costs-Thermal Energy

To make cost estimates of both waste and dedicated well process heat, we began with a conceptual system design and assumed a load on the system to determine its capacity factor. Three heat-delivery cases were studied to determine a cost range. All of these cases assumed that the heat source was either waste heat from the power generation process or from a heat production well located, arbitrarily, near Cresslands.

In Case 1, the heat is delivered over 2.4 kilometers to potential users in Soufrière. The heat is taken from the 160°C (320°F) water from the steam separator. The maximum temperature delivered to the user plant is 140°C (285° F). Case 2 uses a well dedicated to heat production and delivers heat into a Soufrière plant at 223°C (433°F). Case 3 is similar to Case 1 except that the heat is delivered to the Vieux Fort Industrial Park through a 21-km piping system. The final delivery temperature is 132°C (270°F).

Capacity factors (ratio of heat delivered to maximum available for delivery) of 0.22 to 0.94 were used in the cost calculations. The 0.22 capacity factor corresponds to the full output of one well being used in a plant operating on a one-shift, 5-day per week schedule. The 0.94 factor is for a three-shift, 7-day per week schedule, both factors allowing for a 94% availability of the heat transfer and heat source systems. Electricity to drive the system pumps was assumed to cost either $0.216 EC($0.0810 US) per kilowatt hour (approximate busbar cost) or $0.518 EC($0.192 US) per kilowatt hour (assumed sale price). An additional variable is the minimum useful temperature in any particular process heat activity. Two values of temperature, 27°C (80°F) and 66°C (150°F), were used.

Figure 6 shows costs to deliver waste heat to a nearby plant (Case 1). As expected, the data show that to keep heat costs down, the plants should be operated as continuously as possible, and therefore only data for three-shift operations are shown. The use of residual heat from a power cycle results in the lowest costs. At a capacity factor of 0.67 (3 shifts, 5 days a week), heat to Soufriere costs from $2.25 EC($0.83 US) to $4.45 EC($1.65 US) per million Btu. At a factor of 0.94 (3 shifts, 7 days a week), the costs range from $1.73 EC($0.64 US) to $3.62 EC($1.34 US) per million Btu. The costs at Vieux Fort are $7.60 EC($2.81 US) to $14.50 EC($5.37 US) per million Btu for a capacity factor of 0.67 and $5.67 EC($2.10 US) to $11.42 EC($4.23 US) for a factor of 0.94.

In Case 2, the cost of heat are higher because all the heat cost must be charged to the heat production system. This case would only be justified if there were a requirement for the higher temperature that this design can provide.

The costs of the geothermal heat compare favorably with heat from oil, which costs about $21.00 EC($7.77 US) per million Btu.

E. Potential Electricity-Intensive Industries

Although the cost of geothermal electricity is estimated to be less than diesel electric power generation, it still is not cost competitive with electricity prices in many other places. Therefore, it is doubtful that a new industry would be attracted to St. Lucia on the basis of only the projected cost of geothermal electricity for St. Lucia. However, it was noted during the course of the investigation that the cost of process water is high in St. Lucia.

With more data, harnessing geothermal electricity to pump process water from wells may prove economical and attractive to industry.

F. Potential Process Heat Applications

The development of geothermal energy in St. Lucia will make available large quantities of process heat. With assumed well capacities and temperature levels of the available thermal energy, we can consider potential applications. Several industries were considered (Table 2), but for the sake of brevity, only two will be discussed here.

Coconut Oil Production. Copra processing requires heat at temperatures compatible with the geothermal resource. The temperatures required range from 71°C (160°F) to 200°C (392°F). The lower temperatures can easily be supplied by the waste heat cases, but the highest temperatures would require energy from the primary wellhead flow as in Case 2.

The Copra Manufacturing, Ltd., plant in Soufrière is a good candidate for the use of geothermal process heat. This plant now uses 80,000 to 100,000 imperial gallons of Bunker C fuel per year, amounting to a total energy input of 18 billion Btus. The plant operates three shifts, 5 or 6 days per week. If the total number of work days per year is 240 and the boiler efficiency is 85%, the process heat usage rate is 2.66 million Btu/hour. This is less than 4% of the heat available from a well dedicated to heat production. One such well could supply a number of similar plants. Alternatively, the system output could be reduced to match the demand more closely.

