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Geothermal Energy Resources, India: Country Update

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ABSTRACT

New data on the geothermal waters from Bihar, Jharkhand and west Bengal are reported. The most interesting feature is that the thermal gases in these sites are highly enriched in helium and the concentration varies from 1 to 3% v/v. Commercial extraction of helium is being planned. India is still strongly promoting coal based power plants to bridge the supply-demand gap. In the year 2010 India launched an ambitious solar mission to generate 20,000 MWe by 2020, however, it is just generating a merger 130 MWe as of today. Considering the cost of such renewables, water requirement and land requirement, geothermal is the most economical source that the policy makers in India should realize. Countries across the world are making giant progress in the geothermal sector. India is still not able to fix tariff for already approved 25 MWe geothermal power project in Andhra Pradesh. However geothermal is upbeat in India as several states like Gujarat, are coming forward to develop this resource. Oil PSUs (public sector undertaking) are also keen in utilizing their abandoned oil wells in Gujarat and other fields on the east coast of India for extracting geothermal power.

1.0 INTRODUCTION

During the 11th five year plan period, from 2007 to 2012, India added 55,932 MWe to the existing production, taking the total generation to 228,719 MWe as on March 2013 (Table.1). Additional generation came from hydro power (5,544 MWe), thermal power (49,508 MWe) and nuclear (880 MWe). Although the planned increase in electricity generation during the above period is 175,373 MWe, the country could not achieve this because a decrease in the percent of growth from 6.6 in 2009-2010 to 5.58 % in 2010-2011 (MoP, 2013). This growth is expected to fall further if the current trend of growth is of any indication. The growth in 2012-2013 (in the 12th five year plan) was only 3.96%. The augmentation of electricity generation is taking place through coal based thermal power plants. Although the renewable energy statistics show that the generation during the 11th plan period was 24,503 MWe, this growth is not clearly visible in the country. According to the annual report of MNRE 2013 (Ministry of New and Renewable Energy), under the JNNSM (Jawaharlal Nehru National Solar Mission), that was launched in 2010, the country is planning to generated 20,000 MWe by 2020. As on today only 130 MWe grid connected Solar PV based power is generated and 9,366 kWe off grid power was generated. The growth claimed by MNRE (MNRE, 2013) during the 11th plan period includes energy generated through solar thermal, biogas, wind and solar lamps in villages (Table 1). What India needs today is a large quantity robust electricity supply that supports all the urban elite in urban cities. Although the country has vast geothermal resources that can supply baseload grid connected power as well as off grid power, energy policy makers and MNRE are not keen in developing this resource. While geothermal is given priority as a resource mix by all the countries of the world, India is satisfied with small scale development with regard to energy development.

Table 1a. Power generation status

Present Production: 2,28,719 MWe
IPP's contribution: 10760 MWe

Plant/Fuel Type		MWe		Percentage	
Thermal		155967		(68)	
	Coal		134388		55
	Gas		20380		10
	Oil		1199		1
Hydro		39788		17	
Nuclear		4,780		2	
Renewable		28184		12	
Total		228719		100	

Projected increase in: 12 th plan	88537 MWe
Growth 2012-2013	3.96%
Growth 2011-2012	8.1%
Growth in : 2010-2011	6%

2.0 CO_2 AND BLACK CARBON EMISSIONS

On an average, coal based power plants emit 978 kg CO_2/MWh while oil based power plants emit 817 kg CO_2/MWh (Chandrasekharam and Bundschuh, 2008). The current (2012) CO_2 emission by India is 2 billion tonnes (Oliver et al., 2013) out of which about 900 billion kg is emitted by coal based power plants alone. Per capita CO_2 emission in 2012 is 2,000 kg. This amount comes from 75% of the population who have access to electricity. The remaining use is traditional source of energy like fuel wood, dung cake and agricultural waste. Assuming a 13% increase in demand for energy in India, (Oliver et al., 2013) about 340 Mt (metric tonnes) of fuel wood, 140 Mt of dung cake and 130 Mt of agricultural waste is consumed in 2013 (Chandrasekharam and Chandrasekhar, 2011). The black carbon (BC) content in bio-fuels have been estimated by several worker and on an average fuel wood, dung and agricultural waste emit 0.8g/kg, 2.2g/kg and 1g/kg respectively (Chandrasekharam and Chandrasekhar 2011, Sekhar Reddy and Venkataraman, 2002, Bond et al., 2004, Streets et al., 2003, Parashar et al., 2005). The total BC emission by India is 1,343 Gg (Sahu et al., 2008) while the per capita BC emission is about 1,200 g/y (Sahu et al., 2008). Leh village, located in Ladakh where Puga geothermal province is located, alone contributes 82 Mg (Mega grams) of BC while Kargil, another village in the Himalayas, located NW of Ladakh, contributes 70 Mg of BC to the atmosphere over the Himalayan glaciers.

