REPRINT

Preliminary Report: Geothermal Energy, The Potential For Clean Power From the Earth

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CONTENTS

PRELIMINARY REPORT: GEOTHERMAL ENERGY, THE POTENTIAL FOR CLEAN POWER FROM THE EARTH

Introduction

This collaborative effort produced country-by-country estimates of the potential for geothermal energy resources to meet electricity demand. Coordinated by Karl Gawell of the U.S. Geothermal Energy Association, Dr. Marshall Reed of the U.S. Department of Energy and Dr. P. Michael Wright of the Energy and Geosciences Institute at the University of Utah, this assessment involved significant contributions from eighteen leading experts in industry, government agencies, and the national laboratories.

Summary of the Results

The report shows that geothermal resources using today's technology have the potential to support between 35,448 and 72,392 MW of electrical generation capacity. Using enhanced technology currently under development (permeability enhancement, drilling improvements), the geothermal resource could support between 65,576 and 138,131 MW of electrical generation capacity. Assuming a 90% availability factor, which is well within the range experienced by geothermal power plants, this electric capacity could produce as much as 1,089 Billion kWh of electricity annually.

The geothermal potential identified by this analysis represents about 8.3% of total world electricity production, using EIA's 1996 data. The potential varies significantly by region. Central America, South America and Africa having the potential to meet a large proportion of their electricity needs through utilizing geothermal resources. More than half of the current electricity needs of Central and South America (including the Caribbean) could be met by geothermal power. Africa demonstrated the next largest regional opportunity, with 28% of the continents current electricity use being potentially met by geothermal energy.

Estimates for North America indicate a potential for geothermal power between 6,340 MW and 11,700 MW with today's technology, and between 15,080 MW and 25,390 MW using enhanced technology. These resources are in both the U.S. and Mexico, with the United States having a significant majority of the geothermal potential identified for North America.

Worldwide, the report indicates that geothermal power could serve the electricity needs of 865 million people, or about 17% of the world's population. Thirty-nine countries are identified which could be 100% geothermal powered, mostly in Africa, Central and South America and the Pacific. These 39 countries have a total population of 620,637,000 (using 1998 UN population data).

The report assesses the potential electrical production from the hydrothermal resource as it is known today. In light of significant worldwide exploration and development over the past decade, the results represent a refinement over previous estimates. However, these figures do not define the limits of the produceable resource. Hydrothermal resources can be difficult to identify without more extensive investigation than has typically been conducted in most countries, and new and improved technology is expected to continually expand the economically produceable resource.

In addition, significant low temperature resources have been identified in countries throughout the world which are suitable for direct use applications. Direct use applications, such as heating of homes and greenhouses, which are currently estimated to provide as much energy as geothermal electricity production, are not assessed by this analysis.* Neither is the potential contribution from geothermal heat pumps included in this analysis.

Conduct of the Analysis

The report is based upon the results of a detailed survey conducted in January and February of 1999. The coordinators mailed the survey to individuals identified as having extensive experience with geothermal resources. The survey sought the assistance of these experts in defining the geothermal resource on a country-by-country basis. The resource was defined as the hydrothermal resources that could reasonably be expected to be developed with today's technology or enhanced technology. Enhanced technology was defined as including development of drilling improvements, techniques to augment permeability, and related advances envisioned in *the Strategic Plan for the Geothermal Energy Program* released by the U.S. Department of Energy in 1998. The questionnaire asked respondents to exclude consideration of project economics, or the timing of potential development.

The respondents were asked to assign a weight to each of their country responses. Persons having visited a country frequently and examined many geothermal sites would weight their estimate as a five (5), while persons using their expertise to estimate a potential based only on geologic maps and similar information for a specific country were instructed to weight their estimate as a one (1). The final geothermal potential figures used in this report employ these weighted averages, thus giving significant emphasis to estimates from people with extensive, direct experience in the countries. While past estimates for some of the countries included here may be higher, these results are intended to have a higher degree of confidence given the large base of contributors, their extensive experience, and the weighting factors employed.

