INTERNATIONAL GEOTHERMAL ENERGY DEVELOPMENT

A Profile of Government R&D Activities

**U.S. Department of Energy
Geothermal Technology Division
Washington, D.C.**

PRELIMINARY DRAFT - JANUARY 24, 1990

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Prepared by:

**MERIDIAN CORPORATION
4300 King Street, Suite 400
Alexandria, VA 22302**

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I. INTRODUCTION

Energy development throughout the world continues to expand in scope to seriously consider alternative sources. Many countries are turning their attention to the potential of geothermal energy as an indigenous, environmentally safe and economic option.

As U.S. geothermal technologists and industry aim to protect their leading role and seize the international market opportunities, it has become increasingly important to maintain awareness of international geothermal energy activities. It has become particularly critical to understand the role of international governments in supporting the development of geothermal resources technology and industry within their country.

This report examines the characteristics of key international government geothermal research and development (R&D) programs, and, to some extent commercialization and foreign assistance. It also discusses emerging trends in these programs, particularly as they relate to the broader context of energy planning. Section II addresses the contemporary nature of geothermal programs amidst their larger, national energy settings. Descriptions of geothermal energy programs for 17 countries selected for this study, and the energy production and use environment in which these programs exist, are presented in Section III. Section IV presents brief data for several countries with minimal activities or for which little information is available.

The report considers geothermal energy development programs in countries around the globe. Each program is unique, and the government's role in that program can vary across a spectrum of actions from no activity to full-scale commercialization and export promotion, with creative financing packages marketed to prospective country buyers. Distinctions

among research, development and commercialization activities are often subtle and arbitrary. Table 1 characterizes the governmental role in these countries, while Table 2 presents the budgets governments have reported they have committed to geothermal R&D programs. Table 3 summarizes geothermal power production for the world. Specific data on programs, activities, plans, and budget commitments are presented in the following section. The information presented is limited by the data readily available for these countries. Formal information requests are being forwarded to these countries by the DOE Office of International Affairs. Upon receipt, this information will be incorporated into this report.

TABLE 1

NATURE OF GOVERNMENT ROLE AMONG GEOTHERMAL ENERGY PRODUCING COUNTRIES

COUNTRY	GOVERNMENT ROLE		
	R&D	COMMERCIALIZATION	FOREIGN ASSISTANCE
Argentina		•	
Australia		(No apparent government role)	
Belgium		•	
Bolivia	•		
Brazil		•	
Canada		•	
China	•	•	
Costa Rica		•	
Denmark	•		
Djibouti	•	•	
El Salvador		•	
France	•	•	•
Germany	•	•	•
Greece	•	•	
Guatemala		•	
Hungary		(Insufficient data)	
Iceland	•	•	
Indonesia	•	•	
Italy	•	•	•
Japan	•	•	
Kenya	•	•	
Mexico	•	•	
The Netherlands	•		
New Zealand		•	•
Nicaragua		•	
The Philippines		•	
Portugal (Azores)		•	
St. Lucia		•	
Sweden		•	
Turkey	•	•	
United States	•	•	
USSR	•	•	

TABLE 2
R&D BUDGETS FOR GEOTHERMAL ENERGY
IN CURRENT U.S.\$ (MILLIONS)

COUNTRY	BUDGET				
	1985	1986	1987	1988	1989
Argentina					
Australia					
Belgium	.15	.11	.24	.76	
Bolivia					
Brazil					
Canada	.44	.14	.15	.16	
Chile					
Costa Rica					
Denmark	0				
Djibouti					
El Salvador					
France					
Germany	4.28	5.06	1.39	1.42	
Greece	2.53	4.26	1.24	6.24	
Guatemala					
Hungary					
Iceland					
Indonesia					
Italy	.30	2.44	2.35	1.57	
Japan	21.62	35.76	35.71	24.51	49.2
Kenya					
Mexico					
The Netherlands	4.21	1.18	2.37	2.12	
New Zealand	.99	.52		.29	
Nicaragua					
The Philippines					
Portugal			.05	.04	
Spain	1.18	2.06	2.84	4.42	
St. Lucia					
Sweden	.46	.70	.71	.16	
Turkey	.09	.11	.13		
United Kingdom	4.75	6.60	5.56	5.34	5.02
United States	30.80	26.70	22.30	20.73	19.56
USSR					
(Total IEA)	82.30	86.49	76.34	82.86	

NOTE: A blank indicates data are expected to be supplied by country indicated.

SOURCE: IEA

TABLE 3

**NET INSTALLED CAPACITY OF ELECTRICITY GENERATING
PLANTS - GEOTHERMAL (000'S OF KILOWATTS)**

	<u>OUTPUT</u>	<u>YEAR</u>
I. WORLD	4,164	1984
	6,588	1985
	7,138	1986
	7,366	1987
II. AFRICA (ALL IN KENYA)	30	1984
	45	1985
III. NORTH AMERICA	1,703	1984
	3,853	1985
	4,356	1986
	4,488	1987
UNITED STATES	1,368	1984
	3,298	1985
	3,691	1986
	3,708	1987
CANADA	0	1984-87
IV. CENTRAL AND SOUTH AMERICA		
EL SAVADOR	95	1984-87
MEXICO	205	1984
	425	1985
	535	1986
	650	1987
NICARAGUA	35	1984-87
V. ASIA	1,153	1984
	1,153	1985
	1,147	1986
	1,147	1987
INDONESIA	30	1984-87
JAPAN	214	1984-87

TABLE 3 (Cont'd)

**NET INSTALLED CAPACITY OF ELECTRICITY GENERATING
PLANTS - GEOTHERMAL (000'S OF KILOWATTS)**

	<u>OUTPUT</u>	<u>YEAR</u>
VI. EUROPE	1,121	1984
	1,121	1985
	1,121	1986
	1,121	1987
BELGIUM	5	1987
DENMARK	26	1984
	50	1985
	84	1986
	118	1987
WEST GERMANY	0	1984
	3	1985
	0	1986
	0	1987
GREECE	0	1984
	0	1985
	3	1986
	2	1987
ICELAND	42	1984-87
ITALY	447	1984
	439	1985
	452	1986
	506	1987
THE NETHERLANDS	0	1984
	0	1985
	3	1986
	10	1987
PORTUGAL	1	1984-87
SWEDEN	5	1984-87
UNITED KINGDOM	0	1984
	1	1985
	1	1986
	1	1987
YUGOSLAVIA	600	1984-87

TABLE 3 (Cont'd)

NET INSTALLED CAPACITY OF ELECTRICITY GENERATING
PLANTS - GEOTHERMAL (000'S OF KILOWATTS)

		<u>OUTPUT</u>	<u>YEAR</u>
VII.	OCEANIA	157	1984
		396	1985
		399	1986
		396	1987
	AUSTRALIA	250	1985-87
	NEW ZEALAND	157	1984
		146	1985
		149	1986
		146	1987
VIII.	USSR	0	1984-1987

SOURCE: 1987 UN Energy Statistics Yearbook (published 1989) pp. 332 f.
(Table 32)

II. OVERVIEW OF INTERNATIONAL GEOTHERMAL ENERGY DEVELOPMENT

1.0 ENERGY DEVELOPMENT AND POLICY

Energy policy processes have clearly matured as a state function since the early 1970's when oil crises threw country after country into hasty and occasionally ill-conceived efforts to stabilize energy supply and use. In a relatively short decade and a half, nations have adjusted to the necessary prerequisites of planning. Moreover, the structures for establishing effective energy policy have solidified so that policy formation could be made routine.

This has become apparent in this review of various programs and the place of geothermal R&D efforts in each. The countries considered here vary widely in wealth, capacity, level of industrial development, and countless other ways. What does clearly emerge from these very divergent countries is the mosaic of different but strongly similar energy goals. Every country displays some mixture of the following energy objectives:

- To strengthen the energy planning process so as to improve it and heighten its relevance for national development and security.
- To reduce oil consumption as a percentage of overall energy consumption.
- To rationalize (make economically viable) domestic energy resources so as to increase domestic energy competitiveness.

- To diversify energy suppliers and types of energy consumed.
- To maximize domestic energy supplies so as to reduce dependencies on foreign sources.
- To deregulate energy markets.
- To increase international cooperation on energy issues and stabilize the international energy setting.
- To strengthen governmental roles in assisting energy research, development and demonstration programs.
- To promote and facilitate more effective technology transfer activities and commercialization processes.
- To pay greater attention to the environmental impacts of energy use, and specifically the implications of global warming, pollution and greenhouse gases.

Each country considered here has most or all of these objectives as basic tenets of its national energy strategy. They are articulated in differing ways, and with varying degrees of success, dependent perhaps on degrees of national integration. Their congruence, and degree of successful implementation are what determines at least in part - the nature of their national energy "profile."

In considering the geothermal activities of the countries included in this report, it became apparent that each country's energy "profile" or circumstances, are determined not only by expressed policy choices, but by an aggregation of other factors and forces as well. These bear directly on geothermal energy development programs. Briefly, these factors include the following:

- The nature of the geo-physical setting.
- The nature of the domestic energy resource base, and the alternatives or options the country has available.
- The extent of industrial development of the country, and of the economy in general.
- The nature and level of the national economy, and its contributions from rural and urban populations, from industrial, agricultural and other activities, and the relative size of the national economy.
- Traditional philosophies of appropriate roles of government involvement in economic development and energy planning.
- The size of domestic energy demand.
- The historical involvement of the country in a specific energy technology.

