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South Africa Geothermal Country Update (2010-2014)

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ABSTRACT

Since coal is abundant and relatively cheap in South Africa, coal burning power stations are the majority suppliers of South Africa's electrical energy requirements. In the past, very little attention was devoted to research on renewable energy. This is changing slowly with some attention being given to wind and solar energy. None has been devoted to geothermal energy production. This is probably due to the fact that the region is considered to be tectonically stable. Despite this, however, the country is well-endowed with thermal springs. More than 80 thermal springs with water temperatures ranging from 25°C to 71°C have been reported. All the thermal springs are of meteoric origin. Around 29 of the thermal springs have been developed for direct use, mainly as leisure and recreational resorts. The (South African) Water Research Commission funded a research project in 2010 that focused on investigating the potential uses of thermal springs. Other organizations such as the National Research Foundation of South Africa have contributed to recent research. This paper gives an overview of energy production in South Africa, government policies on renewable energy, and the latest research on the geology, geophysics, chemical and biological properties of thermal spring resources and potential uses other than energy production.

1. INTRODUCTION

The Republic of South Africa is located at the southern tip of Africa. It stretches from 22˚ to 35˚S and 17 to 33˚E. Its surface area is 1,219,090 km^2. It is divided into nine provinces. To the north lie the neighboring countries of Namibia, Botswana, and Zimbabwe; while Lesotho is an enclave surrounded by South African territory. It is the 25th largest country in the world by area and its population is about 51 million (OpenEI, 2014).

1.1 South Africa's energy resources

The South African economy is energy intensive and is based on primary extraction and the processing of coal and uranium. This makes South Africa the leading carbon emitter in Africa. In 2011, South Africa produced 253 Mt of coal, which made the country the seventh largest coal producer and sixth largest coal exporter in the world. Coal is plenty and can be extracted cheaply. South Africa continues to research and develop alternative forms of energy from sources such as nuclear, oil and gas, hydro and renewables (solar and wind). Geothermal energy has not been considered to date as an alternative source of energy. This is because South Africa is considered tectonically stable (Dhansay, de Wit and Patt, 2014, 1; Enerdata, 2013, 13).

Table A below shows the percentage of total primary energy supply in South Africa. Energy sources include: coal, hydro, gas, nuclear and oil.

Table A. Percentage of the total primary energy supply in South Africa

Energy source	% Energy supply
Coal	85
Gas	5
Hydro	5
Nuclear	4
Oil	1

Source: Enerdata, 2013

1.2 South African government setting

The South African government has established the following institutions to develop and manage energy used in the country: Department of Energy (DoE), Department of Mineral Resources (DMR), The National Energy Regulator of South Africa (NERSA), The Atomic Energy Corporation (ACE), the Central Energy Fund and the Strategic Fuel Fund (SFF). According to Enerdata (2013), the Department of Energy (DoE) is responsible for energy policy and controlling the Central Energy Fund. The Central Energy Fund is involved in the search for appropriate energy solutions to meet future energy needs. Furthermore, it manages the operation and development of oil and gas assets. The Department of Mineral Resources (DMR) is responsible for developing mining policy. NERSA regulates the energy sector, controls the prices and is responsible for grid management. AEC is in charge of nuclear issues. The SFF is in charge of the oil stocks and controls the reduction of these reserves.

1.3 Government policy and interest

In 2010, the Department of Energy introduced an Energy Plan for the period 2011-2015 which included the following themes:

- Demand management and security supply,
- Efficient and infrastructure network,
- Improved regulation and completion of the energy sector,
- Diversified and adapted energy mix, and
- Protection of environmental assets and natural resources.

According to the South Africa Yearbook (2012/13), the following legislation regulates the energy sector:

- The National Energy Act 34 of 2008 ensures that diverse energy resources are available in sustainable quantities and at affordable prices. The Act also provides for increased use of renewable energies;
- The Electricity Regulation Act 4 of 2006 establishes a national regulatory framework for the electricity supply industry to be enforced by the National Energy Regulator of South Africa (NERSA). Independent power producers (IPPs) are allowed to increase the supply of electricity;
- The Nuclear Energy Act 46 of 1999 provides for the establishment of the National Energy Corporation of South Africa (NECSA) and defines its functions, powers, financial and operational accountability, governance and management.
- In 2012 the Cabinet approved the National Energy Efficiency Strategy of the Republic of South Africa which sets the target for improved energy efficiency in South Africa at 12% by 2015. It also develops energy efficiency policies and guidelines.
- The White Paper on the Promotion of Renewable Energy and Clean Energy Development (2002) commits South Africa to produce 5% of the country's energy supply from renewable energy sources by 2013.

