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Status Report on Geothermal Energy Developments in Brazil

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ABSTRACT

An overview of government setting and policies of interest to geothermal developments is provided along with an updated assessment of geothermal resources and energy use in Brazil. The data base for resource assessment consists of thermal gradient and heat flow measurements at over 450 sites and hydrothermal and energy use data on thermal spring systems at 95 localities. The total resource base is estimated at $2,4x10^{25}$ Joules of which more than 50% is located in areas of sedimentary basins. A significant number of low temperature geothermal resources (with temperatures <90^0C) have been identified in the continental area. The potential for high temperature geothermal systems appears to be restricted to the Atlantic islands of Fernando de Noronha and Trindade. Of the available part of the resources, estimated at $5.2x10^{22}$ J, only a small fraction is being currently exploited. The total capacity of low temperature geothermal systems under economic exploitation is estimated at 362 MWt, while the annual energy use is estimated to be of the order of 6536 TJ. About a dozen of the spring systems account for the bulk of this capacity. Most of them are located in west central Brazil (in the states of Goiás and Mato Grosso) and in the south (in the state of Santa Catarina). The potential for large scale exploitation of low temperature geothermal water for industrial use and space heating is considered to be significant in the central parts of the Paraná basin (situated at southern and southeastern Brazil), where cold winter seasons prevail under subtropical climate conditions.

1. INTRODUCTION

The National Council for Energy Policies (CNPE), operating under the Ministry of Mines and Energy (MME), acts as the advisory body for formal policies and recommendations concerning development and installation of energy sources in Brazil. According to the recent estimates (CNPE, 2000), the total energy generation is estimated at about 198 million TOE (tones of oil equivalent). Systems based on the use of hydrocarbon resources and electrical power generation account for nearly 90% of this total. Table (1) provides a summary of the main systems that make up the energy matrix of Brazil.

This Council has set up technical committees, which draw guidelines for the development and use of different types of energy resources. A specific Committee has not yet been set up exclusively for geothermal energy resources. However the Committee CT5 has the task of examining alternate and renewable energy resources, that potentially also include geothermal energy. Alternate energy resources currently contribute less than 1% of the total energy production. Geothermal energy sources are not directly used for electrical power generation and hence not formally recognized by CNPE. However, according to recent compilations of information on energy use geothermal contribution is the highest the group of alternative energy sources (see Figure 1).

Table (1) Energy Matrix of Brazil. The energy generation is given in units of 10^6 tons of oil equivalent (TOE)

Energy System	Energy Generation	
	(10^6 TEP)	(%)
Petroleum	85.51	43.1
Biomass	53.57	27.0
Hydro Electricity	27.78	14.0
Natural Gas	14.88	7.5
Coal	13.10	6.6
Uranium	3.57	1.8
Others	<1.00	<1.0
Total	198.41	100.0

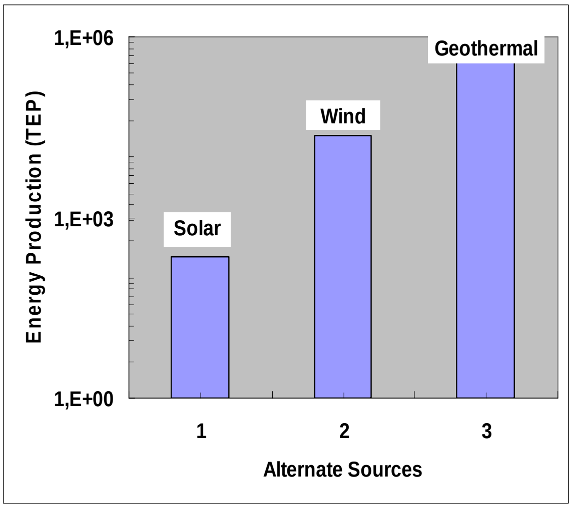

Figure 1: Estimates of present use of Alternate and Renewable Energy Resources in Brazil.