Dry Ice. Dry ice can easily be produced in St. Lucia and could be an easily transportable source of refrigeration (275 Btu/lb at -110°F), which in turn could lead to an expanded fishing industry or could possibly be exported to other Eastern Caribbean countries. The key to the success of such an industry is carbon dioxide (CO_2), which is present in the geothermal steam. Typically geothermal noncondensable gases contain about 1% of CO_2, which could supply approximately 1,400 tons/year per producing well and provide sufficient refrigeration to cool and freeze 3.5 million lb/year of fish from 85 to 0°F.

Dry ice production relies on steam used to drive compressors that raise the CO_2 pressure to 1,100 psi. Each ton of dry ice requires 20,000 pounds of steam. The only other resource required is labor, which averages 8 man-hours per ton. The availability of both low-cost geothermal steam and CO_2 would make this industry attractive. Further detailed studies should be made when the exact composition of the geothermal resource is known.

Other Applications. The other possible uses of geothermal process heat evaluated were timber processing, concrete block production, beer production, alcohol from sugar cane, banana chips, hotel hot water, and fresh water extraction from geothermal fluids. All of these potential applications are worthy of further investigation. Sea water desalination was also considered but did not appear practical.

VIII. ECONOMIC MODELS

The simplest and most aggregate (i.e., inclusive and comprehensive) economic framework contains households that spend all income on consumer goods and firms that sell all output to households (Fig. 7). In our investigation of the St. Lucian economy, the importance of international trade became readily apparent, so international trade in capital goods imports and agricultural exports were added to the basic domestic economy. Fixed investment includes purchases of newly produced capital goods such as machinery and newly built structures. Inventory accumulation was not considered.

Our economic framework covers imports, exports, consumption expenditures, investment, and manufacturing. Data sources for the project include the Government of St. Lucia, Agricultural Producer Cooperatives, and the World Bank.

Geothermal development could have both short- and long-term impacts on the St. Lucian economy. The following two sections present a description of the models used in this two-pronged investigation of the immediate and long-term effects of geothermal development.

A. Comprehensive Economic Modeling

A typical approach for short-term economic forecasting and planning develops an overall, or macroeconomic, framework (model) of the economy using data on economic variables such as production, consumption, government expenditures, etc. The model developed for St. Lucia highlights agriculture and tourism and will be useful in overall economic planning and forecasting. Like many developing countries, St. Lucia has a relatively large foreign trade sector, to which greater attention was accorded in our model. The economic model developed for St. Lucia consists of 21 mathematical expressions describing the economic behavior of important agents in the economy, e.g., producers, consumers. The model is completed by constructing five mathematical definitions describing relationships among economic variables. In the statistical calculations, we make standard assumptions about the mathematical form of these relationships. The model does not consider the monetary sector and consequently does not determine the absolute level of wages or prices.

B. ETA-MACRO Modeling

To estimate long-term growth given a variety of energy supply scenarios, we applied the widely-used computer model, ETA-MACRO (Energy Technology Assessment-Macroeconomic). The model is divided into two parts to account for the beneficial effects of oil import reduction afforded by geothermal developed in the energy-economy interaction shown in Fig. 8. The model can be exercised for energy-economy planning by examining the effects of different world oil prices, rates of geothermal development and industrial development, and other variable factors.

The ETA submodel considers the energy resources and technologies available to St. Lucia and then calculates the best technology mix and time of installation for the available technologies. The model does this by finding the lowest cost of energy supply given the resource, technology, and investment constraints that St. Lucia encounters.

The MACRO submodel maximizes long-run cumulative consumption. Consumption is dependent upon gross output, which in turn is constrained by labor, capital, and energy--the foundations of economic productivity. Energy-economy interactions occur because high-energy costs can prevent rapid economic growth: money spent to pay energy bills cannot be used for investing in new capital or for hiring more labor. Some freedom of substitution of these inputs in the production process is possible and accounted for in the MACRO submodel. A tradeoff also exists between consumption and investment. Consuming all of the country's output today would decrease consumption in the future because saving today is required to maintain or increase investment, output, and consumption in the future. The submodel MACRO selects the level of investment that maximizes consumption in the time period considered (30 years).

The ETA-MACRO model gives (1) a schedule of the least-cost energy technologies that should be used in an economy, (2) the projected growth rate for consumption, and (3) the optimal investment levels.