1.4 Lead agents involved in energy development

Eskom is the national electricity company. It generates, transmits and distributes electricity to consumers in the industrial, mining, commercial, agricultural and residential sectors. It produces about 95% of the electricity consumed in the country. Eskom has a net capacity of 41 GWe. It owns 13 coal power plants with a net capacity of 35 GWe (Enerdata, 2013). Eskom also buys and sells electricity to the countries of the Southern African Development Community (SADC) (*South Africa Yearbook* 2012/13).

Sasol Limited is an integrated energy and chemical company based in Sasolburg, South Africa. It operates two of the largest Coal-to-Liquids production facilities in the world. Sasol Oil handles crude oil refining activities as well as blending and marketing of liquid fuels and lubricants. Sasol Gas supplies pipeline gas to industrial areas. Sasol Mining produces 40 million tons of saleable coal per year (*South Africa Yearbook* 2012/13).

PetroSA is a national company which operates Gas-to-Liquids (GTL) plants. Both PetroSA (55%) and Pioneer USA (45%) operate-GTL plants in Mossel Bay. PetroSA leads developments in gas and infrastructure in the Western Cape.

2. GEOLOGICAL SETTING OF SOUTH AFRICA

According to McCarthy and Rubidge (2005), the evolution of the geology of South Africa occurred in eight general steps. Island arcs amalgamated to form micro-continents, and these accreted to form the Kaapvaal Craton. It comprises mainly of granites (granitoids) and greenstone belts (Visser, 1998). The Kaapvaal Craton estabilised approximately 3,100 million years ago, and forms the nucleus of the southern African sub-continent (McCarthy and Rubidge, 2005; Visser, 1998).

Over the next 400 million years the Dominion Group and Witwatersrand Supergroup were deposited, and very importantly, the Limpopo Belt was formed. The Limpopo Belt separates the Kaapvaal Craton and the Zimbabwe Craton (Visser, 1998), comprising mainly of gneisses (Kramers et al, 2006). The Limpopo Belt is further divided into the Southern Marginal Zone, the Central Zone and the Northern Marginal Zone (Kramers, et al., 2006).

From 2,700 million years ago up until 1,000 million years ago, a sequence of deposition, intrusion (such as the Bushveld Igneous Complex, and metamorphism occurred to form the Ventersdorp-, Transvaal- and Olifantshoek Supergroups, as well as the Waterberg and Soutpansberg Groups (McCarthy and Rubidge, 2005). During this period the Ubendian Belt was formed, which is seen as the zone between the Congo Craton and the Kaapvaal-Zimbabwe Craton. The Namaqua-Natal Belt is known as the zone of metamorphic rocks on the southern edge of the Kaapvaal Craton.

Pangaea (a supercontinent) assembled approximately 500 million years ago during the early Palaeozoic period (Watkeys, 2006). This supercontinent was subsequently split in two to form Laurasia and Gondwana (Watkeys in Johnson et al., 2006). The metamorphic belts along the edges of the fragments comprising Gondwana were named Pan-African Belts. From 500 million years ago to 60 million years ago, the Cape and Karoo Supergroups had formed, and the event describing the Cape Fold Belt had occurred. Gondwana then fragmented to form the current coastline of southern Africa (McCarthy and Rubidge, 2005).

Although South Africa is located in a geologically stable zone, it has a number of thermal springs (Figure 1) with temperatures ranging from 25^{o}C to 71^{o}C. Only seven have temperatures exceeding 50^{o}C. The springs are all of meteoric origin and are associated with crustal faulting. The majority are located on the edges of mobile belts with high numbers of springs occurring in the Limpopo Province in the north and along the Cape Fold belt in the Western Cape Province in the south. The chemical composition of the spring water is determined by the geochemistry of the strata from which they arise. This leads to an interesting anomaly where two adjacent springs may differ significantly with regard to their thermal and chemical properties.