3.0 GEOTHERMAL PROVINCES OF BIHAR, JHARKHAND AND WEST BENGAL

Although mention was made in the earlier country update papers (Chandrasekharam, 2000, 2005, Chandrasekharam and Chandrasekharam 2010) about these thermal provinces, results of detailed investigation was not reported in these publications. Because of this new addition, the direct use has shown an increase over the last report (Tables 3 and 5). The location of these provinces are shown in Figure 1. Between 2010 and 2014 surface geological and tectonic features, geochemistry of thermal waters and oxygen and hydrogen isotope analyses on the thermal waters have been carried out. Munger- Rajgir metasedimentary structure in Bihar hosts several thermal springs with issuing temperatures varying from 35 to 50°C. This structure that holds the thermal springs is part of the SONATA (Son-Narmada-Tapi lineament, Figure 1) and the details of tectonics of SONATA with respect to the geothermal fluid evolution has already been disused (Minissale et al., 2000). The thermal springs are of Ca-HCO_3 suggest that the thermal fluids are circulating within the sedimentary formations (Table 2a) Their high HCO_3 relative to Cl and SO_4 suggest mixing with near surface groundwater during their ascent. The reservoir temperature estimated based on silica concentration (Singh et al, 2014) varies from 104 to 141°C while the reservoir temperatures modeled based on mineral equilibria varies from 160-180°C (Singh et al. 2013, 2014). According to the Na-K and K-Mg geothermometers of Giggenbach (1988), these temperatures may be considered as the re-equilibrated temperature at the near surface environment or the thermal springs may represent steam heated near surface groundwater. Further work is being carried out to establish the evolution of these springs based on isotopic signatures and geophysical investigations are underway to understand the reservoir characteristics.

The Tantloi geothermal site in Jharkhand, unlike the Rajgir geothermal site, registered a higher issuing temperature varying from 68 to 70°C and the thermal waters are of Na-Cl type. The thermal waters are circulating through granites. The reservoir temperature estimated based on Na-K and K-Mg geothermometers of Giggenbach (1988) vary between from 140 to 200°C. However, the "Oxygen shift" exhibited by the thermal waters indicate oxygen isotope exchange at temperatures > 220°C.

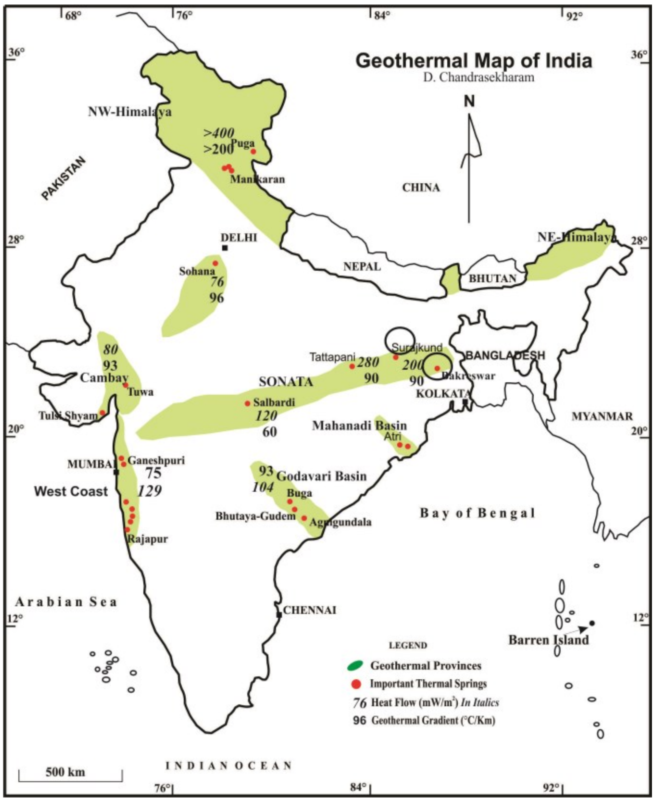

Figure 1. Map showing the geothermal provinces of India. Bihar, Jharkhand and West Bengal sites discussed in this paper fall within the circles shown on the map.