IX. ECONOMIC RESULTS

A. Macro Econometric Model

In the development of the econometric model, attention focused on consumption and output. These two components contain a total of seven behavioral equations. The output equations focused on the important private sectors of the economy: tourism, services, industry, and agriculture. The consumption equations dealt with food and beverages, fuel and light, and durable goods.

Forecasts for these seven important sectors indicate an increase in economic activity led by increases in agricultural output (Table 3). This increase is due in part to higher yields and to the adoption of better cultivation practices in banana production in the posthurricane period.

Consumption of durable goods is expected to slow as automobile imports decline. This decline will reduce output in the service sector, which will depress gross domestic product (GDP) growth. However, a countervailing force is the substitution of geothermal electricity for electricity generated from imported diesel fuel, resulting in higher consumer incomes which lead to a higher durable goods consumption growth rate (a 9.3% increase). Increased consumption (consumer spending) stimulates the overall economy which in turn leads to improved living standards.

B. ETA-MACRO Model

For the longer term examination two electricity-generating technologies were considered for the application of ETA-MACRO to St. Lucia: (1) continued exclusive use of diesel generators; and (2) gradual introduction of geothermal capacity with decreasing reliance on diesel generators. It was assumed that geothermal energy reaches a capacity of 10 MW by 1992 and 30 MW by 2012.

As stated earlier, ETA-MACRO chooses the mix of energy technologies and investment rate that maximizes cumulative consumption. Consumption is calculated on an annual basis by subtracting investment and energy costs from the total output. Consumption is the total amount that St. Lucians have to spend on food, clothing, shelter, and luxury goods. Therefore, a relative increase in consumption raises the standard of living by making spendable income more available. The economic model focuses on the well-being of St. Lucians and so maximizes consumption. As stated earlier, increases in the amount which consumers have to spend also presume investment growth and expansion in all segments of the economy. ETA-MACRO selects an optimal level of investment that will most benefit St. Lucia.

Figure 9 shows the ETA-MACRO results for a specific assumption about oil price increases. The benefit of geothermal energy is examined under two different assumptions about the future price of oil, because the exact future oil price is unknown. The bar graphs show the increase in annual consumption due to installation of geothermal power. Comparison of the bars shows that for both assumptions about future oil prices, consumption is greater if geothermal capacity is installed. In general, as the annual rate of increase for oil prices becomes larger, the relative benefit of geothermal energy to the economy increases.

In summary, the two economic models predict a growing economy led in the short run by increases in agricultural production, followed by increases in tourism. This growth has a spill-over effect that leads to growth in consumption of fuel and light, food and beverages, and to a lesser extent consumer durables. In the longer run as geothermal electric generating capacity is added, a significant increase in the standard of living is seen.

X. CONCLUSIONS

From the engineering and economic study it was concluded that

- The geothermal system was the most economic for the generation of electricity when compared with competing technologies.
- At present, the cost of geothermal electricity alone is not low enough to induce electricity-intensive industries to locate in St. Lucia. However, the abundance of low-cost thermal energy resulting from geothermal development should attract industries that require large amounts of process heat.
- The introduction of geothermal power causes a long-term net increase in consumption of \$25 million EC(\$9.3 million US) to \$50 million EC(18.5 million US) over the projected 30-year period, depending upon assumptions about the price of oil. Increased consumption will stimulate the overall economy, improve the standard of living, and boost the spending power of the population by \$130 to \$250 million EC(\$48.1 to 92.6 million US) over the next 30 years.
- The difference in cost between all-diesel generation and geothermal base-load generation plus diesel peaking will save \$264 million EC(\$9.78 million US) over the 30-year period.

XI. ACKNOWLEDGEMENTS

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TABLE 1

COST COMPARISON--ELECTRICITY FROM GEOTHERMAL ENERGY AND FROM ALTERNATIVE TECHNOLOGIES

System	LLCC[a] ($EC/kWh)	Savings[b] ($M EC)	Remarks
1. Geothermal	0.170	253	No U.N. funds
2. Geothermal	0.167	264	U.N. funds three wells
3. Diesel (peaking)	0.275	---	Add on to base-load system
4. Diesel (total)	0.243	0	Continuation of present system
5. Oil-fired steam	0.233	5	
6. Coal-fired system	0.192	167	

[a]All $ here and elsewhere in this report are 1983 $ unless otherwise noted. See text for US dollar equivalents.