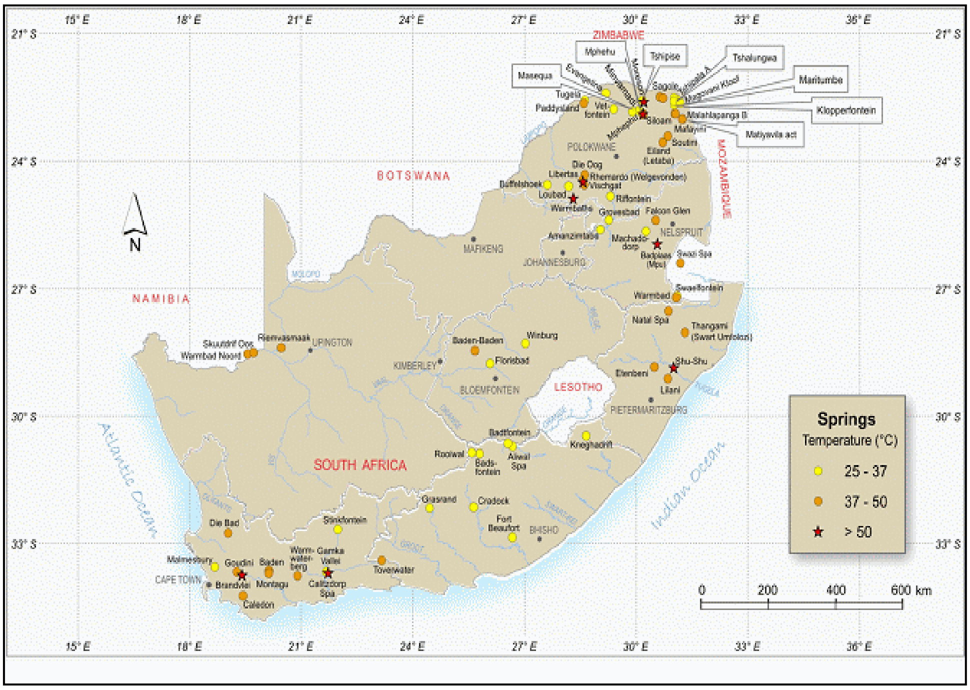

Figure 1: Distribution of thermal springs in South Africa (Olivier & Jonker, 2013).

4. GEOTHERMAL UTILISATION

In view of the low temperatures of thermal springs, no effort has been made to develop geothermal resources to generate electric power. Geothermal utilization in South Africa is thus confined to the use of thermal springs for direct uses. During ancient times the thermal spring waters from Die Eiland (Letaba) and Soutini (Soulting) hot springs, were used for the production of salt. This is still practiced at Baleni (Soutini) in the northern part of Limpopo Province for ceremonial and health purposes. Figures 2A & 2B show how the local communities use indigenous knowledge in the salt-making process.

2A 2B

Figure 2: Salt-making at Baleni (Photo by Tshibalo, 2011).

During the 19th and early 20th centuries, thermal springs were very popular and visited for their alleged medicinal properties. This use has waned over time, and currently the most popular use is leisure and recreation. Those thermal springs with a relatively low flow rate, located far from established transport networks or that were situated in former 'tribal areas' or 'homelands' have either fallen into disrepair or have never been developed. Thus, in comparison with global trends, South African geothermal resources appear to be under-utilized. A research project, aimed at determining the potential uses of thermal springs was funded by the (South African) Water Research Commission (WRC) (Project No. K5/1959/1). This project was undertaken between 2010 and 2013 by a multidisciplinary team from various South African universities and the Council for Geosciences.

During the course of the project, field trips were undertaken to thermal springs for in situ measurement of physical parameters and the collection of water samples for chemical analysis. These were conducted at accredited laboratories at the South African Agricultural Council and the Council of Geosciences. A simple rating scale was used to determine fitness of use whereby the physical and chemical characteristics of the thermal springs were compared with established criteria for each particular use. A 'score' of one (1) indicated conformity to accepted guidelines or standards while a zero (0) score indicated for non-conformity. Potential uses examined included the use of water for bottling, cosmetic uses, agricultural uses (greenhouse heating, irrigation, agricultural crop drying, mushroom farming), aquaculture (production of tilapia and spirulina), water mining, health and wellness, and specialized tourism.

A number of thermal springs originally mapped by Kent (1949) were found to have dried up – often as a result of extraction of groundwater by agriculture or other anthropogenic activities. Results of potential uses of the 50 active springs are presented in Table B below.