The Bakreshwar thermal site in west Bengal and the Tantloi in Jharkhand (Figure 2) are controlled by a N-S fault and have similar geological formations (Singh et al 2013, 2014b). The thermal springs of Bakreshwar are similar in character with respect to the composition and reservoir temperatures. The most significant feature of Tantloi and Bakreshwar is the volume of helium gas that issues from these thermal springs. The helium content in the thermal gases varies from 1 to 3% by volume. The volume of gas that escapes from wells drilled in the above sites is 130 L/h and the flow rate of thermal water is 21,000 L/h. An experimental field station is established in the above sites and the gases are captured in cylinders and are purified to 99.9%. The temperature of the thermal waters vary from 70 to 75°C. The geothermal gradient and heat flow values are 80°C/km and ~200mW/m^2 respectively (Das et al., 2005). It is proposed to drill an exploration drill hole in this area to generate electricity using this thermal waters and install a pilot helium recover plant (Das et al., 2005).

Table 2a. Chemical composition (in mg/L) of thermal springs of Rajgir (1-5), Tantloi (6-7) and Bakreshwar (8-9)

	pH	T °C	Na	K	Ca	Mg	Cl	HCO_3	SO_4
1	5.8	41	2.2	0.6	4.4	0.9	3.1	40	12.9
2	5.8	41	2.2	0.7	4.3	0.9	3.1	40	10.8
3	5.6	42	2.3	0.6	5.5	1.1	3.2	50	12.6
4	5.7	50	4.1	3.2	7	1.6	5.2	50	14.3
5	5.8	48	4.2	3.3	7.1	1.8	3.5	50	14.2
6	9.5	70	92	2.1	1.3	0.01	97	30	29
7	9.5	68	95	2.4	1.5	0.15	99	25	35
8	9.2	70	110	2.2	1.3	0.01	117	60	16
9	9.3	65	109	2.3	1.2	0.01	115	55	18