These factors help explain why, for example, Canadian energy programs, and specifically geothermal technology R&D programs, are not like those of Italy or Japan. It is not just a function of wealth or level of technological sophistication. Canada's huge reserves of energy and relatively weak national energy policy vis-a-vis the individual provinces have defined the national energy environment in ways which are vastly different from those operating in Italy and Japan. French centralized policy is similarly unique. This uniqueness, of course, is true for all countries.

Further, collaborative ventures among nations have grown as countries realize their shared objectives often are of greater importance than other, more competitive policy positions. This does not mean there is no unilateral R&D competitiveness. The existence of the International Energy Agency (IEA), as well as the numerous joint research efforts around the globe, does attest however, to the new reality of cooperative planning among many countries. Technical information is probably circulating sooner and more quickly than previously as the commitment to national pre-planning grows.

The newly devised and increasingly complex R&D policies of nations are a means of dealing with constrained energy options. Some states are fortunate to have broad arrays of energy sources, such as Canada and the United Kingdom. Others, such as Japan or Greece have fewer choices, less flexibility and hence more costly options. Cautious planning promotes economic rationality and resource maximization, regardless of the number of options available; this is even more true for those political entities with fewer reasonable choices.

New technology represents a second path to energy rationality within a country, and clearly this is part of the reason for energy R&D programs. Indeed renewable energy technologies, coal technologies, and certainly nuclear technologies are reflective of this circumstance.

Emerging energy technology is increasingly sophisticated and yet more broadly applicable at the same time. This trend should alter energy use patterns significantly. This may be true for geothermal energy technology, where smaller units are technically and economically feasible in a broader range of applications that were previously inappropriate.

Several other factors are, however, influencing R&D budgets in new ways. The first is the sign of more stability in energy markets. Despite fluctuations in oil prices, supply no longer appears to be as threatened by political and military interventions, because prices are lower for petroleum, and supply appears ample.

Conservation measures in some countries have somewhat dampened demand for energy, thus reducing the sense of urgency to develop new technologies for alternate sources, particularly in the face of revised prices and ample supplies.

The response to Chernobyl is multifaceted and intriguing, for some countries have reversed their nuclear policies and moved to secure "traditional" energy sources. Sweden is an example, Greece another, where the nuclear risk is perceived as too great. Other countries, such as Spain, appear unaffected by the explosion at Chernobyl, and are continuing to develop their nuclear energy capacities. Nuclear energy technology development continues

to be a prominent factor in several countries (e.g., Japan at 35%, United States 55%), but the IEA reports it has "leveled out at reduced figures compared to previous years... while continuing to account for 61% of all IEA member countries." (IEA Energy Policy Review for 1988, p.54.)

Political events in Europe, and relations between East and West-Bloc countries, may have an impact on the funds available for non-defense related research in the future, thus impacting (in as yet unknown ways) energy R&D budgets.

2.0 GEOTHERMAL AND OTHER ENERGY BUDGETARY COMMITMENTS

Present priorities of individual countries, are evident in their most currently available budget figures, provided below in Table 4. Only general conclusions can be drawn from these figures due to issues these budget figures do not reveal, such as the purchasing power of funds in different countries, exchange rate fluctuations, and internal programmatic shifts.

Table 4 does reveal that nuclear energy budgets are dominant (61% for IEA countries) followed by fossil fuels (15%) "electricity generation" at 10%, conservation budgets (7.3%) and renewables at 7%, down from 13.6% in 1980. (It is important to note that electricity generation may include research related to geothermal R&D, and that some countries include hydropower in their geothermal figures.) In 1988, the year for which most extensive data are available, overall energy R&D budgets continued to decline in most countries from the peak reached in 1980 (Table 5). Geothermal R&D spending by IEA member

governments - a wide sample of most but not all countries actively involved in geothermal research - has declined 75% to less than 25% of its 1981 maximum, and has stabilized at about the 1987 level of \$81-83 million yearly. (Table 6) When presented graphically, this decline is more evident. (Figure 1.)

TABLE 4

1988 International Energy Agency (IEA) Government Energy R&D Expenditures by Country¹
(Millions of 1988 United States Dollars and per cent)

	Austria		Belgium		Canada		Germany		Greece		Italy		Japan		Netherlands	
	\$	%	\$	%	\$	%	\$	%	\$	%	\$	%	\$	%	\$	%
GROUP I:																
TOTAL CONSERVATION	10.73	42.40	3.03	4.04	32.89	10.02	14.24	2.47	0.72	8.77	60.80	7.53	63.46	2.94	45.68	28.17
GROUP II:																
TOTAL OIL AND GAS, COAL	1.61	6.37	24.85	33.17	255.70	77.91	274.36	47.66	1.92	23.46	185.26	22.96	1075.31	49.81	53.52	33.01
GROUP III:																
Solar Heating and Cooling	0.44	1.72	1.12	1.50	2.92	0.89	0.57	0.10	0.58	7.11	4.77	0.59	3.80	0.16	1.26	0.78
Photo Electric	0.40	1.57	0.76	1.01	1.22	0.37	56.37	9.79	1.06	12.95	18.93	2.35	54.20	2.51	2.98	1.84
Solar Thermal Electric	0.02	0.06	0	0	0	0	22.78	3.96	0	0	0.71	0.09	0.58	0.03	2.93	1.81
Wind	0.07	0.26	0.18	0.24	1.62	0.49	19.36	3.36	0.66	8.08	19.99	2.48	2.93	0.14	6.42	3.96
Ocean	0	0	0	0	0.32	0.10	0	0	0	0	0	0	0.76	0.04	1.01	0.62
Biomass	3.27	12.92	0.25	0.34	7.63	2.33	0.85	0.15	0.08	1.04	6.54	0.81	23.72	1.10	4.96	3.06
Geothermal	0.02	0.09	0.76	1.02	0.16	0.05	1.42	0.25	2.64	32.29	1.57	0.19	42.51	1.97	2.12	1.31
TOTAL NEW ENERGY SOURCES	4.21	16.63	3.07	4.09	13.89	4.23	101.36	17.61	5.03	61.46	52.53	6.51	128.50	5.95	21.70	13.39
GROUP IV:																
TOTAL ADVANCED NUCLEAR	1.03	4.06	41.64	55.38	14.29	4.35	172.03	29.88	0.51	6.19	244.51	30.30	797.45	36.94	10.77	6.65
GROUP V:																
TOTAL OTHER SOURCES AND NEW VECTORS	0.84	3.31	1.13	1.51	1.62	0.49	0	0	0.01	0.17	0.20	0.02	17.89	0.83	0	0
GROUP VI:																
TOTAL ELECTRIC POWER CONVERSION, TRANSMISSION, STORAGE, SYSTEMS ANALYSIS	6.89	27.23	1.21	1.61	9.83	2.99	13.67	2.37	0.71	8.72	263.56	32.66	76.22	3.53	30.45	18.78
TOTAL ENERGY RD&D BUDGET	25.30	100.00	74.92	100.00	328.22	100.00	575.65	100.00	8.18	100.00	806.86	100.00	2158.83	100.00	162.13	100.00

TABLE 4

1988 International Energy Agency (IEA) Government Energy R&D Expenditures by Country¹
(Millions of 1988 United States^a Dollars and per cent) (Continued)

	Norway		Portugal		Spain		Sweden		Switzerland		United Kingdom		United States		Total 1988	
	\$	%	\$	%	\$	%	\$	%	\$	%	\$	%	\$	%	\$	%
GROUP I:																
TOTAL CONSERVATION	7.35	17.53	1.20	20.85	4.16	6.56	23.72	27.59	17.77	17.57	36.82	9.25	164.90	8.07	487.45	7.09
GROUP II:																
TOTAL OIL AND GAS, COAL	24.15	57.59	1.77	30.73	17.32	27.33	11.78	13.70	28.71	28.38	107.79	27.07	963.50	47.15	3027.54	44.01
GROUP III:																
Solar Heating and Cooling	0	0	0.41	7.21	2.25	3.55	5.96	6.93	5.47	5.41	3.38	0.85	6.00	0.29	38.93	0.57
Photo Electric	0	0	0.27	4.65	2.81	4.43	0.24	0.28	3.42	3.38	0	0	35.60	1.74	178.27	2.59
Solar Thermal Electric	0	0	0	0	0.56	0.89	0	0	1.37	1.35	0	0	17.80	0.87	46.75	0.68
Wind	0.77	1.83	0.19	3.27	1.41	2.23	2.77	3.23	1.37	1.35	7.29	1.83	8.90	0.44	73.94	1.07
Ocean	0.44	1.06	0.16	2.80	0	0	0	0	0	0	2.13	0.54	4.00	0.20	8.83	0.13
Biomass	1.12	2.67	0.43	7.49	9.91	15.64	8.97	10.44	2.05	2.03	3.38	0.85	31.00	1.52	104.18	1.51
Geothermal	0	0	0.04	0.64	4.42	6.98	0.16	0.19	0.68	0.68	5.34	1.34	21.00	1.03	82.86	1.20
TOTAL NEW ENERGY SOURCES	2.92	6.95	1.50	26.07	21.36	33.71	18.11	21.06	14.35	14.19	21.52	5.40	124.30	6.08	534.34	7.77
GROUP IV:																
TOTAL ADVANCED NUCLEAR	0.11	0.26	0	0	4.90	7.73	10.39	12.09	21.19	20.95	193.70	48.64	335.00	16.39	1847.52	26.85
GROUP V:																
TOTAL OTHER SOURCES AND NEW VECTORS	4.65	11.09	0.25	4.43	0	0	0	0	2.73	2.70	0.18	0.04	0	0	29.51	0.43
GROUP VI:																
TOTAL ELECTRIC POWER CONVERSION, TRANSMISSION, STORAGE, SYSTEMS ANALYSIS	2.76	6.59	1.03	17.93	15.62	24.66	21.98	25.56	16.40	16.22	38.24	9.60	455.70	22.30	954.28	13.87
TOTAL ENERGY RD&D BUDGET	41.94	100.0	5.75	100.0	63.35	100.0	85.98	100.0	101.16	100.0	398.26	100.0	2043.40	100.0	6879.92	100.0

1. For Australia, Denmark, Ireland, New Zealand and Turkey no 1988 data are available. Norway's undifferentiated solar: \$58m, 1.39% of total R&D.
SOURCE: Country submissions.