Table B: South African thermal spring resorts

Name	Nearest Town/ Province	Accommodation
The Overberger	Caledon, Western Cape	Hotel
Goudini Spa	Worcester, Western Cape	Chalets, flats, camping sites
Brandvlei	Rawsonville, Western Cape	Picnic facilities only
Avalon Springs	Montagu, Western Cape	Hotel, self-catering flats
Warmwaterberg	Ladismith, Western Cape	Flats, log cabins, caravans, caravan sites
Calitzdorp Spa	Calitzdorp, Western Cape	Self-catering chalets, flats, caravan sites
The Baths	Citrusdal, Western Cape	Chalets, flats, caravan sites
Aliwal Spa	Aliwal North, Eastern Cape	Chalets
Badsfontein Guest Farm	Aliwal North, Eastern Cape	Cottage
Cradock Spa	Cradock, Eastern Cape	Chalets, caravan sites
Riemvasmaak	Kakamaas, Northern Cape	Camping site
Forever Vaal Spa	Christiana, North West Province	Chalets, hotel, caravan sites
Florisbad	Bloemfontein, Free State	Picnic sites
Thangami Safari Spa	Vryheid, KwaZulu-Natal	Chalets, caravan sites, guesthouse
Natal Spa	Vryheid, KwaZulu-Natal	Hotel, caravan sites
Shu Shu Hot Springs	Kranskop, KwaZulu-Natal	On island in Tugela River Caravan and camping sites
Lilani	Greytown, KwaZulu-Natal	Chalets
Mabalingwe Spa	Bronkhorstspruit, Gauteng	Chalets
Forever Spa (Badplaas)	Carolina, Mpumalanga	Hotel, chalets, caravan park
Zimthabi	Thabazimbi, Limpopo	Chalets caravan sites
Die Oog	Mookgophong, Limpopo	Chalets, caravan sites
Rhemardo	Mookgophong, Limpopo	Chalets, caravan sites
Mphephu	Louis Trichardt, Limpopo	Chalets
Sagole Spa	Sagole, Limpopo	Chalets, dormitories
Forever Eco Tshipise	Musina, Limpopo	Chalets, hotel, guesthouse, caravan sites
Forever Eco Eiland	Tzaneen, Limpopo	Chalets caravan sites
Makutsi Safari Farm	Tzaneen, Limpopo	Chalets

Libertas (Borehole)	Mookgophong, Limpopo	Chalets, log cabins, caboose (train coach), caravan sites
Lekkerrus (Borehole)	Mookgophong, Limpopo	Chalets, log cabins, caravan sites
Môreson	Musina, Limpopo	Private, houses, caravans
Vischgat	Mookgophong, Limpopo	Guesthouse

Source: Boekstein, (1998, modified).

Details regarding the chemical composition of the springs can be accessed via the home page of the South African Water Research Commission at www.wrc.org.za (Report No. TT 577/13).

The suitability assessments of the springs are shown in Table C below.

Table C: Suitability assessment of springs in South Africa

USE			AGRICULTURE			AQUACULTURE				MINING						
	Bottling	Cosmetics	Greenhouse & Mushrooms	Irrigation	Crop drying	Tilapia	Tilapia	Spirulina	Spirulina	Minerals	Salt	Kieselguhr	Electricity	Balneology	Tourism	Swimming
SPRING	W	W	H	W	H	W	H	W	H	W	W	W	W	W	W	W
Tshipise																
Sagole																
Evangelina																
Moreson																
Mphephu																
Siloam																
Warmbad																
Rhemardo																
Soutini																
Die Oog																
Vischgat																
Loubad																
Buffelshoek																
Minvamadi																
Eiland Source																
Lekkerrus																
Libertas																
Tshalungwa																
Tshipala A																
Maritumbe																
Magovani Hoof																
Malahlapanga																
Malahlapanga B																
Mafayini																
Matiyavila Act																
Brandvlei																
Citrusdal																
Caledon																
Toverwater																
Goudini																
Calitzdorp																
Montagu																
Aliwal																
Cradock																
Fish Eagle Spa																
Badsfontein																
Florisbad																
Baden Baden																