[b]Savings represent difference in total expenditures between continued diesel generation and using diesels for peaking only plus alternate systems for base-load for 30-year period.

TABLE 2

POTENTIAL APPLICATIONS OF GEOTHERMAL HEAT IN THE SOUFRIÉRE OR VIEUX FORT AREAS

	Source of Heat		
Activity	Power Plant Residual	Wellhead	Feasibility
Coconut oil production	X	X	yes
Timber processing	X		yes
Concrete block production	X		yes
Beer production	X	X	yes
Alcohol from sugar cane	X		yes
Dry ice production	X		maybe
Banana chips	X	X	yes
Hotel hot water	X		yes
Fresh water from geothermal fluids	X		maybe

TABLE 3
FORECAST LEVELS OF CONSUMPTION AND PRODUCTION;
ST. LUCIA, 1983 AND 1984

	1983	1984	% Change
	$1,000 EC($370 US)		
Consumption			
Food & Beverages	30,321	30,683	1.2
Fuel & Light	4,384	4,547	3.7
Durable goods	8,136	8,147	0.14
Production			
Agriculture	26,863	28,576	6.4
Tourism	11,872	12,327	3.8
Industrial	20,315	20,798	2.4
Services	71,743	71,969	0.32

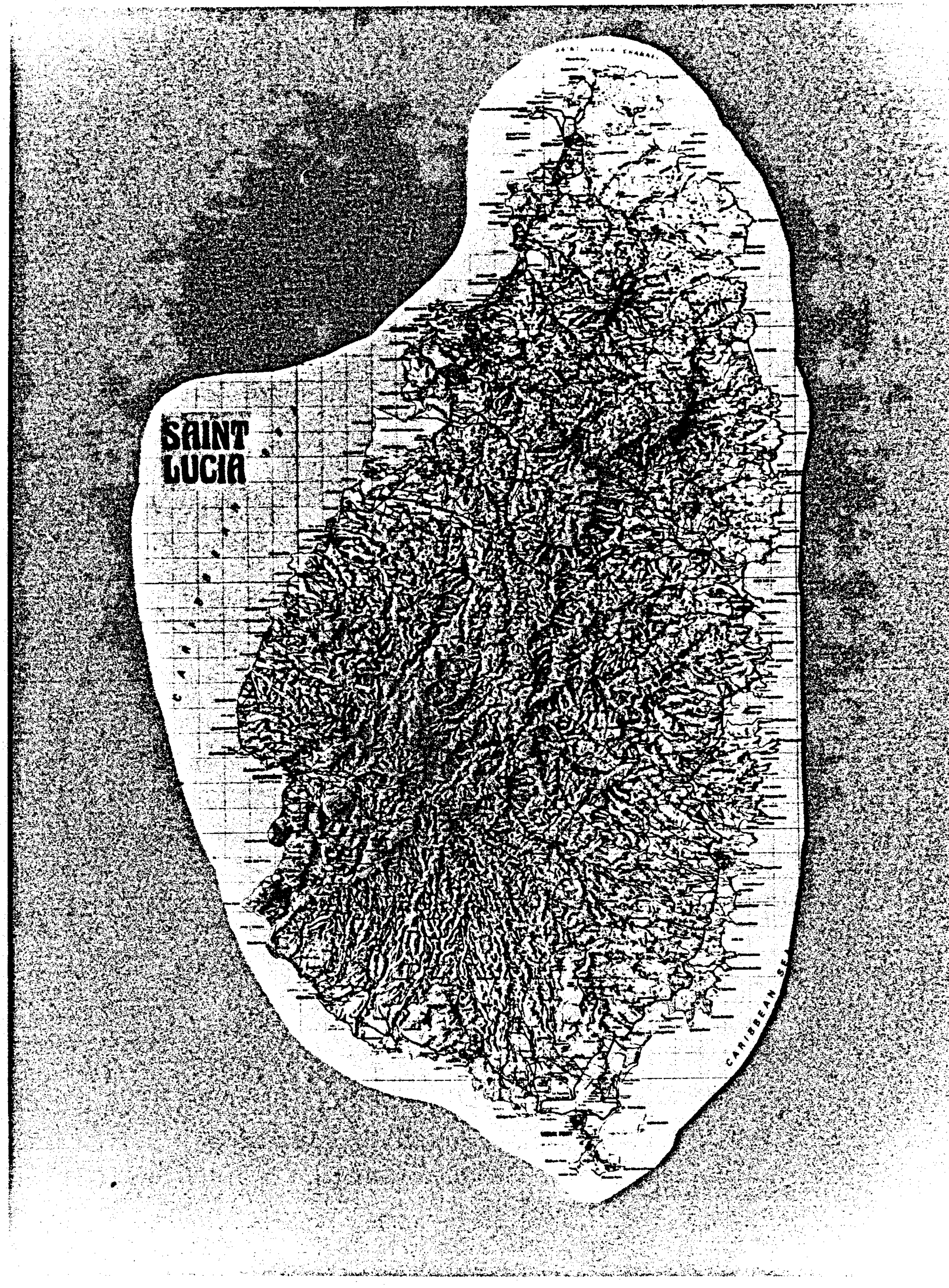

Fig. 1. Map of St. Lucia.

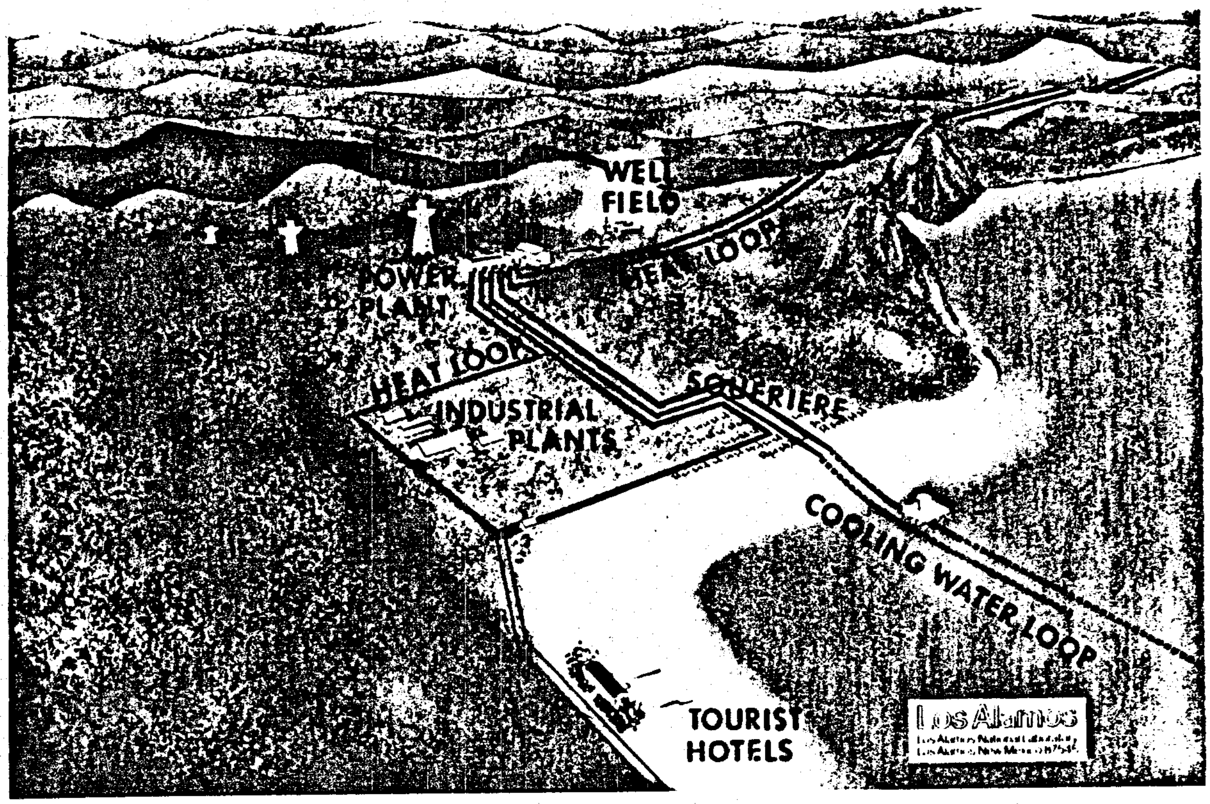

Fig. 2. Artist's conception of future geothermal power and heat production systems in St. Lucia.