TABLE 5
IEA Government Energy R&D Budgets in 1988 United States' Dollars¹
International Energy Agency
(Millions)

	1975	1977	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Average 1988 Exchange Rate Unit per \$
Canada	272.8	303.1	371.3	346.9	408.7	422.3	484.0	549.6	447.0	432.0	348.4	328.2	1.2315
United States	2,464.1	4,452.8	5,639.4	5,561.1	4,279.1	3,303.5	3,101.3	2,587.4	2,586.4	2,308.1	2,038.8	2,043.4	1.0000
Australia	n.a.	41.4	67.2	86.4	98.3	n.a.	113.9	n.a.	105.7	n.a.	53.1	n.a.	1.2813
Japan	1,079.3	1,339.9	1,810.3	2,613.1	2,780.6	2,783.7	2,798.2	2,822.8	2,967.5	3,038.9	2,635.4	2,158.8	128.1620
New Zealand	7.1	7.0	11.8	20.1	17.2	15.5	14.5	17.3	16.1	8.9	3.0	n.a.	1.5289
Austria	10.9	34.8	36.7	39.8	37.0	40.4	38.2	42.0	40.0	24.5	21.2	25.3	12.3448
Belgium	182.2	147.2	123.3	153.9	133.6	122.9	110.8	118.0	108.2	97.8	81.5	74.9	36.7718
Denmark	18.3	30.2	48.8	35.7	23.5	22.6	22.0	20.0	18.7	25.4	25.4	n.a.	6.7300
Germany	1,053.6	1,131.9	1,330.0	1,352.9	1,457.2	1,858.9	1,093.3	1,091.9	1,036.6	761.3	582.5	575.7	1.7561
Greece	n.a.	1.4	6.8	48.3	40.5	9.3	8.6	10.9	14.4	12.6	9.3	8.2	141.6377
Ireland	2.4	4.0	8.2	9.8	11.5	9.7	6.1	2.5	3.5	3.5	n.a.	n.a.	0.6569
Italy	n.a.	352.7	487.0	504.8	859.3	660.5	773.6	1,021.9	954.1	899.4	730.9	806.9	1301.6822
Netherlands	119.5	175.1	189.8	192.8	199.1	164.5	164.2	141.3	192.5	141.1	138.1	162.1	1.9768
Norway	28.9	40.1	56.4	51.7	44.1	39.2	32.6	31.0	30.9	36.5	37.1	41.9	6.5172
Portugal	n.a.	n.a.	n.a.	6.1	4.9	4.9	6.0	9.6	9.1	6.3	7.0	5.7	143.9430
Spain	83.5	70.0	99.7	116.6	109.9	100.5	229.1	236.1	71.0	46.1	46.3	63.3	116.4913
Sweden	91.4	103.8	172.1	164.9	229.0	183.4	164.2	146.0	133.8	103.5	84.3	86.0	6.1291
Switzerland	26.1	56.5	88.1	93.7	88.0	83.1	85.6	84.1	90.2	90.6	94.4	101.2	1.4630
Turkey	n.a.	n.a.	n.a.	2.8	1.2	1.9	2.8	2.4	2.3	2.5	2.8	n.a.	1419.4296
United Kingdom	611.4	524.9	635.7	633.8	677.8	616.3	657.3	610.2	581.0	459.6	403.5	398.3	0.5622
IEA Total	6,051.5	9,014.2	11,450.2	12,471.2	11,789.6	10,965.5	10,467.8	10,022.1	10,012.1	9,072.9	7,343.3	6,879.9	
EC	n.a.	197.6	267.6	435.9	289.0	522.3	561.6	477.0	602.8	574.3	445.5	n.a.	0.8462

1. Values in Table C3 have been derived from those present in Table C2 (Government Energy R&D Budgets expressed in 1988 National Currencies), by using 1988 average exchange rates to the United States' dollar.

SOURCES: Country submissions; OECD Economic Outlook.

TABLE 6
Total R&D for Individual Areas of Renewables
in 1988 United States' Dollars
(Millions)

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Solar Heating	185.3	251.1	305.1	201.8	218.6	120.9	88.6	90.5	73.5	54.9	38.4	38.9
Solar Photo	68.0	111.3	212.9	303.0	305.4	246.2	183.6	264.6	199.9	161.8	153.1	178.3
Solar Thermal	100.3	154.7	184.3	321.9	222.6	132.1	96.6	68.6	55.6	36.7	51.2	46.7
Wind	59.4	80.7	129.2	146.8	193.2	125.2	98.0	102.0	114.8	71.4	65.4	73.9
Ocean	30.3	64.9	89.5	93.9	71.7	47.5	28.9	13.6	10.3	9.5	11.1	8.8
Biomass	26.9	54.6	98.3	120.4	156.0	138.3	167.3	157.6	123.4	95.6	93.7	104.2
Geothermal	123.5	192.6	279.6	335.3	342.3	207.5	180.2	131.9	100.4	97.6	81.4	82.9
Total Group	600.8	909.8	1,298.9	1,523.2	1,510.6	1,028.7	883.3	835.1	678.2	527.9	495.2	534.3

SOURCE: Country submissions for IEA 1988 Energy Summary, p. 104.

Figure 1

**Geothermal Funding History for IEA Countries
in 1988 U.S. Dollars (millions)**

SOURCE: IEA, 1988 Energy Summary, p. 104.

As yet unpublished (and incomplete) data from OECD and non-OECD countries demonstrate the overall growth and importance of geothermal energy for electricity production. These data are provided in Table 7 attached.

As environmental concerns impose ever more stringent controls on energy options, the need for governments to continue or increase their role in energy R&D will grow. The unknowns surrounding environmental change and global warming issues, plus the great significance of these issues for the future of the earth, suggest that solutions to energy problems will need to be broadly applicable among major energy consuming countries. Further, these solutions will need to be sophisticated enough to be flexible to individual country circumstances. New technologies, or more refined existing technologies, will require a sustained commitment on the part of technologically advanced nations if they are to be identified in time to meet their emerging needs. This will be true for geothermal energy technologies as much or more than others because of its uniquely advantageous environmental and baseload reliability characteristics.

This document cites budget items in U.S. dollars current for the year for which they are cited. Thus, some adjustment may be considered if inflation has been significant in any specific country. Further, it should be noted that labor rates, per capita incomes, and other country-specific economic factors will influence the ultimate yield of a country's energy budget. Thus \$2 million may buy a different mix of goods and services in Indonesia than in Germany, for example.

TABLE 7
Selected OECD and Non-OECD Geothermal Electricity Production (GWH)

	1980	1981	1982	1983	1984	1985	1986	1987	1988
Greece	0	0	0	0	0	0	0	2	5
Hungary	0	0	0	64	54	58	60	0	0
Iceland	50	40	77	93	94	92	225	248	260
Indonesia	0	0	78	209	217	210	210	210	0
Italy	2,672	2,664	2,737	2,714	2,840	2,681	2,760	2,986	3,082
Japan	900	896	1,273	1,443	1,356	1,494	1,384	1,329	1,358
Kenya	0	0	0	0	0	0	340	336	0
Mexico	915	964	1,296	1,353	1,424	1,641	3,394	4,418	4,633
New Zealand	1,185	1,107	1,147	1,178	1,238	1,139	1,174	1,185	0
Other American (Unit: GWH)	345	574	589	707	946	1,031	1,030	1,000	0
Philippines	2,077	2,770	3,586	4,093	4,543	4,945	4,586	4,945	0
Portugal	1	0	0	0	3	4	2	1	2
Turkey	0	0	0	0	22	6	44	58	69
Uruguay	38	55	51	53	56	57	59	58	60
USA	5,352	6,027	4,934	6,141	7,842	9,885	10,926	11,422	10,918

SOURCE: IEA/Paris, 12/89, personal communication

III. SELECTED COUNTRY PROGRAMS

BELGIUM

1.0 OVERVIEW OF ENERGY SETTING

Despite Belgium's modest evidence of domestic geothermal resources, the country's stated goal of reducing its heavy dependence on imported fuels (oil, natural gas) has caused it to commit some funding to geothermal development. In 1988, \$760,000 was designated for geothermal exploration, equal to 1.02 percent of Belgium's \$74.92 million energy R&D budget. 1987 expenditures had been \$240,000 of a \$91.5 million energy R&D budget.