Individuals providing significant information to the report are listed as contributors. They were asked to participate as individuals, and their estimates do not necessarily represent the views of their company or institution. Participation as a contributor does not necessarily indicate approval of the results of this study by any individual or organization listed. A few contributors asked to remain anonymous, and the coordinators have respected their request.

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*See, "Direct Use of Geothermal Energy Around the World," Ingvar B. Fridleifsson, President, International Geothermal Association.

GEOTHERMAL ENERGY
THE POTENTIAL FOR CLEAN POWER FROM THE EARTH

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We also with to recognize Christopher Gaunt and Daniella Stratulat for their assistance with this report

GEOTHERMAL POTENTIAL BY WORLD REGIONS

(all countries)

EIA Region	Geothermal Potential (Billion kWh)	Current Electricity Use (Billion kWh)	% Geothermal
North America	200	4,333	4.6%
Central & S. America	224	623	36.0%
w/Caribbean	354	669	52.9%
Europe/Former USSR	97	4155	2.3%
Asia and Pacific	337	3304	10%
Africa	101	357	28%
WORLD TOTAL	1089	13,142	8.3%

39 COUNTRIES WHICH COULD BE 100% GEOTHERMAL POWERED

Country	Population
Bolivia	7,957,000
Burundi	6,457,000
Comoros Islands	658,000
Costa Rica	3,841,000
Djibouti	623,000
Dominica	71,000
Ecuador	12,175,000
El Salvador	6,032,000
Ethiopia	59,649,000
Fiji	796,000
Grenada	93,000
Guadeloupe	443,000
Guatemala	10.801,000
Honduras	6,147,000
Iceland	276,000
Indonesia	206,338,000
Kenya	29,008,000
Malagasy Republic	15,057,000
Malawi	10.346,000
Martinique	389,000
Montserrat	11,000
Mozambique	18,880,000
Nicaragua	4,807,000
Panama	2,767,000
Papua New Guinea	4,600,000
Peru	24,797,000
Philippines	72,944,000
Rwanda	6,604,000
Solomon Islands	417,000
Somalia	9,237,000
St Kitts & Nevis	39,000
St. Lucia	150,000
St. Vincent	112,000
Sudan	28,292,000
Tanzania	32,102,000
Tonga	98,000
Uganda	20,554,000
Vanuatu	182,000
Yemen	16,887,000
TOTAL	620,637,000

FIFTY PERCENT GEOTHERMAL POWERED

Burma
Chile
Congo
New Zealand

TWENTY PERCENT GEOTHERMAL POWERED

Argentina
Columbia
Macedonia
Mexico
Zambia

TEN PERCENT GEOTHERMAL POWERED

Australia
Dominican Republic
Greece
Hungary
Turkey
Venezuela
Vietnam
Zimbabwe

Summary Table

The attached table displays the results of the analysis based upon the weighted average of the responses received. The totals indicated for each region and the world are totals for those countries listed only. The table displays the following information:

Country

This column lists the countries included in the analysis

Today's Technology (TTHigh-MW, TT-Low-MW)

These two columns provide the range of potential for geothermal electricity production in terms of Megawatts of capacity based upon today's technology.

Enhanced Technology (ETHigh-MW), ET Low-MW)

These two columns provide the range of potential for geothermal electricity production in terms of Megawatts of capacity based upon enhanced technology.

Potential (Billion kWh)

This column presents an estimate of annual electricity production in billions of kilowatt hours using the ETHigh estimate and assuming an availability factor of 90%.

Current Use (Billion kWh)

This column presents the 1996 annual electricity production for the country listed in billions of kilowatts hours from the Energy Information Administration International Energy Database, Table 6.3, December 1997

% Geothermal Possible

Based upon the previous two columns, the percentage of annual production which could be met by potential geothermal production is expressed.