The National Department of Mineral Production (DNPM) under the Ministry of Mines and Energy is the lead government agency involved in setting guidelines for the development and use of geothermal water. The Geological Survey of Brazil (CPRM) works in close cooperation with DNPM and has been engaged in mapping geothermal areas and in compiling related geological and geophysical data. It has also carried out drilling and logging operations as part of projects for development of geothermal energy resources. Mention must also be made to the exploration and deep drilling activities carried out, in connection with oil exploration, by the state owned oil company, PETROBRAS. Remote sensing of surface thermal anomalies is being carried out at the National Institute of Space Research (INPE). However, conventional ground surveys for geothermal research are currently being conducted by the Geothermal Laboratory of the National Observatory in Rio de Janeiro. This laboratory (under the Ministry of Science and Technology) is equipped with facilities for temperature logs in drill holes, thermal surveys in underground mines, laboratory and field measurements of thermal properties, continuous monitoring and sampling and analysis of thermal fluids. It also maintains a computerized Geothermal Data Base with information on the nature and occurrence of Brazil's geothermal resources. Basic research in geothermics is also being carried out in several universities. Among these are the Institute of Astronomy and Geophysics of the University of São Paulo, in southeast, and the Geoscience Departments at the Federal Universities in Manaus and Belem, in northern Brazil.

Systematic investigations of geothermal resources in Brazil began in the 1970s. Since then, quite a significant amount of information has been acquired on the nature and occurrence of geothermal manifestations and their physical and chemical characteristics. In addition, studies have also been carried out for mapping the distribution of temperature gradients, thermal properties, radiogenic heat production and heat flow in different parts of the country. The data acquired so far has been of considerable help not only in understanding the geothermal regimes of the different tectonic units (Hamza et al, 1984; Hamza and Muñoz, 1996) but also in the assessment of geothermal resources on regional and local scales (Hamza and Eston, 1983). Concomitant with data compilation, attempts have also been made to monitor developments in utilizing geothermal resources. An appraisal of the current state of geothermal energy use in Brazil is the main purpose of the present work.

2. GEOLOGY BACKGROUND

The continental segment of the Brazilian territory is situated within the eastern part of the South American Platform. Results of regional scale geological and geophysical studies (see Figure 2) provide insights into thermal characteristics of the crustal layers in this region. It appears that significant parts of this platform area have been tectonically quiescent since Precambrian era.

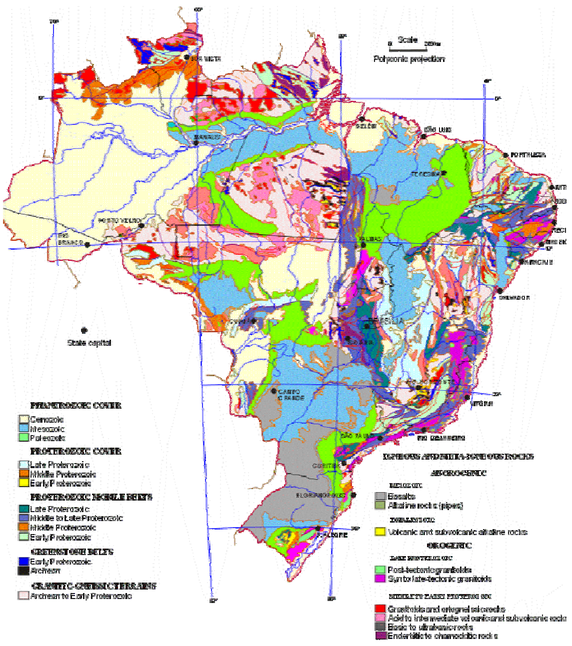

Figure 2: Simplified Tectonic Map of Brazil (CPRM, 2000)

During Paleozoic time the Brazilian platform was affected by considerable vertical movement of the crustal blocks, leading to the formation of large sedimentary basins in its interior parts. During Mesozoic time, horizontal movements associated with plate tectonic activity contributed to the formation of sedimentary basins along the coastal areas. With the exception of the large number of alkaline intrusions in southern and southeastern Brazil, the region has been practically free of any significant magmatic or volcanic activity since the beginning of the Tertiary period. Such characteristics of the geologic history have profound influences not only on the thermal regime at shallow depths but also on the type and occurrence of geothermal resources.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Early works on evaluation of potential for geothermal energy and assessment of resources in Brazil were carried out by Hamza et al (1978) and Hamza and Eston (1983). The emphasis of these early works has been mainly on the results of heat flow measurements, which reveal low to normal values (in the range of 40 to 70 mW/m^2) in most parts of the Precambrian cratonic areas and fold belts and also in phanerozoic sedimentary basins. Higher than normal heat flow (>80 mW/m^2) have been encountered only in limited portions of overthrust terrains of central Brazil, in areas of alkaline intrusive of Tertiary age, and in isolated localities of thermal springs. The heat flow data in conjunction with the available information on geological and geochemical characteristics of the upper crust has been useful in obtaining regional estimates of geothermal resources. The updated estimates of the resource base calculated on the basis of the volume method are given in Table (2).