2.0 GEOTHERMAL ENERGY FUNDING

A summary funding history would yield the following figures (in corresponding \$U.S.):

TABLE 8: BELGIAN GEOTHERMAL FUNDING LEVELS

	<u>Dollars</u>	<u>Percent of R&D Expenditures</u>	<u>Total Energy R&D Budget (m)</u>
1985 -	\$150,000	.25	\$62
1986 -	\$110,000	.15	\$74
1987 -	\$240,000	.26	\$91.5
1988 -	\$760,000	1.02	\$75

SOURCE: IEA

3.0 GEOTHERMAL ACTIVITIES

4.0 EMERGING TRENDS

A center-left government has attempted to reduce dependence on selected imported fuels, diversify energy sources; reduce domestic coal losses; establish a greater balance among energy sources; promote greater rationalization of energy use on a regional level within Belgium; tighten management of strategic energy stockpiles; pay greater heed to environmental issues; and develop future electricity generating capacities without resort to nuclear generating facilities. Support is offered in the national energy budget for 1988 (most recent available) for selective energy technologies development.¹

Since 1973, combined hydropower/geothermal sources provided the following amounts of Belgium's energy : (Unit: Mtoe and percent of overall energy)

TABLE 9: BELGIAN HYDROPOWER/GEOTHERMAL POWER PRODUCTION

1973	1979	1986	1987	1990	1999	2000
.1(.3%)	.1(.3%)	.3(.7%)	.3(.7%)	.1(.2%)	.1(.2%)	.1(.2%)

SOURCE: IEA

Annual percentage growth rates of Belgium's total primary energy requirement for hydropower/geothermal sources are as follows in Table 10:

TABLE 10: BELGIAN HYDROPOWER/GEOTHERMAL POWER PRODUCTION GROWTH HISTORY

1973-79	1979-83	1983-86	1986-87	1986-90
-1/9%	19.4%	6.0%	5.1%	-24.8%

SOURCE: IEA

The 1987 UN Energy Statistical Yearbook reports Belgian installed capacity to be 5 MW.²

It is clear from these data that geothermal energy has not figured nor does not figure prominently in Belgium's energy planning at present. The Embassy officer in Washington responsible for energy issues, Mr. Denis Dewez (Ph.333-6900; fax 331-3079), reported exploratory wells had been developed in previous years, and that current funding for geothermal research was much more modest.³

The national government in past years has played a major role while encouraging greater regional government participation within the context of a diversified, "balanced" energy supply profile. Future government commitments will focus on the rationalization of geothermal R&D expenditures in the larger national energy context.

Government policy at present emphasizes non-geothermal energy funds and energy issues over geothermal. Security of supply, diversified supplies, greater rationalization of energy supply and demand, and tighter management of energy stockpiles are the present focal points of Belgium energy program.⁴

5.0 REFERENCES

- 1) IEA Energy Policies and Programs Review for 1985, 1986, 1987, 1988.
- 2) 1987 UN Statistical Yearbook.
- 3) Belgian Embassy, Washington, D.C.
- 4) IEA Energy Policies and Programs Review, 1988.

BOLIVIA

1.0 OVERVIEW OF ENERGY SETTING

Energy concerns which influence other areas of the world are being felt in Bolivia as well. Specifically, concern about global warming, energy security, growing demand, rising imported fuel costs as a percent of GNP/GDP or of foreign earnings, all shape Bolivia's current energy policies. Additionally, however, the region's level of public indebtedness has restricted near-term public investment, thus opening opportunities for private sector investors in energy areas.

The Inter-American Development Bank (IDB) has lent \$10.5 billion for energy projects within 44-member countries, approximately 10% of total capital lent to date. The IDB has projected a 10 to 20 fold increase in geothermal energy use by 2000 A.D. in the region. The IDB's specific targets include hydroelectric plant construction, oil and gas pipeline development, electric power transmission systems, and urban and rural electrification efforts, among other projects in the energy field.¹

2.0 GEOTHERMAL ENERGY FUNDING

3.0 GEOTHERMAL ACTIVITIES

Bolivia, encouraged by Mexican and El Salvadoran successes in the geothermal field, is considering development of its geothermal energy potential. Following issuance of a report by a private consulting firm that its geothermal resource is characterized by "moderate to important potential for electric power generations," Bolivia is examining this conclusion in the context of its overall long-term energy needs. Geothermal plants typically range from \$1659-2200 per kW, (average is \$1940), \$400 below the average cost per kW generated by large-scale hydroelectric plants of \$2350. This is more costly than other electricity sources such as co-generating or diesel plants, due to the higher cost of field development. Geothermal energy unit costs average \$.04 per KWh, lower than all other base options.¹

Bolivia has recently signed a protocol with Brazil called the Geothermal Plan, to implement a joint strategy for geothermal energy development. It will likely include development of the geothermal energy resource identified at Andes-Laguna Colorado. Financial assistance is expected from the national governments involved, private investors, provincial governments and the Inter-American Development Bank, or other international development agencies. Thirty MWe capacity was planned for development by the Bolivian Government by 1990.²

4.0 EMERGING TRENDS

Bolivia is projected by the IDB to develop 40 MWe by the year 2000. Despite these and other activities and despite greater costs, the World Bank continues to view with more favor energy options other than geothermal, due (according to one IDB official) to the World Bank's greater familiarity with hydroelectric power generation.

In sum, at present in Bolivia and most other Central and South American nations, geothermal energy is important but not yet a primary energy option. Bolivia's recently signed "Geothermal Plan", however promising, has not yet been implemented.

5.0 REFERENCES

- 1) Inter-American Development Bank.
- 2) Mr. Gonzalo Bernal, Counselor, Bolivian Embassy, Washington, DC.
1987 UN Energy Statistics Year Book.

CANADA

1.0 OVERVIEW OF ENERGY SETTING

Energy issues are important to Canada not because of a potential threat of shortages, but because energy itself plays so central a role to the Canadian economy and lifestyle. The 1988 IEA review of Canadian energy developments reports that Canada is the most energy intensive of IEA members, due to climate, the size of the country, its affluent lifestyle, and the nature of its industrial economy. Canada is a net exporter of energy, and the world's leading producer and exporter of uranium. Large markets for Canadian energy among its neighbors, and the implementation of the US - Canadian Free Trade Agreement, will serve to strengthen interest in Canadian energy matters in the future. Perhaps in recognizing this, and in response to international environmental alarms, the Canadian Federal Government, along with provincial governments, has undertaken a process of developing future energy policy options in accordance with Canadian circumstances. Government involvement in energy issues remains strong, but provincial policies vary as they relate to regulatory or free market pricing policies.

2.0 GEOTHERMAL ENERGY FUNDING

Canadian geothermal research and development activities are relatively modest in scale, perhaps due to the prominence of other energy sources. The Canadian expenditures for geothermal R&D totaled \$160,000 in 1988 U.S. dollars, or .05 percent of the total energy

R&D budget, up from \$150,000 in 1987 and \$140,000 in 1986. The 1985 expenditure was \$440,000 or .12 percent of the total budget. Thus the past years have showed a marked decline in an already minuscule national commitment.¹

3.0 GEOTHERMAL ACTIVITIES

The 1987 UN Energy Statistics Yearbook cited no installed geothermal generating capacity.²

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) IEA Energy Policies and Programs Reviews for 1985-88.
- 2) The 1987 UN Energy Statistics Yearbook.
- 3) Canadian Embassy in Washington; (Ms. Martin) at Phone: 682-1740.
- 4) Mr. William Jarvis, Director General of the Efficiency and Alternative Energy Branch, Department of Energy, Mines and Resources (EMR), 580 Booth Street, Ottawa, Canada K1A-OE4, Phone: (613) 992-1405.
- 5) Technologies for Energy Efficiency and Fuel Switching, IEA, Paris, 1988.

DJIBOUTI

1.0 OVERVIEW OF ENERGY SETTING

Djibouti, formerly French Somaliland, located at the upper end of the Great Rift Valley seismic zone in the Horn of Africa, has been known to possess geothermal potential but has not been explored until recently. In order to determine the nature of this resource, six wells have recently been drilled, two at Hanlé and four at Rift d'Assal to assess the high enthalpy potential. Temperature, gradient and pressure have been considered, along with other salient factors characterizing the overall exploitable potential for electricity generation.³

2.0 GEOTHERMAL ENERGY FUNDING

3.0 GEOTHERMAL ACTIVITIES

The Hanlé drillings produced disappointing results causing further drillings in the Rift d'Assal, where high temperature fluids were known to be present at about 1000 meters. This drilling was undertaken in June 1987. This second reservoir's examination has resulted in the development of a profile of gradient, temperatures and the geologic layers along a perpendicular axis within the rift. Extensive knowledge regarding the Djibouti geothermal resources has been acquired as a result, and two wells have proven likely to be

productive. Concern exists regarding declining pressure, high salinity at lower levels, and the presence of silicon particulates that precipitate at high temperature and pressure. A study is proposed to attempt the avoidance of a large decrease in productivity at these wellsites. Reservoir capacity and the reduction of the scaling phenomenon will also be examined in order to ensure the economic viability of the wells involved, and the megawattage to be expected from the zone.³

The project is administered in Djibouti by the Institute Supérieur D'Etudes et de Recherches Scientifique et Techniques (ISERST).² The VITA organization in Rosslyn, Virginia is acting in an advisory capacity to ISERST, with Mr. Steven Hirsch assuming the lead position.¹

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) Djibouti Embassy, Washington, D.C.
- 2) Mr. Steven Hirsch, VITA, Rosslyn, Virginia.
- 3) Resultats Actuels Du Project D'Exploration Geothermique En Republique De Djibouti, a French language report on Djiboutian geothermal resources, ISERST, Djibouti.