Pop., 1998 (thousand)

The population of the country for 1998 is listed, based upon the United Nations 1998 Revision of the World Population Estimates and Projections.

People served by Geothermal

Based upon the previous two columns, the number of people whose electricity needs could be met by geothermal electricity is presented.

Country	Today's Technology		Enhanced Technology		Potential	Current Use	% Geothemal	Pop., 1998	People served
	TTHigh-MW	TT Low-MW	ETHigh-MW	ETLow-MW	Billion kwh	(Billion kwh)	Possible	(Thousand)	by Geothermal
USA	6520	3780	18880	10660	148.85	3628.70	4.10	274,028	11,241
Mexico	5180	2560	6510	4420	51.32	154.40	33.24	95,831	31,856
Total North America	11,700	6,340	25,390	15,080	200	3783.10	5.29	369,859	43,096
Argentina	1010	490	2010	940	15.85	64.67	24.50	36,123	8,852
Bolivia	1260	510	2490	1070	19.63	2.95	665.46	7,957	7,957
Chile	1630	780	2350	1400	18.53	35.81	51.74	14,824	7,670
Colombia	1370	700	2210	1340	17.42	53.73	32.43	40,803	13,233
Costa Rica	1990	970	2900	1290	22.86	4.79	477.82	3,841	3,841
Ecuador	850	420	1700	910	13.40	8.45	158.61	12,175	12,175
El Salvador	1450	660	2210	1210	17.42	3.58	487.37	6,032	6,032
Guatemala	2260	1050	3320	1690	26.17	3.10	844.35	10,801	10,801
Honduras	590	310	990	470	7.81	2.73	285.90	6,147	6,147
Nicaragua	2270	1080	3340	1940	26.33	1.67	1581.54	4,807	4,807
Panama	230	130	450	220	3.55	3.55	99.94	2,767	2,765
Peru	1410	600	2990	1530	23.57	16.21	145.41	24,797	24,797
Venezuela	480	370	910	390	7.17	73.00	9.83	23,242	2,284
Brazil	200	100	500	300	3.94	285.72	1.38	165,851	2,288
Uruguay	200	0				8.35		3,289	
Paraguay	200	0				45.03		5,222	
Total Latin America	17400	8,170	28370	14700	224	613	36.47	368,678	113,649
Dominica	680	240	1390	530	10.96	0.04	27396.90	71	71
Grenada	360	180	1110	400	8.75	0.07	12501.77	93	93
Montserrat	280	130	940	370	7.41	0.02	49406.40	11	11
St. Kitts & Nevis	590	450	1280	670	10.09	0.08	12458.67	39	39
St. Lucia	260	110	680	260	5.36	0.11	4873.75	150	150
St. Vincent/Grenadi	420	150	890	320	7.02	0.06	11317.35	112	112
Cuba	30	10	50	10	0.39	10.61	3.72	11,116	413
Dominican Republi	50	10	150	50	1.18	6.70	17.65	8,232	1,453