Table 2. Estimates of Geothermal Resource Base (Adapted from Hamza et al, 1983).

Classification	Area (10^6 km^2)	Rate of heat Loss (10^9 W)	Resource Base (10^{24}J)
Cratonic Areas	3.304	139	5.7
Precambrian Fold Belts	2.042	131	4.8
Phanerozoic Interior Basins	3.116	190	8.5
Alkaline Intrusions	0,003	0.2	0.009
Over-thrust Terraines	~ 0,02	4	0.1
Geothermal Areas	0,003	0.5	0.01

The spatial distribution of these earlier estimates of resource base has been examined recently by Hamza (2003). The contour map of resource base per unit area (see Figure 3) reveals an arc-shaped region of relatively high values (>10^{22}J) in south-central parts of Brazil, mainly in the states of Goiás and Mato Grosso. Smaller areas of similar types of resource base are also found in the northeastern and southern parts. More recently detailed resource assessments have been carried out in two regions: the State of Goiás in the central parts and the State of Rio de Janeiro in the southeast coastal region. The results of these recent studies are discussed briefly in the following items. It is perhaps convenient to point out that the methodology adopted in these works have been discussed in detail by Ferreira (2003) and Gomes (2003). Additional details are also provided in a companion paper of this volume (Ferreira and Hamza, 2004). In this work, the discussion is therefore limited to presentation of the main results and conclusions.

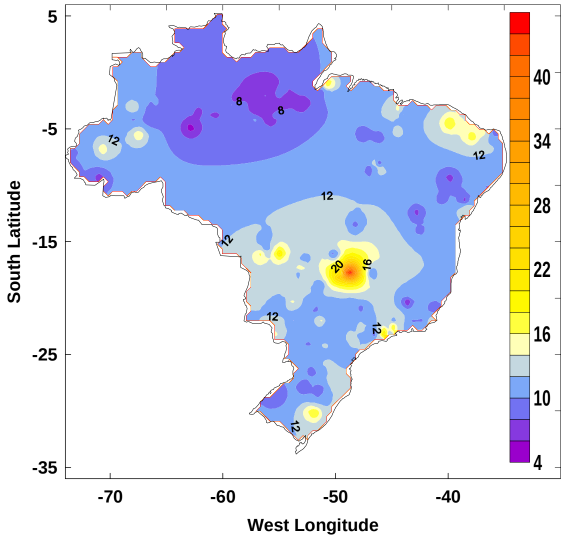

Figure 3. Regional distribution of geothermal resource base in Brazil (Hamza, 2003). The contour values are in units of 10^{21} J/m^2.

3.1 State of Goiás in Central Brazil

New geothermal and hydrogeologic studies were carried out over the last few decades in the region of Central Brazil, mainly in the state of Goiás. Ferreira and Hamza (2003) presented estimates of resource base and recoverable resources on the basis of the results of these investigations. Two different methods were employed in assessing resources: the conventional volumetric method and the random simulation method (Ferreira and Hamza, this volume). There are indications that the conventional approach based on the volumetric method tend to overestimate resources. Random simulation method was used as part of an attempt to minimize these difficulties. The geographic distribution of resource base per unit area (see Figure 4) reveal that the eastern and southern parts of the state of Goiás may hold potentially interesting targets for exploration of low enthalpy geothermal resources. The pattern of regional variations in RB (Resource Base) have some degree of correspondence with the local geologic structure, a consequence of the ‘geologic control’ on the random generator. Also the pattern of RB has relatively sharp boundaries that appear to be consistent with the local geologic pattern and compatible with the region of known geothermal manifestations.

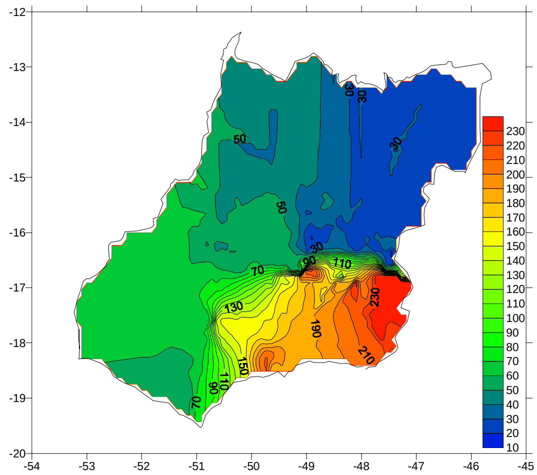

Figure 4. Map of geothermal resource base of the state of Goiás. The contour values are in units of 10^{12} J/m^2.(Ferreira and Hamza, this volume).