FRANCE

1.0 OVERVIEW OF ENERGY SETTING:

Geothermal research and development activity in France is found at numerous sites across France including the cooperative EEC R&D venture at Soultz, with German, Italian, and perhaps other country partners; the Dogger basin near Paris; Guadeloupe and Martinique in the Caribbean, and the island of Reunion in the Indian Ocean. Research is directed by the Joint Institute for Geothermal Research (L'Institute Mixte de Recherches Geothermiques - IMRG), a collaborative effort of two French government agencies. The goals of the organization are to evaluate, exploit and manage the national geothermal heat and electricity potential for the immediate future and to develop future exploration and exploitation technologies by the year 2000. Beyond the next decade, IMRG intends to develop its capabilities in areas of underground energy storage, and surface water exploitation. Active areas of research within the French program at present include geochemistry, volcanology, geophysical structural analysis, above and below ground estimates of national geothermal energy potential, reservoir modeling, and the development of both pilot and full-size production plants for research and utilization purposes.

Each of these objectives has its own division within IMRG'S overall organization of approximately thirty researchers and technical personnel.

2.0 GEOTHERMAL ENERGY FUNDING

Current budget figures for IMRG'S project activity are as follows:

- 1) Low temperature geothermal research: \$4m over 5 years.
- 2) Mid point and high temperatures geothermal energy: \$480,000 over 5 years.
- 3) Mid-point geothermal energy sources and thermal storage: \$800,000 over 5 years.
- 4) Long term "deep" geothermal research: \$3.3 - 4.5m over 5 years with other EEC partners, including Germany and the United Kingdom.

3.0 GEOTHERMAL ACTIVITIES

France is not a member of IEA, but does work collaboratively with other EEC member nations on geothermal energy technology transfer and joint research program implementation. At present, France operates a 4.2 MWe power plant in Guadeloupe, according to the GRC Bulletin for May 1988.

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) Drs. Badia and Beutin, French Embassy, Washington, D.C., Phone: (202) 944-6216.
- 2) GRC Bulletin, Vol. 17, No.5, (May 1988) pg. 11.
- 3) 1985 International Symposium on Geothermal Energy - International Volume,
published by GRC for DOE, Claudia Stone, editor; DiPippo, pgs. 9 and 12.
- 4) French Government Budget Documents - Geothermal R&D Projects.
- 5) Agence Francaise Pour La Maitrise De L'Energie (AFME) booklet "Supply and Demand".
- 6) Institut Mixte de Recherches Geothermiques (IMRG) publication, no title, 10/83.

GERMANY

1.0 OVERVIEW OF ENERGY SETTING

Recent updating of German energy policy has re-established certain guidelines for energy development and use. These include the following objectives:

- 1) to reduce oil use and increase the use of other energy sources;
- 2) to diversify energy suppliers, particularly oil;
- 3) to further rationalize energy production and use;
- 4) to strengthen energy emergency response mechanisms;
- 5) to supply and use energy fuels with the least environmental impact;¹

2.0 GEOTHERMAL ENERGY FUNDING

German commitments to all renewable energy R&D is almost three times greater than the U.S. in percentage terms, (or 17.6% of budgeted energy R&D as of FY88), but despite this relative prominence in budgetary terms, German spending on geothermal R&D has declined in both percentage and real terms since 1985.¹ Table 1 presents these data below:

TABLE 11: RECENT GERMAN EXPENDITURE ON GEOTHERMAL AND ALL-RENEWABLES (U.S.\$ - Millions)

<u>YEAR</u>	<u>GEOTHERMAL</u>	<u>ALL-RENEWABLES</u>	<u>% GEO/ENERGY RD&D BUDGET</u>
1985	\$4.28	74.70	.78
1986	5.06	65.88	.90
1987	1.39	70.05	.23
1988	1.42	101.36	.25

SOURCE: IEA

More recent data from Bonn will help explain this decline.²

3.0 GEOTHERMAL ACTIVITIES

One explanation for budgeting reductions may be increased participation by Germany in the EEC Soultz Project, jointly managed by France and Germany,³ who each contribute 37% of the annual budget, with the remaining 25% contributed by other EEC countries.

The Soultz Project objectives are:

- 1) to establish local geothermal gradients
- 2) to map the stress regime
- 3) to locate joint and fracture systems

- 4) to evaluate the geochemistry of the area
- 5) to examine the physical properties of the site
- 6) to establish the hydraulic impedance of natural and artificial fractures.

German geothermal resources are modest in any event. State ("lander") governments participate in sponsoring thermal research. The Franco-German project team has proposed sponsoring an HDR conference in 1991.

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) IEA Energy Policies and Programs, 1988.
- 2) Mr. Ruede, German Embassy, Washington, D.C., Phone: 298-4000.
- 3) Discussion with Mr. James Rannels, GTD/DOE.
- 4) Dr. Sandtner, Ministry of Research and Technology, Bonn., Phone: 011-49-228-59-3138, Dr. Sandtner's assistant is Mr. Komorowski, at 011-49-228-59-3049.
- 5) Trip report: International HDR Conference, prepared by J. Rannels, 08/25/89.

GREECE

1.0 OVERVIEW OF ENERGY SETTING

Greece, like most other nations, is trying to enhance its domestic energy resources while limiting energy imports. Domestic energy policy has been successful in reducing oil imports and diversifying suppliers, rationalizing energy use, and strengthening indigenous resource use. Electricity generation via lignite and hydropower fuel sources has expanded significantly, thus reducing oil consumption further.

Renewable energy, including geothermal, is a recognized addition and a yet largely unrealized source of future energy. In an effort to replace diesel generators on smaller, off-grid islands, the Greek government began a study in 1988 to further exploit a geothermal field on the island of Milos, already the site of a 2 MW demonstration facility. Additionally, the geothermal potential of the island of Nissyros is under examination, through an EEC venture. Italian assistance is prominent in these two ventures. Greece is also examining the potential of low- and medium-temperature hydrothermal resources on the mainland; at present low enthalpy, geothermal water heats 100,000 square meters of greenhouse space.¹

2.0 GEOTHERMAL ENERGY FUNDING

Budgetary expenditures for geothermal development activities are as follows in Table 1 below:

TABLE 12: RECENT GREEK EXPENDITURES ON GEOTHERMAL AND ALL - RENEWABLES (U.S.\$ - Millions)			
<u>YEAR</u>	<u>GEOTHERMAL</u>	<u>ALL RENEWABLES</u>	<u>% GEO/ENERGY R&D BUDGET</u>
1985	\$2.53	\$4.43	27.23
1986	4.26	9.66	27.87
1987	1.24	7.56	12.80
1988	2.64	5.03	32.29
SOURCE: IEA			

3.0 GEOTHERMAL ACTIVITIES

4.0 EMERGING TRENDS

The table above demonstrates some uncertainty regarding the long-term commitment to geothermal R&D funding on the part of the Greeks, although the spending curve rises sharply in FY1988 over the previous year. Data from Athens should update and amplify

your understanding of as well as describe the nature of Greek thinking and program planning for the present and the future regarding geothermal energy development.

5.0 REFERENCES

- 1) IEA Energy Policies and Programs Reviews for 1985, 86, 87, and 88.

ICELAND

1.0 OVERVIEW OF ENERGY SETTING:

Iceland has long been prominent in geothermal energy production and development due no doubt to its accessible geothermal resources and their importance to Iceland's national economy, in which energy options are both constrained and strategically important. In 1985, Iceland reported geothermal capacity was 39 MWe, with no projected increase in that level to 1990. The 1987 UN Energy Statistics Yearbook, published in 1989, reported 42 MWe of installed capacity during the 1984-1987 period. (The Geothermal Energy Institute of New York reports 39 MWe of installed energy and in operation as of October 19, 1989, with 3.6 MWe planned additional capacity.¹

2.0 GEOTHERMAL ENERGY FUNDING

Specific geothermal program operations and budget data are offered by Dr. G. Palmason at the National Energy Authority ("Orkustofaun") of the Ministry of Industry and Energy, upon receipt of a request.

The uses to which Iceland's geothermal resources have been put, in addition to electricity generation, include industrial process heat, district heating systems (public and private), greenhouses, swimming pools and aquacultural applications.

3.0 GEOTHERMAL ACTIVITIES

Iceland was considering participation in an undersea electricity supply cable to Scotland that was to require \$3.2 million. The status of this investment is unknown.²

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) Correspondence from the Geothermal Energy Institute, 12/89.
- 2) Euromoney, January, 1988, pgs. 25, 28.
- 3) The Icelandic Embassy, Washington, D.C., Phone: 265-6653.
- 4) Dr. G. Palmason, National Energy Authority, Reykjavik, Phone: 011-354-1-83600.
- 5) 1985 International Symposium on Geothermal Energy - International Volume, GRC, Sacramento, 1985.

ITALY

1.0 OVERVIEW OF ENERGY SETTING

Like numerous other nations, Italy is highly dependent on energy imports for the maintenance of its economy. Unlike most others, Italy has a sizeable geothermal resource that has long made a tangible contribution to the country's domestic energy. Despite this fact, Italy remains highly dependent on oil for electricity generation. Oil-fueled generators produced 44% of Italy's electricity requirements in 1987.

Previous energy planning designed to increase the use of coal and nuclear power for electricity generation and thus reduce oil consumption in this sector was undone by the Chernobyl accident. Public reactions against nuclear power, and the siting issues associated with coal and non-fossil fueled power plants caused the government to develop a new set of energy objectives. The resulting National Energy Plan will promote five objectives:

- 1) increased energy conservation
- 2) greater attention to environmental safeguards
- 3) increased reliance on domestic energy research
- 4) broadening the number of energy input suppliers
- 5) maintaining a competitive domestic energy production environment.