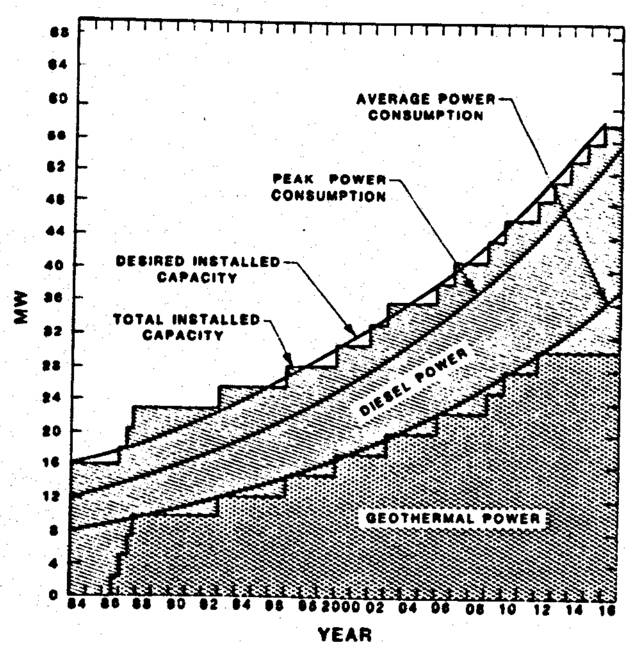

Fig. 3. A scenario for the introduction of geothermal electric power in St. Lucia.

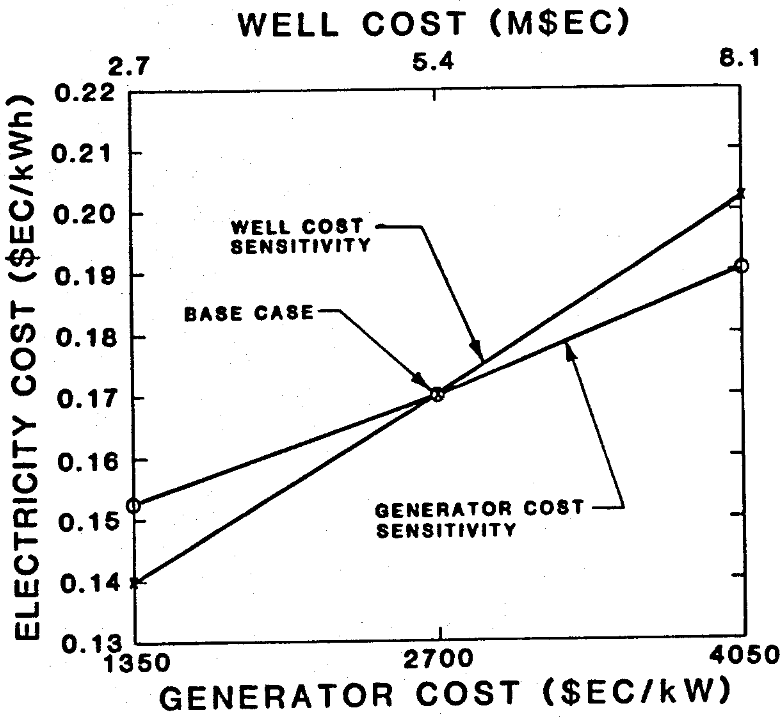

Fig. 4. The sensitivity of the cost of geothermal electricity to variation in the cost of drilling wells and the cost of generating equipment.