3.2 State of Rio de Janeiro in the Southeastern Coast

Results of recent geothermal and hydrogeologic studies, carried out in 72 localities in the coastal region of Southeastern Brazil, have been used recently by Gomes and Hamza (2003) in estimating resource base of the state of Rio de Janeiro. Reproduced in Table (3) are the estimates of resource base for the five different regions with distinct geologic characteristics.

Table 3. Resource base for the major geologic units in the state of Rio de Janeiro (Gomes and Hamza, 2003).

Geology	Area	Resource Base	
		Mean	σ
	(km^2)	(10^{20} J)	(10^{20} J)
Precambrian Basement	29889	700	35
Sediment cover	8551	200	10
Batholiths	5037	120	6
Alkaline Intrusive	433	10	0,5
Total	**43910**	**1030**	**52**

The geographic distribution of resource base per unit area (see Figure 5) reveal that the areas with potential for exploration of low enthalpy geothermal resources are scattered along an east-west trending narrow belt. The pattern of regional variations in RB have some degree of correspondence with the local geologic structure, as it is almost coincident with the belt of alkaline intrusives of Tertiary age.

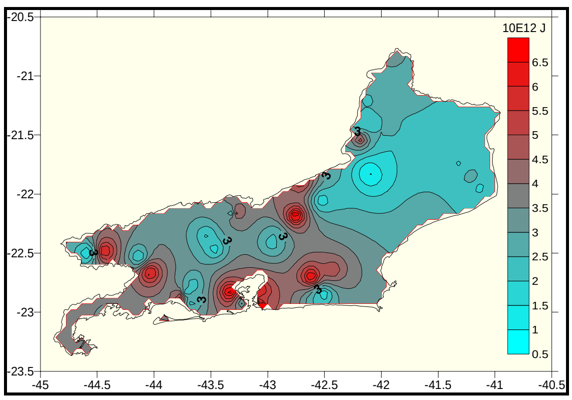

Figure 5. Distribution of resource base per unit area in the state of Rio de Janeiro (Gomes and Hamza, 2003).

3.3 Paraná Basin in the Southwestern Region

Apart from spring systems, huge deposits of thermal water are also found in some of the Phanerozoic sedimentary basins. Basins with significant thermal water aquifers are Paraná in the south, Parnaíba in the north and Amazon in the west. Thermal energy resources associated with thermal water aquifer systems in sedimentary basins in Brazil are estimated to be of the order of 10^{21} Joules (Hamza and Eston, 1983).

Detailed geothermal data are currently available only for the Paraná basin. The geographic distribution of heat flow in this basin (see figure - 6) indicate the existence several isolated anomalies along its eastern and northern borders. Deep wells drilled under petroleum exploration programs have encountered several thermal water aquifers at depths of 1 to 3 kilometers. The area extent of these aquifer systems, which includes parts of western Uruguay and northeastern Argentina, is estimated to be over one million square kilometers. In most of the wells, flow occurs under artesian conditions with temperatures varying from 40 to 80^0C. Pumping tests indicate that it is possible to extract thermal water at rates of 100 to $400 m^3/h$ using large diameter wells, whereas even higher flow rates seem viable if directional drilling techniques can be employed. A project is under way for detailed assessment of geothermal resources of this basin.

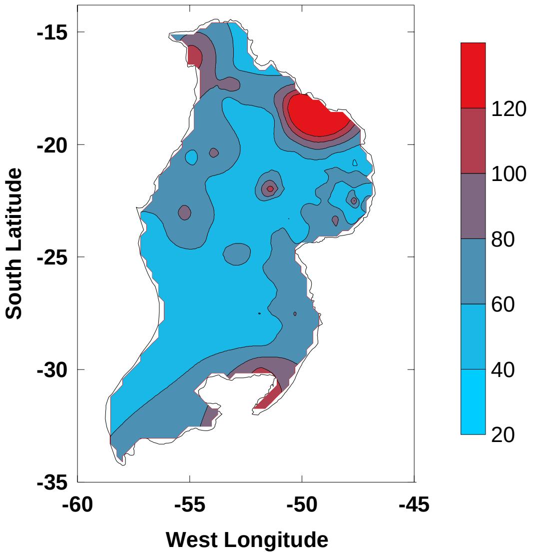

Figure 6. Preliminary heat flow map of the Paraná basin. The contours are in units of mW/m^2.