New electricity generating new capacity was to be met as follows by the year 2000:

Coal-fired plants would increase to 29.2%,

Gas-fueled plants would assume 25.4%,

Hydro-geothermal-produced electricity would decline from 23.4% to 20.2%,

Oil-fueled electricity would decline further to 23.3%.¹

The focus of Italy's energy R&D efforts in the geothermal area was on the development of low enthalpy fluid systems, and the resolution of "material problems" associated with geothermal technology. These research attributes are being directed by ENEA, the Government's lead agency for energy R&D.²

2.0 GEOTHERMAL ENERGY FUNDING

**TABLE 13: ITALIAN GEOTHERMAL R&D FUNDING AND PERCENT
OF TOTAL ENERGY R&D BUDGET**

<u>YEAR</u>	<u>GEOTHERMAL</u>	<u>ALL-RENEWABLES (MILLIONS OF U.S.\$ IN CURRENT \$)</u>	<u>% GEO/ENERGY R&D BUDGET</u>
1985	.30	17.00	.05
1986	2.44	29.47	.32
1987	2.35	32.51	.32
1988	1.57	52.53	.19

SOURCE: IEA

3.0 GEOTHERMAL ACTIVITIES

Italy's international geothermal activities at present include collaboration with Indonesia, the Philippines, Greece, and in Hawaii, where a 10-year effort is underway to install 500 MW of geothermal-powered generating capacity at a life-of-project cost of \$2 billion. Additionally, Italy is collaborating with French and German partners in the development of HDR technology at the Soultz project site in France.³

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) IEA Energy Policies and Programmes Reviews for 1985, 1986, 1987 and 1988.
- 2) The Italian Embassy in Washington, D.C. via Dr. Orzaes; Drs. F. Remondino and Ricci at E.N.E.L. offices in New York City, Phone: 212-599-3060.
- 3) Mr. Guido Cappetti, E.N.E.L. Engineer at the State of Hawaii's public information office at the Department of Business and Economic Development, Phone: 808-548-7208.

JAPAN

1.0 OVERVIEW OF ENERGY SETTING

Due to its heavy reliance on imported energy and its paucity of domestic fossil fuels, Japan continues to examine its geothermal options through a vigorous program of resource identification and evaluation coupled with technology development and commercialization activities. The government-initiated New Energy and Industrial Technology Organization (NEDO) seeks to alleviate Japan's dependence on external energy resources by "undertaking research and development which will be able to enhance the results of basic research conducted by national and other research organizations to the level at which industries in the private sector can better utilize them for commercial applications." At present, Japan's overall energy objectives are to seek a stable and reliable oil supply, to promote the development and use of alternative energies, and encourage conservation of energy at all levels within Japan. Among IEA countries Japan is the largest importer of energy, importing 80% of its energy needs, 56% of which is petroleum fuels. With more than two-thirds of its oil coming from Middle East suppliers, Japan's vulnerability to supply interruptions remains a reality and an inducement to find new energy sources.

2.0 GEOTHERMAL ENERGY FUNDING

Japan is reported by the GRC Bulletin (10/89) to have 214.6 MW of installed capacity as of 3/89, steady since 1984 according to UN data.¹² Its recent energy budget history is as follows: (in corresponding year dollars):

TABLE 14: JAPAN'S GEOTHERMAL R&D FUNDING AND PERCENT OF TOTAL ENERGY R&D BUDGET

<u>Year</u>	<u>Dollars</u>	<u>% of Energy R&D Spending</u>	<u>Total Budget</u>
1985	\$22 m	1.39	\$1,558 m
1986	\$36 m	1.55	\$2,311 m
1987	\$36 m	1.53	\$2,340 m
1988	\$43 m	1.97	\$2,159 m

SOURCE: IEA

Japan's sense of national energy urgency, its levels of technical capacity, and its experience with geothermal energy technology, power production and financial resources all combine to produce an aggressive overall R&D program. Its geothermal budget of \$42.5m constitutes more than half (51.3 %) of the \$82.86 million total IEA member nation funding for 1988, twice that of the United States and eight times the next largest budget for geothermal research, that of the United Kingdom, at \$5.34 million. Its emphasis on domestic resource assessment will allow Japan to market this skill internationally in the near future, thus positioning the Japanese for assuming a central, perhaps commanding role in international geothermal development activities. Coupled with creative investment packages and knowledgeable export promotion schemes, Japan is certain to be a keen competitor in international geothermal development.³

Domestically, Japan has nine geothermal power plants operating as of March, 1989. Geothermal resources have been evaluated in at least 29 areas. NEDO selects three new

sites annually for evaluation as part of its Geothermal Development Promotion Survey Project. Subsidies of 20% to 50% by government agencies to private sector drillers resulted in 17 subsidized wells being drilled throughout the country in 1988. Four others were drilled without subsidy.

The major thrusts of NEDO'S Geothermal Energy Technology Research Program are as follows:

- 1) Surveys to Promote Geothermal Development
- 2) Nationwide Geothermal Resources Exploration Project
- 3) Development of Geothermal Reservoir Evaluation Technology
- 4) Confirmation Studies on Effectiveness of Exploration Techniques for Deep Geothermal Resources
- 5) Development of Hydrothermal Power Plants via - Development of the Binary Power Plant, Development of Hot Dry Rock Generation Technology, and Development of High Accuracy Magnetotelluric Exploration Technology.

4.0 EMERGING TRENDS

NEDO'S energy research foci, apart from these associated with geothermal energy research, are the development of photovoltaic energy, and coal liquefaction and gasification technologies. These are presented in Table 15 below:

TABLE 15: JAPAN'S 1988 ENERGY R&D BUDGET

The FY 1988 Energy R&D Budget, in millions of yen, was allocated as follows:

I.	Conservation	¥8,135
II.	Oil, Gas, Coal, Nuclear	
	Oil and Gas	10,144
	Coal	29,076
	Nuclear (non-breeder)	88,231
III.	New Energy Sources:	
	Solar	7,510
	Wind	376
	Ocean	97
	Biomass	3,041
	Geothermal	5,450
IV.	Advanced Nuclear	102,233
V.	Other Sources	2,293
VI.	Supporting Technologies	
	Electricity	5,510
	Energy Storage	3,791
	Others	471
	Total	¥266,358

SOURCE: NEDO

Employing a 144:1 conversion rate of yen to one U.S. dollar, \$37.85 million was committed in FY1988 to geothermal activities, specified as follows:*

- 1) Exploration techniques for geothermal energy.
- 2) Utilization of hot water in geothermal power plants.
- 3) Verification of geothermal exploration techniques.
- 4) Comprehensive investigation on geothermal resources throughout Japan
- 5) Development of power plants utilizing hot water.
- 6) Evaluation techniques for the reservoir layer structure.

*(IEA budget figures of \$43m may be based on a different conversion rate, or different figures reported by the Japanese Government.)

5.0 REFERENCES

- 1) GRC Bulletin, Vol. 18, No.9, (Oct, 1989), pgs. 17-20.
- 2) 1987 UN Energy Statistics Yearbook (Pub. 1989), pg. 332.
- 3) "NEDO - New Energy and Industrial Technology Development Organization",
(an official brochure outlining NEDO's structure, functions, project activities,
and relationships to the Ministry of International Trade and Industry (MITI),
its parent ministry.)

- 4) "Conference Report - 8th Annual Conference on Geothermal Energy Technology", NEDO, September 1988, pgs. 3-15.
- 5) Energy Policies and Programs of IEA Countries for 1988, pg. 331.
- 6) "Research and Development Projects - FY 1988" NEDO, April 1988.
- 7) Mr. Yamamoto, NEDO representative in Washington, D.C.

MEXICO

1.0 OVERVIEW OF ENERGY SETTING

Mexico's geothermal resources are well known and increasingly utilized. As of October 1989, Mexico had 675 MWe of installed capacity, with 300 MWe additional capacity planned for near future development. This capacity is generated by 22 units, 16 at Cerro Prieto, 6 at Los Azufres, which came on line in 1989. Mexico's first geothermal power plant was installed in 1973. With its present capacity, Mexico thus follows the United States and The Philippines in total capacity. Future development is expected to take place at La Primavera and Los Humeros, as feasibility studies there and elsewhere are undertaken.¹

2.0 GEOTHERMAL ENERGY FUNDING

As of 1987, the geothermal energy budget amounted to 18% of Mexico's total alternate energy budget, although precise figures were unavailable.

3.0 GEOTHERMAL ACTIVITIES

Additional facts about the Mexican geothermal energy setting:

Geothermal energy production more than doubled from 1983-1987, even in the face of major national economic crises and budget pairings. Proven reserves grew to 1,220 MWe. Domestic mobile production facilities are planned in Mexico, increasing the country's capacity to exploit its natural resources without dependence on foreign suppliers.²

4.0 EMERGING TRENDS

It is clear that Mexico can be understood as a major energy supplier in the Americas as oil, natural gas and other energy sources, including geothermal energy, are exploited. Domestic consumption remains low relative to overall productive capacity, thus allowing Mexican energy exports to assume greater importance as a factor in Mexico's drive to earn foreign currency.

5.0 REFERENCES

- 1) Geothermal Energy Institute, October 19, 1989.
- 2) Geothermal Report, June 15, 1987, cited in Geothermal Progress Monitor, No. 11 (draft), pg.57
- 3) GRC Bulletin, Vol. 17, No. 5, (May 1988), pg. 11.
- 4) GRC Transactions, Vol. 12, (1988), pgs. 137-142, 161-166, and 197-202.