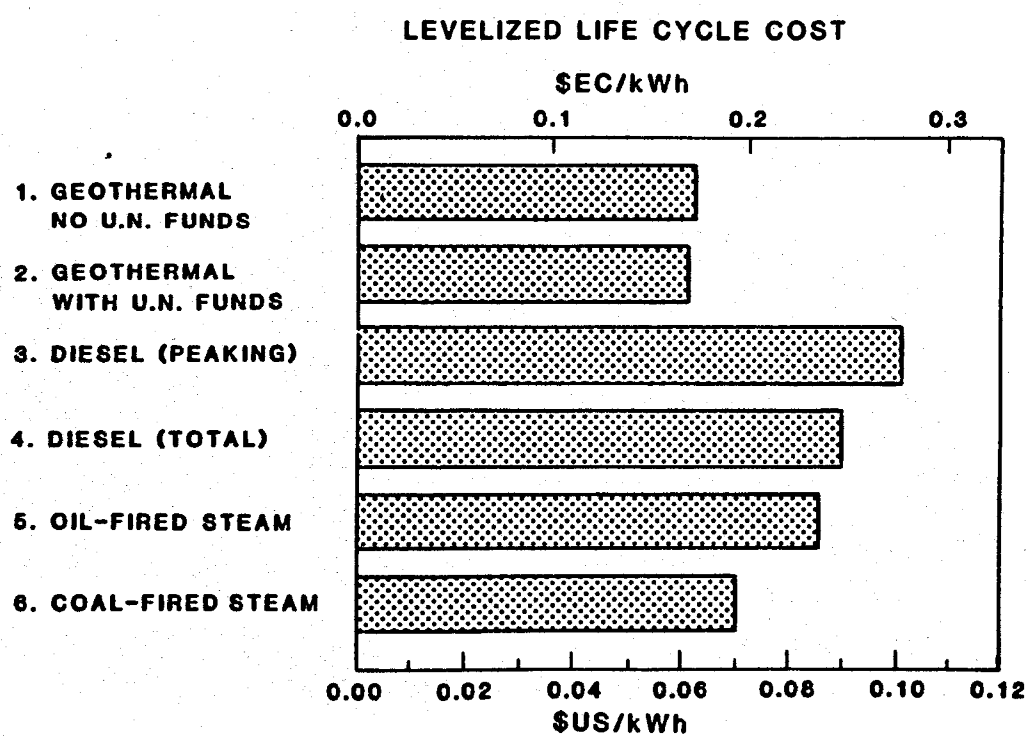

Fig. 5. Cost comparison of electricity from geothermal generation and from alternative technologies.

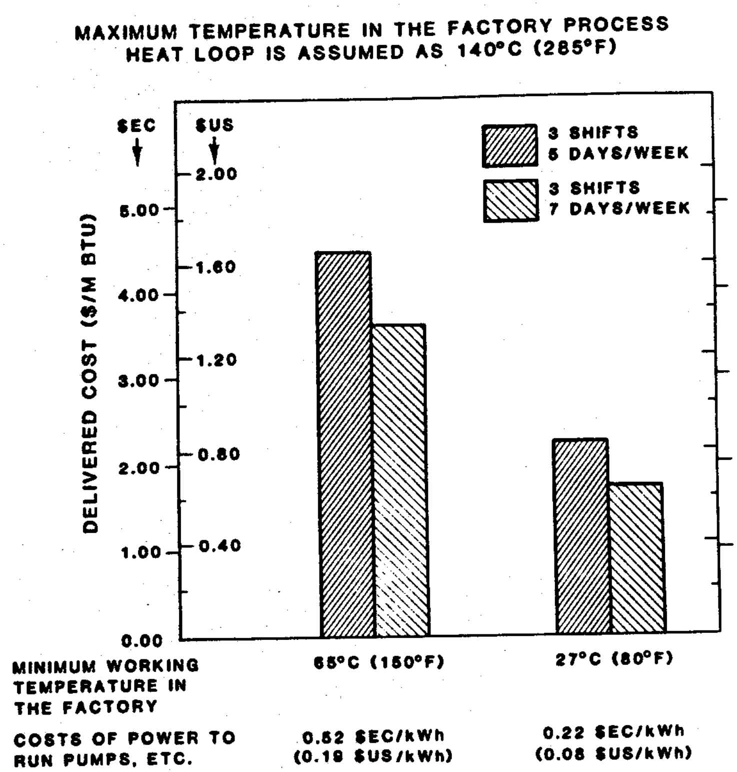

Fig. 6. Cost of process heat delivered to a factory over a distance of 2.4 kilometers.