4. GEOTHERMAL ENERGY UTILIZATION

Recently, the Geothermal Laboratory of the National Observatory has compiled information on the main geothermal systems currently being exploited commercially in Brazil. This compilation includes data on flow rates, range of use of temperatures and chemical characteristics of thermal fluids. In the present context we have found it convenient to classify the information on spring systems into groups, based on such key factors as perspectives for direct use, proximity of large urban centers and local climate characteristics. They are designated as: BRT (Bathing, Recreation and Tourism), PIS (Potential for Industrial use and Space heating) and TDB (Therapeutic, Drinking and Bathing) groups. Listings of thermal springs belonging to these groups are presented respectively in tables A1, A2 and A3, in the Appendix. Also given in these tables are estimates of the thermal capacity of the spring systems in units of MWt (Megawatt Thermal) and of the annual energy use in units of TJ/yr (Tera Joules/Year). The geographic distribution of the main thermal and mineral springs belonging to the three above mentioned groups is illustrated in Figure (7). As can be seen in this figure, the concentration of thermal springs is relatively high in southern and south-central parts of Brazil, compared with northern parts. Also indicated in this figure are the sites where industrial use of thermal water has been made.

The spring systems belonging to the BRT group have an estimated total thermal capacity of 16 MWt and an annual energy use of about 189 TJ. The localities of these thermal springs (see Table A1) have become popular tourist attractions over the last few decades. Commercial exploitation of such small-scale manifestations are currently being carried out by small groups or individuals, there being no specific incentives for geothermal developments in Brazil. Currently such small scale thermal and mineral spas are visited by an estimated 1.5 million tourists per year. To cater to the increasing demands of tourism, special facilities for transportation, accommodation and recreation have been set up in several of the prominent spring sites. This in turn has spurred considerable local economic activity. The emphasis at these thermal spas and tourist centers is on entertainment and physical conditioning under programs for revitalizing the body in a relaxing environment. Some of these programs claim relief from undesirable effects of stress and depression and overweight reduction.

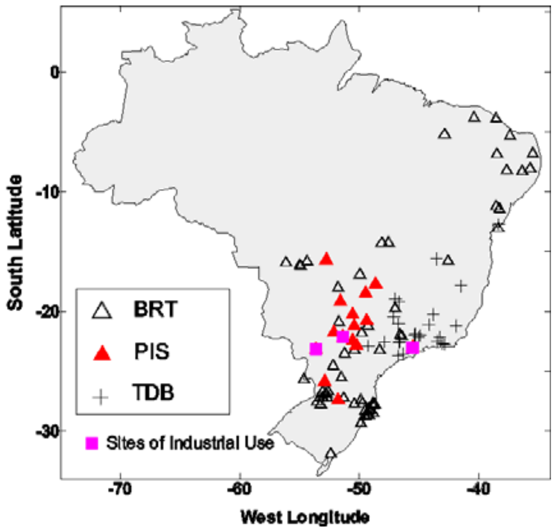

Figure 7 Locations of major geothermal systems under development.

Larger spring systems belonging to the PIS group have an estimated total thermal capacity of 343 MWt and an annual energy use of about 6291 TJ. Currently the thermal resources at these sites (see Table A2) are being used almost exclusively for bathing and recreation, in spite of their considerable potential for industrial applications and space heating. Industrial use of thermal water has so far been attempted only in a few localities. In the town of Taubaté, in southeastern São Paulo geothermal water at 48^0C was used, during 1970s and 1980s, for industrial wood processing (pre-heating prior to peeling). In Cornélio Procópio, in the state of Paraná, geothermal water at 50^0C pumped from a 950-meter deep well has been used, since 1980, as pre-heated water for boilers, in industrial production of coffee powder. The economic feasibility of employing low temperature geothermal water for leather processing as well as for a variety of other agro-industrial processes was demonstrated by Hamza et al (1990a) in a site-specific study on thermal water in Presidente Prudente, in the state of São Paulo. In a follow-up work Hamza (1990b) examined the price structure of low temperature geothermal resources for generation of low grade heat in industrial applications in Brazil. According to the results of these investigations, only large-capacity geothermal ventures are capable of retaining competitive advantages against alternative systems based on the use of electrical energy or hydrocarbon fuels for thermal process heat. Such systems ideally should have flow rates higher than 100 m^3/h and useful excess temperatures of over 20^0C. The time period for investment return was estimated to be about ten years, for industries located within a radial distance of four kilometers from the production well. This time period may now be considered attractive, because of the low inflation rates and the relatively more stable economic conditions. The main obstacle continues to be the high initial capital investment required for drilling and installing production and distribution systems.