THE NETHERLANDS

1.0 OVERVIEW OF ENERGY SETTING

The Netherlands' energy circumstances are characterized by the strong dominance of natural gas as an energy source with gas supplying 60% of all energy needed to generate electricity, and 52% of total national energy use. The Netherlands relies less on imported oil than most other industrial countries because of its large domestic natural gas use. Moreover, electricity use is low at 11% of total national use (or "total final consumption" in IEA parlance). Government policy has focused on the development of domestic fossil renewable energy technologies (and wind in particular), and on the increased efficiencies to be derived from energy saving technologies and means of production. The electricity production and distribution industry is to be restructured to strengthen coordination among electricity producers, heighten the efficiency of production units, while (not contradictorily) increasing the overall competitiveness of the electricity producers and distributor industries.

2.0 GEOTHERMAL ENERGY FUNDING

Budgetary commitments to geothermal energy development have declined from 3.67% (\$4.21m) of total energy R&D budget in 1985, to 1.31% (\$2.21m) in 1988. Insufficient data does not allow even speculation about this drop in funding and hence geothermal energy's priority of importance within The Netherlands' energy planning, but clearly it is not key to future energy planning. Budget amounts for the 1985 - 1988 period are as follows:¹

TABLE 16: DUTCH GEOTHERMAL BUDGETS, 1985-88

YEAR	AMOUNT IN CURRENT U.S.\$ (MILLIONS)
1985	\$4.21 (3.67%)
1986	1.18 (.73%)
1987	1.55 (1.55%)
1988	2.12 (1.37%)

SOURCE: IEA

3.0 GEOTHERMAL ACTIVITIES

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) IEA Energy Policies and Program Review(s) for 1985, 1986, 1987 and 1988.
- 2) Geothermal Energy Institute's, Geothermal Power Plants in Operation Worldwide (as of 10/19/89) pg. 2.
- 3) GRC Bulletin, Vol 17, No. 5 (May 1988) pg. 11.
- 4) Technologies for Energy Efficiency and Fuel Switching - Collaboration... The Netherlands, IEA, Paris, 1988.

NEW ZEALAND

1.0 OVERVIEW OF ENERGY SETTING

New Zealand continues its transition from being that of a public sector-dominated geothermal energy developer and promoter, within the larger national energy context, to a widely deregulated and privatized energy country. Pricing strategies and the operation of the marketplace have been used to rationalize energy consumption in New Zealand, with government participation in many energy research and development activities being curtailed or terminated entirely. The New Zealand Energy Research and Development Committee, a government organization founded to develop New Zealand's capacity to use energy sources other than imported oil, has been disbanded and its activities subsumed within the Ministry of Energy along with those of the Liquid Funds Trust Board. Energy planning has become increasingly decentralized with local government energy initiatives assuming greater prominence.¹

2.0 GEOTHERMAL ENERGY FUNDING

The impact of these policy initiatives at the national level is witnessed in the supply and budgetary figures for geothermal energy. While hydro/geothermal energy productions rose from 1973 to 1987 by 49% and was projected to increase by 83% by the year 2000, expenditures by the New Zealand Government in 1987 were US \$290,000 or almost 12% of the country's R&D budget for energy. Figures for 1988 and 1989 were not available;

a spokesman at the New Zealand Embassy in Washington reported the national geothermal R&D effort had been eliminated as part of government's energy policy reorientation towards the private sector. This trend is reflected in budget figures for 1985-87 below.²

TABLE 17: NEW ZEALAND'S GEOTHERMAL R&D FUNDING

<u>Year</u>	<u>Amount in US \$</u>	<u>% of Energy Research Budget</u>
1985	\$99m	10.
1986	52m	13.21
1987	29m	11.6
1988	n.a.	n.a.

SOURCE: IEA

3.0 GEOTHERMAL ACTIVITIES

The United Nations reports in its most recent energy statistics yearbook that New Zealand's installed geothermal capacity declined from 157 MWe in 1984 to 146 MWe in 1987. No reason was provided for this decline.³

Embassy officials in Washington reported international geothermal development activities had been undertaken by New Zealand in Indonesia and the Philippines in the recent past, although they were unable to provide further details.

4.0 EMERGING TRENDS

In sum, the New Zealand Government's geothermal program has been terminated as part of the larger policy decision about energy development, planning and management, and the respective roles of government and the private sector in these activities.

5.0 REFERENCES

- 1) Mr. Derrick Gill, Embassy of New Zealand, Washington, DC, Phone 328-4857.
- 2) IEA Energy Policies and Programmes of IEA Countries, Reviews for 1985-88.
- 3) 1987 UN Energy Statistics Yearbook, published in 1989.

OTHER SOURCES:

1985 International Symposium on Geothermal Energy - International Volume, prepared by the Geothermal Resources Council, Claudia Stone, editor.

SPAIN

1.0 OVERVIEW OF ENERGY SETTING

Spain's energy planners who are developing the country's electricity supply and demand projections through 1996, believe present capacity of 7.8 GW from ten nuclear power plants is sufficient to handle annual increases in demand of 3.3% until 1992.¹ No further electricity generating capacity is planned at present.²

2.0 GEOTHERMAL ENERGY FUNDING

Recent Budgetary Information on Geothermal Expenditures and Renewables (in U.S.\$ - millions):

TABLE 18: SPAIN'S GEOTHERMAL AND RENEWABLE ENERGY BUDGETS AS PERCENT OF TOTAL ENERGY R&D

<u>YEAR</u>	<u>GEOTHERMAL</u>	<u>MILLIONS U.S.\$ ALL RENEWABLES</u>	<u>% GEO OF Energy R&D</u>
1985	\$1.18	\$39.22	26.56
1986	2.06	19.42	2.94
1987	2.84	14.14	5.91
1988	4.42	21.36	6.98

SOURCE: IEA

3.0 GEOTHERMAL ACTIVITIES

Nonetheless, Spain's plan for renewables include funding for geothermal development activities, following solar and biomass technologies in order of priority. The Spanish renewable development plan has stressed commercialization of its renewable technologies for export, but few details about this or other aspects of the Spanish renewable energy development program are available.

4.0 EMERGING TRENDS

5.0 REFERENCES

- 1) IEA Energy Policies and Programmes for 1985, 1986, 1987 and 1988.
- 2) The Geothermal Energy Institute does report 1 MWe of planned capacity in the Canary Islands, however, as of 10/19/89.

SWEDEN

1.0 OVERVIEW OF ENERGY SETTING

Sweden is in some ways similar to Japan as a national energy environment: Sweden's energy intensity factor (as a component of production) is high, as is Japan's; Sweden imports significant portions of its energy, and relies on export sales of industrial goods for maintenance of its economy. What distinguishes Sweden from Japan and other industrial nations is its neutralist, pragmatic, ethical stance vis-a-vis energy policy. Responding to the oil crisis of the 1970's, Sweden moved to reduce oil imports and diversify energy suppliers. While implementing this strategy the country reacted to the so-called "Harrisburg" incident (Three Mile Island) of 1979 by voting to reduce any dependence on nuclear power, a move further hastened by the Chernobyl accident.

The resulting potential energy shortages caused by the cuts in oil and nuclear energy supplies are to be met by predictable means: conservation, urgent efficiency measures; increased use of indigenous and renewable energy sources; and fuel-switching strategies. Sweden's position is further shaped by its political neutrality and thus its perceived need to reduce singular dependencies and broaden its energy options. Nuclear power plants are scheduled for shutdown soon, with all nuclear plants phased out by the year 2010 and perhaps even earlier, according to Swedish Embassy sources.¹

2.0 GEOTHERMAL ENERGY FUNDING

**TABLE 19: SWEDISH GEOTHERMAL BUDGETS AS PERCENT OF
TOTAL ENERGY R&D BUDGETS**

	<u>Geothermal funding</u> <u>(U.S.\$)m</u>	<u>% of R&D</u> <u>Expenditures</u>	<u>Total Energy</u> <u>R&D Budget</u>
1985:	\$46	.56	\$19.26
1986:	.70	.88	17.35
1987:	.71	.93	15.13
1988:	.16	.19	18.11

SOURCE: IEA

3.0 GEOTHERMAL ACTIVITY

4.0 EMERGING TRENDS

Indigenous energy use in Sweden will mean greater hydroelectric power production, and has included the search for geothermal energy sources. As seen above, budgetary commitments rose from approximately a half-million dollars in 1985 (\$460,000) to \$710,000 by 1987. Poor results and the apparent greater promise of other renewable technologies has caused geothermal spending to drop precipitously, to \$160,000 in 1988. Research has shifted from Swedish government agencies to university settings, with some emphasis on direct heat

technology development, presently employed by some homeowners via ground water heat pumps.²

Further details of Sweden's geothermal program are available from both the Swedish Embassy in Washington (Messrs, Sandberg and Sven-Olos Heftmark of the Science and Technology Office) and the Ministry of Energy in Stockholm.

5.0 REFERENCES

- 1) Swedish Embassy, Washington, D.C. Ph: (202) 337-5186 or 944-5600.
- 2) IEA Energy Policies and Program Review(s) for 1985, 1986, 1987 and 1988.

OTHER SOURCES:

IEA publications: Technologies for Energy Efficiency and Fuel Switching:
Sweden's Integrated Approach to the Building Sector (Paris, 1988).