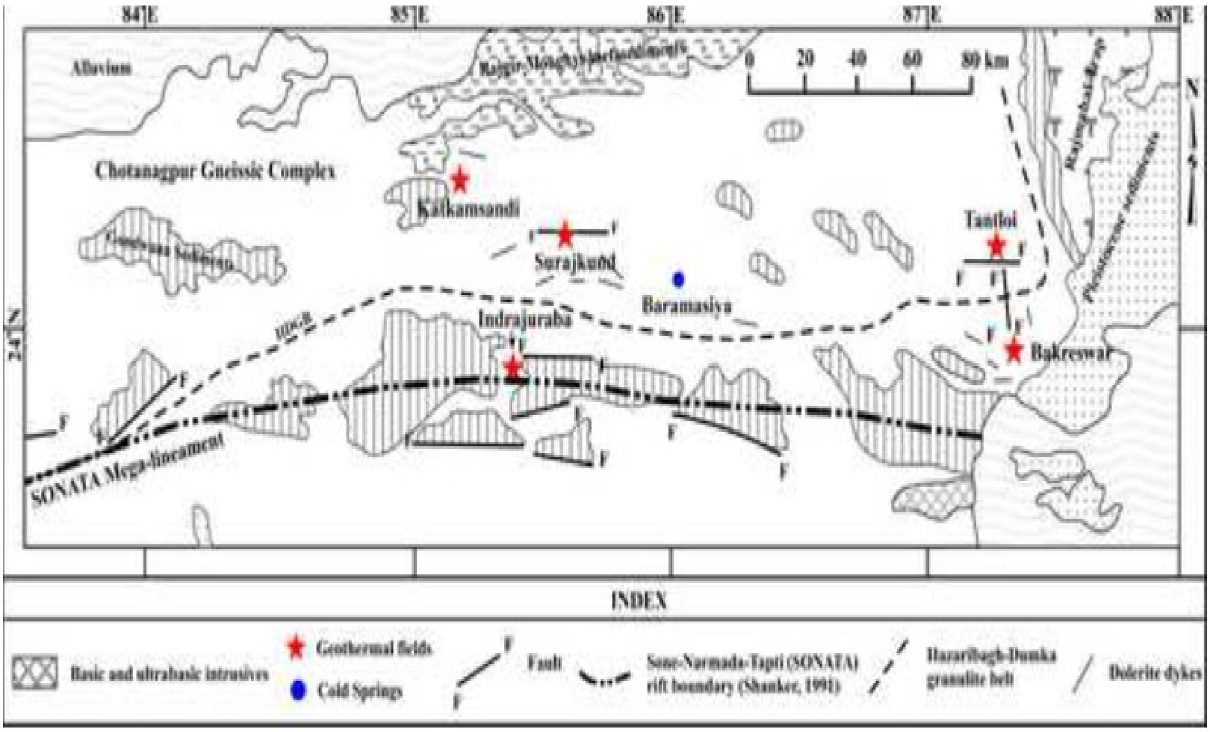

Figure 2. Geological map of Jharkhand and West Bengal geothermal provinces showing the location of Tantloi and Bakreshwar geothermal sites (modified after Nagar et al., 1996).

4.0 NEW DEVELOPMENTS

M/s GeoSyndicate Power Pvt. Ltd (GS) made substantial progress in making the country realize the potential of this energy source to reduce the demand supply gap and to reduce the carbon dioxide emissions. The government of Andhra Pradesh realized the potential of this energy within the Godavari geothermal province (Chandrasekhar and Chandrasekharam, 2009, Chandrasekharam and

Chandrasekhar, 2010) and signed the country's first geothermal power purchase agreement with GS in August 2010 for establishing 25 MWe. The company is waiting for tariff ratification by the new state government, post the division of the concerned state. Similarly the company signed a MoU with the government of Gujarat in January 2013 to develop 55 MWe from the geothermal reserves under Phase One. Gujarat has sufficient geothermal resources in Cambay rift (Minissale et al., 2003, Chandrasekharam and Chandrasekhar, 2010). Under this MoU, detailed geophysical exploration (MT and deep resistivity survey) is being undertaken, The company, under an agreement with the national and state oil exploration companies, are developing all the abandoned oil wells to develop geothermal power. The company is proposing to establish a 10 MWe unit in certain wells in the Cambay basin. Geophysical investigations along the west coast of India geothermal provinces have been completed to assess the power generating potential of the reservoirs. Similarly geophysical exploration investigation in the Puga and Chummatang geothermal sites have been completed. Besides the wet geothermal systems development briefed above, M/s GeoSyndicate has undertaken detailed assessment of the country's EGS resources (Chandrasekharam and Chandrasekhar, 2009, 2010c). Physico-chemical and stress analyses on the high heat generating granites from certain sites have been completed (Singh et al., 2014b). As reported earlier Indian granites will be the future warehouse of EGS. It is estimated that these granites have the capacity to generate energy equivalent to 3.133 x 10^{22} BTU (Chandrasekharam and Chandrasekhar, 2010c). The geothermal course for the graduate students at IIT Bombay is showing a steady state registration by the students and most of them are being placed in oil based companies or in geothermal based companies in Philippines and Chile (Table 7).

Public funding in geothermal activity has shown a decline over the years while private participation is showing a sharp increase (Table 8). The government and energy policy makers should realize the cost benefits of geothermal over other renewables. For example, the tariff for generating 1 MWe from solar PV is 25 to 30 US cents/kWh while with goverment subsidy it is 13 to 15 cents/kWh (MNRE, 2013). This is extremely high considering the free source available. A major part of the tariff includes cost of the support system and cleaning the panels. In addition, solar PV needs 1,000 L/MWe of fresh water (IEA, 2012) and land requirement for generating 1 MWe is 7 acres. Geothermal power plants, on the contrary, need 1 acre/MWe and the tariff is 3 to 5 cents/kWh. Now that air cooled towers are in use, the water consumption by geothermal power plants (wet systems) will be far less than that of solar PV. Technology to use CO_2 as circulating fluid in EGS system is in the development stage (Brown, 2000). In future EGS will provide a clean source of energy (MIT, 2006) and will also provide most of the competitive power tariff over other renewables and this source is available in all the countries.