The spring systems belonging to the TDB group have an estimated total thermal capacity of 3 MWt and an annual energy use of about 56 TJ. Exploration of non-thermal mineral water for therapeutic purposes is quite widespread. According to recent estimates, revenues generated by the mineral water industry make up a significant component of the economy in many municipalities. In this respect it is convenient to note that the list given in Table A3 represents only a tiny fraction of the current total mineral water production.

5. DISCUSSION

The alternate energy sources contribute less than 1% of the current energy use in Brazil. Nevertheless the perspectives for large scale developments of low enthalpy geothermal resources may be considered significant, in view of the current uncertainties in the global energy market.

The total capacity of low temperature geothermal systems in use is estimated at 362 MWt and the annual energy use at 6536 TJ. About a dozen of the spring systems account for the bulk of this capacity. Most of the major springs are located in central Brazil (in the state of Goiás) and in the south (in the state of Santa Catarina). According to Hamza et al (1990), only a tiny fraction of the available geothermal resources (estimated at 10^{22} joules) is currently being exploited. The potential for large-scale exploitation of low temperature geothermal water for industrial use and space heating may be considered as significant in southern and southeastern parts of Brazil, where cold winter seasons with temperature below 10^0C prevail under subtropical climate conditions.

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APPENDIX – A

Table (A1). Selected set of small capacity (< 2*MWt*) geothermal systems, classified as belonging to the BRT (bathing, recreation and tourism) group. *Tin* and *Tout* are inlet and outlet temperatures. The units are: *MWt* – Megawatt thermal; *l/s* – liters per second; *TJ/yr* – Terra Joules per year. The flow rate and temperature data are from Hurter et al (1983) and Furumoto (1990).

Locality	**Flow Rate**	**Temperature (^{0}C)**		**Capacity**	**Average Flow**	**Annual Use**	**Capacity Factor**
	(l/s)	**Tin**	**Tout**	**(MWt)**	**(l/s)**	**(TJ/yr)**	
Caldas Cipó	30.83	36	30	0.8	18	14	0.58
Itapicuru - Jorro	30.83	48	30	2.0	18	43	0.58
Alto Paraiso Goiás	13.89	38	30	0.5	8.1	9	0.58
Jataí	13.89	36	30	0.3	8.1	6	0.58
Bom Jardim	5.83	44	30	0.3	3.4	6	0.58
Jaciara	5.56	42	30	0.3	3.2	5	0.58
Juscimeira	7.78	44	30	0.5	4.5	8	0.58
Poxoreu	5.56	40	30	0.2	3.2	4	0.58
Três Lagoas	13.89	46	30	0.9	8.1	17	0.58
Araxá	13.89	37	30	0.4	8.1	7	0.58
Caldas	5.56	46	30	0.4	3.2	7	0.58
Poços de Caldas	5.56	44	30	0.3	3.2	6	0.58
Rio Pardo de Minas	27.78	40	30	1.2	16.2	21	0.58
Bandeirantes	13.89	38	30	0.5	8.1	9	0.58
Foz do Iguaçu	13.89	48	30	1.0	8.1	19	0.58
Londrina	5.56	48	30	0.4	3.2	8	0.58
Antenor Navarro	13.89	34	30	0.2	3.3	2	0.24
Salgadinho	5.56	38	30	0.2	3.2	3	0.58
Mossoró	13.89	54	30	1.4	8.1	26	0.58
Iraí	5.56	36	30	0,1	3,24	3	0.58
Rio Pelotas	6.67	39	30	0,3	3,89	4	0.58
Águas Mornas	13.89	40	30	0,6	8,10	11	0.58
Aguinhas-Chapecó	13.89	37	30	0,4	8,10	7	0.58
Correia Pinto	2.78	42	30	0,1	1,62	3	0.58
Gravatal	33.33	38	30	1,1	19,44	21	0.58
S.A. de Imperatriz	2.78	40	30	0,1	1,62	2	0.58
São Domingos	2.78	38	30	0,1	1,62	2	0.58
São João do Sul	2.78	41	30	0,1	1,62	2	0.58
S.P. de Alcantara	2.78	38	30	0,1	1,62	2	0.58
Taquaruçu	2.78	38	30	0,1	1,62	2	0.58
Total				16		189	

Table (A2). Large capacity (>2*MWt*) geothermal systems, classified as belonging to the PSI (Potential for Industrial use and Space heating) group. The flow rate and temperature data are from Hurter et al (1983) and Furumoto (1990).