THE UNITED KINGDOM

1.0 OVERVIEW OF ENERGY SETTING

The United Kingdom's energy policy is a mirror of the Thatcher Government's philosophy of free market economic development, guided by a minimum or at least a decreasing degree-of government regulation and intervention. As a net energy exporter, with various energy options to supply domestic needs, the United Kingdom's policy toward future energy development assumes the following characteristics:

- 1) development of domestic oil resources.
- 2) pursuit of energy efficiency through market forces.
- 3) monitoring nationalized industries' use of energy.
- 4) selling off publically-owned industries to the private sector when perceived to be in the public's best interest.¹²³

The Government's interest in the development of renewable energy options for the future are witnessed in the white paper on renewable energy, Energy Paper Number 55: "Renewable Energy in the UK: The Way Forward." The review paper proposes a £50M (approximately \$75 million) over the 1988-1990 period to pursue the development of various renewable energy technologies. Private sector involvement is to be encouraged as technologies evolve toward commercialization. Renewable energy technologies may help alleviate the environmental concerns raised by fossil and nuclear fuels use. The strategy

proposed in Energy Paper Number 55 sees collaboration between Government and the private sector on the development of technologies that are "economic, environmentally acceptable and capable of making a contribution to UK energy supply." Regarding geothermal hot dry rock, the White Paper perceives a estimated 210 TWh/y, potentially available, with a contribution of up to 10 TWh/y by the year 2025. (See Annex 4 of this report for a summary of Government's perspective on this technology.) The HDR technology is considered promising but uncertain at this juncture. The Camborne School of Mines has lead responsibility for the development of geothermal HDR technology in Great Britain. Dr. Peter Hackett is principal of the institution, with approximately 40 scientists committed to the research at present.⁵ The United Nation reports 1 MWe of installed capacity in the United Kingdom as of 1987.⁶

2.0 GEOTHERMAL ENERGY FUNDING

Budgetary commitments for geothermal R&D in the United Kingdom since 1985 are as follows:⁷

**TABLE 20: BRITISH GEOTHERMAL BUDGETS AS PERCENT OF
TOTAL ENERGY R&D BUDGETS**

<u>YEAR</u>	<u>DOLLARS</u>	<u>% OF R&D EXPENDITURES</u>	<u>TOTAL ENERGY BUDGET</u>
1985	\$4.75 M	1.3%	\$364.0 M
1986	6.06 M	1.74%	378.4 M
1987	5.05 M	1.54%	361.3 M
1988	5.34 M	1.34%	398.3 M

SOURCE: IEA

3.0 GEOTHERMAL ACTIVITIES

The HDR research project at the Camborne School will attempt to assess technical and economic feasibility, followed by a full-scale field trial conducted with industry by the middle 1990's. The 1988 HDR program review resulted in a three-year program of effort budgeted at approximately \$12.31 m.

The British HDR program at the Camborne School has been conducted with the collaboration of the private sector. Two phases had been completed by the close of 1988. The British companies of Rio Tinto Zinc and Taylor Woodrow have been actively involved in Phase 2 research activities.*

4.0 EMERGING TRENDS

Geothermal HDR energy development efforts are likely to continue in the United Kingdom following the review in 1988 and the determination that the technology was promising if uncertain. Great Britain's generally favorable array of energy sources reduces the urgency for geothermal R&D, but unstable oil prices and increasingly vocal government support for environmental issues may be sufficient to sustain the research program for the intermediate future.

5.0 REFERENCES

- 1) Mr. Neil MacDonald, British Technical Service Corporation, Washington, D.C., Phone: (202)331-7858.
- 2) Messrs. Temple and Lomley, British Embassy, Washington, D.C., Phone: 898-4312 or 462-1340.
- 3) Mrs. Ann Williams, British Embassy, Phone: 898-4389.
- 4) Publication available from HMSO, London: Renewable Energy in the United Kingdom: The Way Forward (June 1988, Energy Paper #55).
- 5) Mr. James Rannels, GTD, US DOE.
- 6) Publication: UK/DOE R&D Activities for 1989, Pgs. 124-141.
- 7) Publication: Energy Policies and Programmes of IEA Countries - Annual Reviews for 1985, 1986, 1987, and 1988, OECD, Washington, D.C.
- 8) Publication: Drawing Heat From the Earth - Geothermal Energy Technology in Britain, UK/DOE.

USSR

1.0 OVERVIEW OF ENERGY SETTING

Reliable information as to the nature and size of the Soviet Union's geothermal energy resources is somewhat difficult to acquire, more so than Western industrial nations. Recent improvements in East-West relations may make information exchanges more commonplace, with the information being more reliable and able to be confirmed as a result. The United Nations's Energy Statistics Yearbook for 1987 reports no productive capacity, while other reports exist that the Kamchatka peninsula is the site of an 11 MW operational plant, with as much as 2,000 MW available in the future.^{1,2,3}

2.0 GEOTHERMAL ENERGY FUNDING

3.0 GEOTHERMAL ACTIVITIES

Professor Paul Kruger of Stanford University's Geothermal Research Program reports the Soviets intend to commit \$30m to the development of their HDR capabilities in the near future.⁴ Since the USSR is not a member of IEA, researchers are dependent on data from trade journals on geothermal technology developments for translation of Russian academic and technical reviews.

4.0 EMERGING TRENDS

Soviet scientists and energy planners are estimating that 5% of the country's electrical energy will be derived from geothermal sources as soon as the year 2000. A 50 MW section of the Mutnovsky facility will be operational during the 1986-1990 period.⁵

5.0 REFERENCES

- 1) United Nations Energy Statistics Yearbook for 1987, pg. 332.
- 2) GRC, 1985 International Symposium on Geothermal Energy,
International Volume; pgs. 505-509.
- 3) GRC Bulletin: 1/85, pg. 23.
- 4) Professor Paul Kruger, Stanford University, phone conversation with author,
Fall 1989.
- 5) GRC Bulletin, op.cit., pg. 23

OTHER SOURCES:

Review of International Geothermal Activities and Assessment of U.S.
Industry Opportunities - Final Report, Los Alamos National
Laboratory, LA - 11066 -MS, Vol.1, pgs. B-16, B-17.

IV. OTHER COUNTRY ACTIVITIES

1.0 INTRODUCTION

This survey has involved the identification of selected countries which are active in geothermal research and development or use a significant way. Once a group of countries was established, data was sought about these nations from as wide a range of sources as possible. In many cases there was sufficient information to develop a summary statement about the country's activities. In numerous instances the data were requested from embassies or government energy offices who universally expressed their willingness to provide information. This information is awaited. Nonetheless, brief comments may be made about several geothermal energy programs which have not yet been addressed. For purposed of thoroughness these national geothermal programs are mentioned here, in alphabetical order. No implications are made regarding the importance of the country programs, merely that less information about them is available to date.

ARGENTINA: Argentina installed it first geothermal plant in Neuquen Province. The binary cycle facility produces .6 MWe for the Neuquen Province Energy Company.¹

AUSTRALIA: Australia has made significant use of geothermal wells for direct heat, but only minimal electricity generation - less than 1 MWe from two units as of late 1989.²

CHILE: Chile is "moribund" regarding geothermal energy development.³

CHINA: Chinese geothermal power production was reported to be 15 MWe from 15 units scheduled for completion by the start of 1987.⁴⁵ EPRI has estimated that China has the world's largest geothermal energy potential, 535,000 MWe for thirty years, with 3,000 fields having been explored or assessed. In the past, Italy, Japan, Iceland and the U.S. have expressed interest in assisting China to develop this resource further.⁶

COSTA RICA: Costa Rica is emerging as a country of major geothermal activity. Although United Nations data reports no geothermal power production as of 1987, geothermal exploration in Costa Rica began as far back as 1975. Eight wells have been drilled in the Miravalles region, with six wells determined to be producible. Plans are to develop two 55 MW power plants with a total capacity of 110 MW by 1995.⁷

GUATEMALA: Since study of Guatemala's geothermal resources began in 1971, the country's large potential for geothermal electricity production has become widely known. However, the country has moved to develop its hydropower resources instead, resulting in "not one" kilowatt of geothermal electricity being produced as of June 1989. A 15 MW plant is being developed at Zunil, and is scheduled for completion in 1992 or 1993. Issues of technical security surrounding Guatemala's Chixoy hydropower facility may increase interest in geothermal energy in the future.⁸

HONDURAS: The country's geothermal energy potential, from six sites investigated by Los Mamos and other, is estimated to be as high as several hundred megawatts of power. The Platanares field appears to be the most promising, but no geothermal funding is provided for in Honduras' future energy expansion plan.⁹

INDONESIA: Indonesia has begun to develop its geothermal capacities with the 30MW and 55MW plants going on-line in 1982 and 1987 respectively. Total capacity as of 1987 was 140MWe. New Zealand has been active in assisting the Indonesians with its geothermal production requirements.¹⁰

KENYA: Kenya has signed agreements with New Zealand interest to develop its geothermal program of development and pre-construction studies, funded with a low-cost IDA loan for \$40.7 millions over twenty years.¹¹

REFERENCES

- 1) GRC Bulletin, June, 1988
- 2) Geothermal Energy Institute, October, 1989
- 3) IDB interview, November, 1989
- 4) Geothermal Energy Institute, 10/19/89
- 5) GRC Bulletin, May, 1988, pg. 11
- 6) Geothermal Report, September, 1987, as reported in GPM, No. 11, pp. 53-54 (draft)

- 7) NGA Trade Mission to Central America, June, 1989, pg. 41
- 8) Ibid., pg. 11
- 9) Ibid., pg. 34
- 10) GRC Bulletin, 2/89, as reported in GPM, No. 11, pp. 57-58
- 11) Geothermal Report, July, 1989, as reported in GPM, No. 11, pp. 58