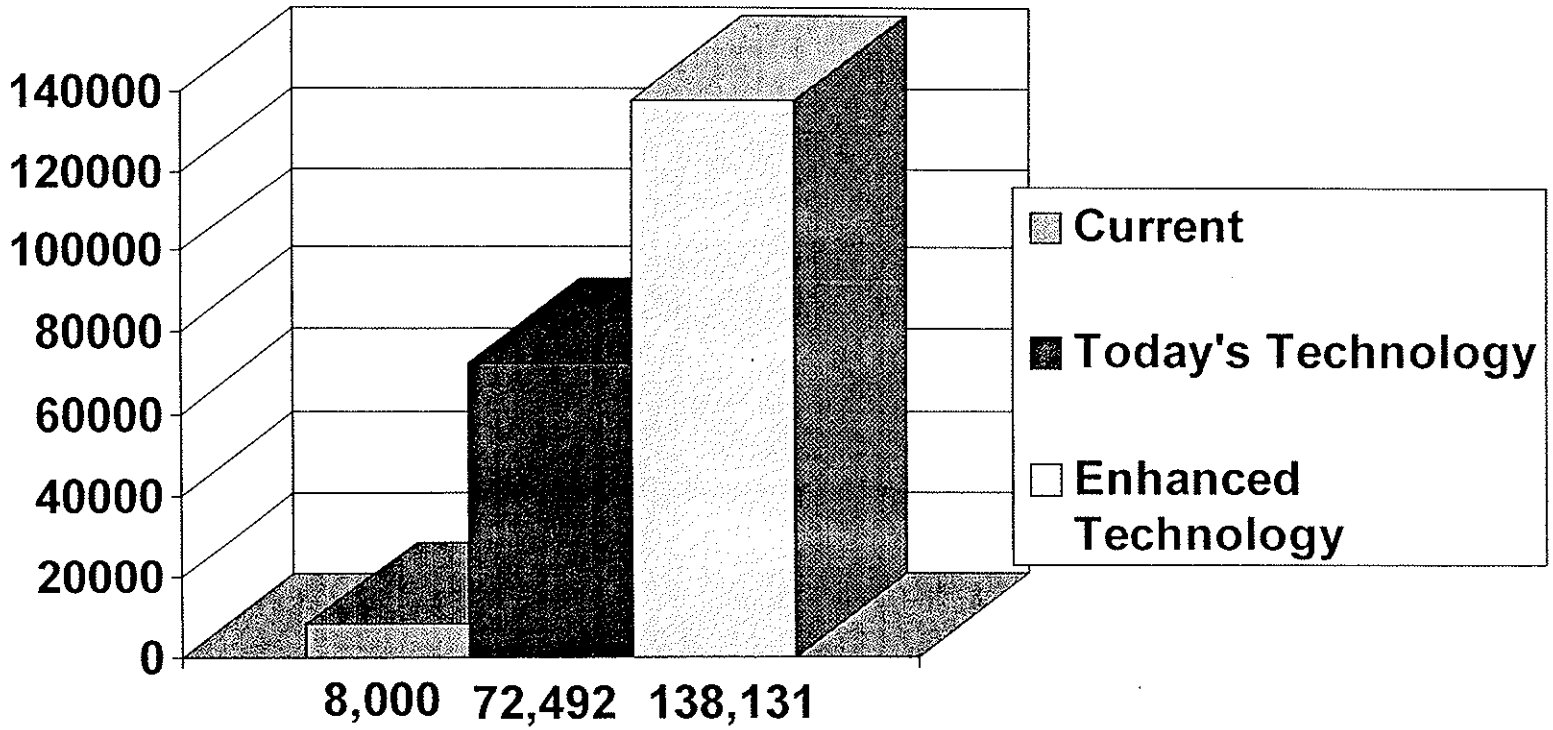
Saba	1000	500	3000	1000	23.65			N/A	
Guadeloupe	1500	500	3500	1000	27.59	0.96	2874.38	443	443
Martinique	1500	500	3500	1000	27.59	0.86	3227.37	389	389
Total Caribbean	6670	2780	16490	5610	130.01	19.50	666.60	20,656	3,174
Azores	240	90	440	190	3.47	N/A	N/A	N/A	
Iceland	890	390	1730	670	13.64	5.05	270.22	276	276
Total Atlantic	1130	480	2170	860	17.11	5.05		276	276
Former USSR	1902	768	3741	1501	29.49	1229.28	2.40	261,659	6,278
Greece	450	160	900	340	7.10	40.03	17.73	10,600	1,879
Hungary	380	220	820	340	6.46	33.16	19.49	10,116	1,972
Poland	110	50	300	100	2.37	134.73	1.76	38,718	680
Turkey	740	360	1380	630	10.88	91.20	11.93	64,479	7,693
Italy	1000	500	2000	1000	15.77	226.71	6.96	57,369	3,990
Slovakia	100	50	200	100	1.58	25.81	6.11	5,377	328
Macedonia	100	50	200	100	1.58	6.06	26.02	1,999	520
Yugoslavia	100	50	200	100	1.58	36.16	4.36	10,635	464
Romania	100	50	200	100	1.58	59.25	2.66	22,474	598
Bulgaria	100	50	200	100	1.58	41.58	3.79	8,336	316
Total Eastern Europe/Mediterranean	5082	2,308	10141	4411	80	1924	4.16	491,762	24,718
Burma (Myanmar)	150	50	280	100	2.21	3.75	58.87	44,497	26,194
China	1860	830	3450	1500	27.20	1000.20	2.72	1,255,698	34,148
Fiji	70	20	150	50	1.18	0.55	216.99	796	796
India	280	100	560	220	4.42	404.48	1.09	982,223	10,721
Indonesia	9790	5600	15650	7960	123.38	66.80	184.71	206,338	206,338
Papua New Guinea	1610	480	2780	1030	21.92	1.70	1289.27	4,600	4,600
Philippines	5730	3500	8620	4790	67.96	32.20	211.06	72,944	72,944
Solomon Islands	80	40	170	70	1.34	0.03	4467.60	417	417
Taiwan	210	90	460	150	3.63	134.91	2.69	21,500	578