Locality	**Flow Rate**	**Temperature (C)**		**Capacity**	**Average Flow**	**Annual Use**	**Capacity Factor**
	(l/s)	**TIN**	**Tout**	**(MWt)**	**(l/s)**	**(TJ/yr)**	
Cachoeira Dourada	139	40	30	6	81	107	0,58
Caldas Novas	333	57	32	35	194	641	0,58
Itajá	4028	38	30	135	2350	2480	0,58
Rio Quente	1667	42	32	70	972	1283	0,58
General Carneiro	152	46	30	10	89	187	0,58
Águas do Veré	694	38	30	23	405	427	0,58
Piratuba	194	39	30	7	113	135	0,58
Cornélio Procópio	14	48	30	2	16	38	0,58
Araçatuba	417	48	30	31	243	577	0,58
Fernandópolis	14	59	30	2	8	31	0,58
Jales	14	61	30	2	8	33	0,58
Paraguaçu Paulista	14	48	30	2	16	38	0,58
Presidente Epitácio	28	78	30	6	16	103	0,58
Presidente Prudente	56	63	30	8	32	141	0,58
São José do Rio Preto	28	45	30	2	16	32	0,58
Taubaté	28	48	30	2	16	38	0,58
Total				343		6291	

Table (A3). Selected set of thermo-mineral springs classified as belonging to the TDB (therapeutic, Drinking and Bathing) group. The flow rate and temperature data are from Hurter et al (1983) and Furumoto (1990).

Locality	**Flow Rate**	**Temperature (C)**		**Capacity**	**Average Flow**	**Annual Use**	**Capacity Factor**
	(l/s)	**TIN**	**Tout**	(MWt)	**(l/s)**	(TJ/yr)	
Camaçari	119	33	30	1.5	69	27	0.58
Cambuquira	5.56	22	20	0.1	3.2	1	0.58
Caxambu	5.56	26	20	0.1	3.2	3	0.58
Lambari	5.56	22	20	0.1	3.2	1	0.58
Patrocínio	5.56	28	20	0.2	3.2	3	0.58
São Lourenço	2.78	22	20	0.02	1.6	0.4	0.58
Ibiraci	5.56	24	20	0.1	3.2	2	0.58
Itabirito	5.56	24	20	0.1	3.2	2	0.58
Pocinhos Rio Verde	5.56	24	20	0.1	3.2	2	0.58
Salitre	2.78	24	20	0.1	1.6	1	0.58
Teófilo Otoni	2.78	24	20	0.1	1.6	1	0.58
Tiradentes	2.78	24	20	0.1	1.6	1	0.58
Itaborai	5.56	33	25	0.2	3.3	4	0.60
Águas de Lindóia	5.56	28	20	0.2	3.2	3	0.58
Águas da Prata	5.56	26	20	0.1	3.2	3	0.58
Amparo	5.56	22	20	0.1	3.2	1	0.58
Poá	2.78	22	20	0.02	1.6	0.4	0.58
Total				3		56	

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2004			15140	51500	65311	3446000	2007	13800			82458	3511300
Under construction in December 2004												
Funds committed, but not yet under construction in December 2004												
Total projected use by 2010												