5.0 DISCUSSION

Electricity generation growth percent has decreased from 6% in 2011 to 3.69 % in 2013 (Table 1a). This is mainly related to the fuel (coal) supply issues. The country has to depend on coal to increase its production to reduce the demand-supply gap. As on date 900 billion kg of CO_2 is emitted from coal based power plants. This comes from 75% of the population (urban) who have access to electricity. The remaining 25%, rural population, although have no access to electricity, also contribute black carbon (BC) to the atmosphere. This is a very peculiar situation the country is facing. There are two options before the country to solve this situation: 1) by increasing the electricity production from coal, rural population can be brought under grid connected power supply; and 2) by using renewable energy sources. The second option is sensible as it will help the country to mitigate both CO_2 and BC related issues. Although solar PV programme was launched in the year 2010 to generate 20,000 MWe by 2020 and connect the rural India with clean power, this initiative is still limping with the generation of only 130 MWe grid connected power. Now that the country has realized the advantage of geothermal resources, in future this resource will be able to save large amount of CO_2 as well as BC. Since 80% of the electricity generated is spent for space cooling, a large amount of CO_2 can be saved using ground source heat pumps (GHP) and thus electricity thus saved can be supplied to rural population. As of this date the geothermal heat is being utilized for bathing, and in certain cases as a source of energy for cooking. Total annually usage of geothermal energy for bathing, swimming and balneology has increased to 4,302 TJ (2014) from 2,545 TJ (2010)(Chandrasekharam and Chandrasekhar, 2010a). This increase is due to the reporting of new geothermal sites that were not included in the year 2010. India has a large scope to utilize this energy source for greenhouse cultivation in the cold climatic regions like Ladakh and Kargil and also for dehydration of agricultural produce. These small initiatives will save power and CO_2 and bring thousands of rural villages under electricity grid.

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STANDARD TABLES

Table 1. Planned production of electricity

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2014	nil		155967	1000000	39788	245280	4780	34000	28184	98756	228319	1378036
Under construction in December 2014	35	276	4000	25000	600	4000	3800	29640	25*	197	8450	59034
Funds committed, but not yet under construction in December 2014	35	276	4000	25000	300	2000	nd	nd	25*	197	4350	27394
Estimated total projected use by 2020	100	850	199605	1200000	40679	250000	14270**	100000	21492	75000	276146	3915848 *

Data on other reviewable; nd: data not available; ** data from IEA, 2011. Other renewables include Solar PV, biomass and small hydro.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2014 (other than heat pumps)

[1] I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables) — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

[2] Enthalpy information is given only if there is steam or two-phase flow

[3] Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[4] Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

[5] Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1]	Maximum Utilization: Flow Rate (kg/s)	Temperature (°C) Inlet	Temperature (°C) Outlet	Enthalpy[2] (kJ/kg) Inlet	Enthalpy[2] (kJ/kg) Outlet	Capacity[3] (MWt)	Annual Utilization: Ave. Flow (kg/s)	Energy[4] (TJ/yr)	Capacity Factor[5]
Himalayas	B,O	1000[a]	95	15			335	100	1055.2	0.087
Cambay	B	1200[b]	85	25			301	80	633	0.066
West coast	B	100[c]	72	30			22	10	55.39	0.098
SONATA	B	100[e]	95	25			18	100	923.3	1
Bakreswar(W.Benga	B	600[f]	89	30			148	100	778	0,17
Jharkhand	B	400[g]	89	25			107	66	557	0.16
Bihar	B	360[h]	50	25			38	60	198	0.16
Godavari	B	150[i]	58	30			17	28	103.4	0.925
TOTAL							986	544	4302	0.14

O: Cooking
a: cumulative discharge of 10springs
b: cumulative discharge of 15 springs
c: cumulative discharge of 16 springs
d: cumulative discharge from 6 springs
e: discharge from two bore wells
f: cumulative discharge from 6 springs
g: cumulative discharge of 5 springs
h:cumulative discharge of 6 springs
i:cumulative discharge from 6 spirings Godaavari

Table 5. Summary table geothermal direct use as of 31 December 2014.

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W
since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

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]			
Snow Melting			
Bathing and Swimming[7]	986	4302	0.138
Other Uses (specify)			
Subtotal			
Geothermal Heat Pumps			
TOTAL	986	4302	0.138

[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2010 TO DECEMBER 31, 2014 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)	31	82	113		0.1-0.6
Production	>150° C					
	150-100° C					
	<100° C			113		
Injection	(all)					
Total		31	82	113*		0.1-0.6

* exploration cum production wells

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 Aid Progra
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	nil	nd	20*	nil	nil	15
2011	nil	nd	20	nil	nil	15
2012	nil	nd	20	nil	nil	15
2013	nil	nd	20	nil	nil	15
2014	nil	nd	20	nil	nil	15
Total	nil	nd	100	nil	nil	75

nd: no data
*includes graduate stuents and staff

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2014) US$

Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	0.022	nil	0.00816			100
2000-2004	0.133	nil	0.0122		70	30
2005-2009	0.503	nil	0.0321		75	25
2010-2014	10	5	0.5		100	0