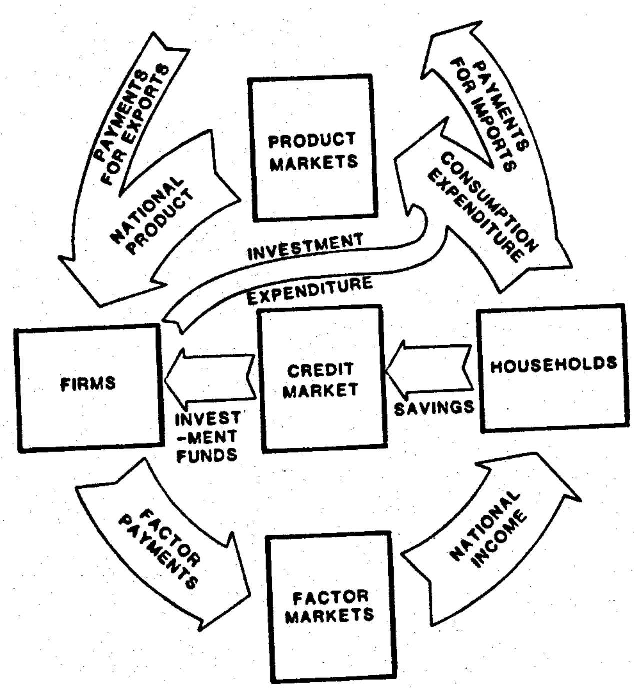

Fig. 7. Circular flow of payments in an economy.

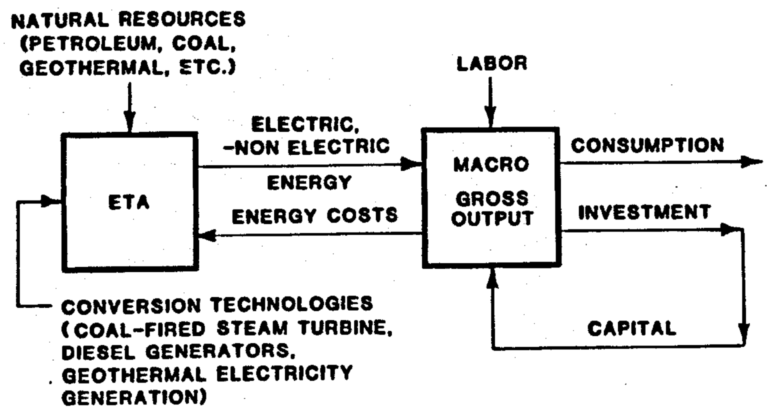

Fig. 8. An overview of ETA-MARCO.

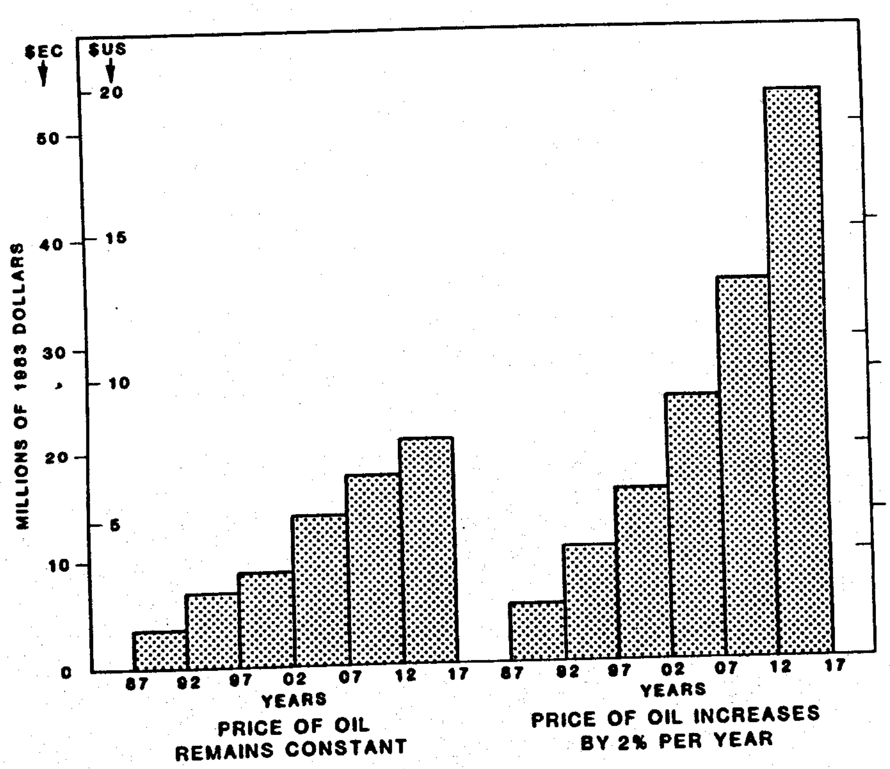

Fig. 9. Increase in annual consumption due to installation of geothermal power.