Thailand	120	40	320	125	2.52	82.00	3.08	60,300		1,855
Tonga	60	20	110	40	0.87	0.03	2890.80	98		98
Vanuatu	80	30	160	60	1.26	0.03	4204.80	182		182
Vietnam	160	70	360	160	2.84	14.88	19.07	77,562		14,794
Australia	400	100	2500	100	19.71	166.68	11.83	18,520		2,190
New Zealand	2000	1000	3500	1500	27.59	35.53	77.66	3,796		2,948
Japan	1460	860	3640	1730	28.70	948.56	3.03	126,281		3,821
Total Asia-Pacific										
	24060	12830	42710	19585	336.73	2892.33	11.64	2,875,752		382,624
Burundi	80	20	170	50	1.34	0.12	1098.59	6,457		6,457
Comoros Islands	30	10	70	20	0.55	0.02	3679.20	658		658
Djibouti	460	230	860	380	6.78	0.18	3874.42	623		623
Ethiopia	1710	640	2930	1230	23.10	1.32	1750.01	59,649		59,649
Kenya	1810	850	3000	1450	23.65	3.81	620.79	29,008		29,008
Malagasy	240	70	470	140	3.71	0.60	622.77	15,057		15,057
Malawi	90	20	230	60	1.81	0.80	226.67	10,346		10,346
Mozambique	80	20	210	60	1.66	0.55	301.03	18,880		18,880
Rwanda	170	50	340	120	2.68	0.16	1634.49	6,604		6,604
Somalia	100	30	210	60	1.66	0.26	641.72	9,237		9,237
Sudan	220	70	490	180	3.86	1.32	293.78	28,292		28,292
Tanzania	380	140	680	260	5.36	1.82	294.57	32,102		32,102
Uganda	330	120	610	250	4.81	0.79	611.09	20,554		20,554
Congo (Kinshasa)	320	130	640	250	5.05	6.40	78.84	49,139		38,741
Zambia	90	20	200	60	1.58	7.84	20.11	8,781		1,766
Zimbabwe	90	20	200	60	1.58	8.50	18.55	11,377		2,111
Eritrea	150	50	1250	600	9.86	N/A	N/A	3,577	N/A	
Yemen	100	50	300	100	2.37	1.86	127.09	16,887		16,887
Total Africa										
	6450	2,540	12860	5330	101	36	279.06	327,228		296,972
TOTAL ALL	72,492	35,448	138,131	65,576	1089	9274	11.74	4,454,211		864,509

*Source: United Nations Department of Economic and Social Affairs, Population Division (1998)

World Geothermal Potential

Megawatts of Electrical Capacity



U.S. Geothermal Potential

Megawatts of Electrical Capacity