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Águas de Chapecó	B	3	37	30			0,1	2	1,5	0,6
Águas do Veré	B	694	38	30			23,2	405	427,2	0,6
Águas Mornas	B	14	40	30			0,6	8	10,7	0,6
Aguinhas-Chapecó	B	14	37	30			0,4	8	7,5	0,6
Alto Paraiso de Goiás	B	14	38	30			0,5	8	8,5	0,6
Araçatuba	B	417	48	30			31,4	243	577,1	0,6
Araxá	B	14	37	30			0,4	8	7,5	0,6
Bandeirantes	B	14	38	30			0,5	8	8,5	0,6
Cachoeira Dourada	B	139	40	30			5,8	81	106,9	0,6
Caldas	B	6	46	30			0,4	3	6,8	0,6
Caldas Novas	B	333	57	32			34,8	194	640,5	0,6
Cipó	B	31	36	30			0,8	18	14,2	0,6
Concordia	I	28	48	30			2,1	16	38,5	0,6
Cornélio Procópio	I	28	48	30			2,1	16	38,5	0,6
Correia Pinto	B	3	42	30			0,1	2	2,6	0,6
Fernandópolis	B	14	59	30			1,7	8	31,0	0,6
Foz do Iguaçu	B	14	48	30			1,0	8	19,2	0,6
General Carneiro	B	152	46	30			10,2	89	187,1	0,6
Gravatal	B	33	38	30			1,1	19	20,5	0,6
Imaruí	B	3	38	30			0,1	2	1,7	0,6
Itajá	B	4028	38	30			134,8	2350	2479,2	0,6
Itapicuru	B	31	48	30			2,3	18	42,7	0,6
Jaciara	B	6	42	30			0,3	3	5,1	0,6
Jales	B	14	61	30			1,8	8	33,1	0,6
Juscimeira	B	8	44	30			0,5	5	8,4	0,6
Lins	B	6	42	30			0,3	3	5,1	0,6
Londrina	B	6	48	30			0,4	3	7,7	0,6
Mossoró	B	14	54	30			1,4	8	25,6	0,6
Nova Veneza	B	3	38	30			0,1	2	1,7	0,6
Palhoça	B	3	40	30			0,1	2	2,1	0,6
Palmeiras	B	3	40	30			0,1	2	2,1	0,6
Palmitos	B	3	37	30			0,1	2	1,5	0,6
Paraguaçu Paulista	B	28	48	30			2,1	16	38,5	0,6
Pedras Grandes	B	3	37	30			0,1	2	1,5	0,6
Petrolândia	B	3	37	30			0,1	2	1,5	0,6
Piratuba	B	194	39	30			7,3	113	134,6	0,6
Poços de Caldas	B	6	44	30			0,3	3	6,0	0,6
Poxoreu	B	6	40	30			0,2	3	4,3	0,6
Preisdente Prudente	B	56	63	30			7,7	32	141,1	0,6
Presidente Epitácio	B	28	78	30			5,6	16	102,6	0,6
Rio Fortuna	B	3	38	30			0,1	2	1,7	0,6
Rio Pardo de Minas	B	28	40	30			1,2	16	21,4	0,6
Rio Pelotas	B	7	39	30			0,3	4	4,6	0,6
Rio Quente	B, F	1667	42	32			69,7	972	1282,6	0,6
S.A. de Imperatriz	B	3	40	30			0,1	2	2,1	0,6
S.A. do Leverger	B	3	42	30			0,1	2	2,6	0,6
S.J. do Rio Preto	B	28	45	30			1,7	16	32,1	0,6
S.P. de Alcantara	B	3	38	30			0,1	2	1,7	0,6
Salgadinho	B	6	38	30			0,2	3	3,4	0,6
Saltinho	B	3	38	30			0,1	2	1,7	0,6
Santa Rosa de Lima	B	3	38	30			0,1	2	1,7	0,6
São Domingos	B	3	38	30			0,1	2	1,7	0,6
São João do Sul	B	3	41	30			0,1	2	2,4	0,6
Tangará	B	3	38	30			0,1	2	1,7	0,6
Taquaruçu	B	3	38	30			0,1	2	1,7	0,6
Taubaté	B	28	48	30			2,1	16	38,5	0,6
Três Lagoas	B	14	46	30			0,9	8	17,1	0,6
Treze de Maio	B	3	38	30			0,1	2	1,7	0,6
Trombudo Central	B	3	37	30			0,1	2	1,5	0,6
TOTAL							360,1		6622,4	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

Use	Installed Capacity[1)] (MWt)	Annual Energy Use[2)] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3)]
Individual Space Heating[4)]			
District Heating [4)]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5)]			
Industrial Process Heat[6)]	4,20	77,0	0,58
Snow Melting			
Bathing and Swimming[7)]	355,9	6545,4	0,58
Other Uses (specify)			
Subtotal	360,1	6622,4	0,58
Geothermal Heat Pumps			
TOTAL	360,1	6622,4	0,58

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)		10			5
Production	>150° C					
	150-100° C					
	<100° C		10			5
Injection	(all)					
Total			20			10

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	2		5			2
2001	2		5			2
2002	2		5			2
2003	2		5			2
2004	2		5			2
Total	10		25			10

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2004) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1990-1994	0,3	0,8	0,5		80	20
1995-1999	0,3	0,8	0,5		80	20
2000-2004	0,3	0,5	0,1		80	20