Riemvasmaak	Red	Dark blue	Dark blue	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Natal Spa	Red	Pale blue	Dark blue	Red	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Lilani	Red	Pale blue	Dark blue	Red	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Thangami	Red	Red	Dark blue	Red	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Red	Pale blue	Pale blue	Red
Shu-Shu	Red	Pale blue	Dark blue	Red	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Pale blue	Red	Pale blue	Red
Warmbaths	Red	Pale blue	Dark blue	Red	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Birlanyoni	Red	Pale blue	Dark blue	Red	Red	Red	Pale blue	Dark blue	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Badplaas	Red	Red	Dark blue	Red	Red	Red	Pale blue	Red	Pale blue	Pale blue	Red	Red	Pale blue	Pale blue	Pale blue	Red
Grovesbad	Red	Red	Dark blue	Red	Red	Red	Pale blue	Red	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Machadodorp	Red	Red	Dark blue	Red	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Falcon Glen	Red	Red	Dark blue	Pale blue	Red	Red	Pale blue	Pale blue	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
Amanzimtaba	Red	Red	Dark blue	Red	Red	Pale blue	Pale blue	Dark blue	Pale blue	Pale blue	Red	Red	Red	Pale blue	Pale blue	Red
Sulphur Spring	Red	Red	Dark blue	Red	Red	Red	Pale blue	Red	Pale blue	Pale blue	Red	Red	Red	Red	Pale blue	Red
H = HEAT; W = WATER																
Red = not suitable; pale blue = suitable; dark blue – very suitable																

The suitability assessments revealed that each thermal spring can be used for a number of different purposes. In general, the hottest springs are suitable for a greater variety of uses. Only two thermal springs, namely Brandvlei and Tshipise (where temperatures exceed 50°C and which have a high flow rate) possibly could be used on a small scale during winter when the differential between thermal spring water and ambient temperatures reach a maximum.

Application of this rating scale also showed that the majority of thermal spring waters, barring those in the Western Cape, have unacceptably high concentrations of fluorine and are not suitable for consumption. Despite the non-conformity of water for recreational use at some resorts (due to high fluoride levels), the small amount of water ingested during recreational activities such as swimming should not pose a hazard. However, even those springs which were fit for consumption, do not conform to South African National Bottled Water Association (SANBWA) standards and thus are unsuitable for bottling.

It is important to note that the very properties of spring water that prohibit its use for some purposes may make it eminently suitable for another. For example, spring water that might be unfit for drinking and bathing purposes due to high mineral content could be suitable for water mining. Technological advances over the last few years have made it possible to extract specific minerals from brines. Although the concentrations of minerals in South African spring waters are low in comparison to the very hot geothermal resources in countries with volcanic springs, small scale water mining for minerals appears to be feasible especially for the extraction of boron, titanium and strontium.

Ideally, a thermal spring development should exploit the full potential of a spring. This could be done by cascading the thermal waters through many tiers of uses with benefits accruing at each tier.

This project provided the first opportunity to investigate the bacterial and algal diversity of South African thermal springs. Bacterial identification was conducted using 454 genome sequencing. Most of the microbes found in these springs also occur under mesophilic conditions and are not true thermophiles. However, there is a possibility that some thermal springs in the Limpopo Province might contain novel species. If so, they might have considerable industrial potential. It also appeared that some algae growing in thermal spring waters are very specific to the physical and chemical composition of the springs (Jonker et al., 2013). This should be investigated further, since it might be possible to use algae as indicator species – offering an inexpensive and fast method of identifying geology at source.

Generally, many of the South African thermal springs are used for health, entertainment and recreational purposes. Many are therefore developed as recreational resort centers. These include: Badplaas, Christiana, Natal Spa, and Forever Resorts Tshipise.

5. DISCUSSION

Table 1shows that coal is still the major source of energy in South Africa. Other sources of energy at lower levels include hydro, nuclear, and gas. New coal-fired power stations are under construction. These are the Kusile Power Station (4,800 MWe) in Mpumalanga and the Medupi (4,764 MWe) at Lephalale.

Table 3 reveals that bathing and swimming take place at 23 thermal spring resorts throughout the country.

Six researchers from the University of South Africa, University of Johannesburg and University of Pretoria were involved in the research activities in the field of geothermal resources (thermal springs) since 2010. They were joined by researchers from the Council for Science. The research project, which was funded by the South African Water Research Commission, lasted from 2010 until 2013. One Honors student, three Master's students and one doctorate student formed part of the project. One further PhD student has yet to complete his degree. There is a PhD student at the University of Free State who is doing research in the geothermal field.

Funding from the Water Research Commission amounted to US$ 0.2 Million (2010-2013).

6. FUTURE DEVELOPMENT AND INSTALLATIONS

In 2012/13, the Department of Energy was allocated 0.68 US$ billion of which 4.04 US$ million was allocated for the Renewable Energy Fund Subsidy Scheme (South Africa Yearbook 2012/13). Aquaculture is also a priority development area for the Department of Agriculture. A Parliamentary Brief was prepared to inform Parliament of the opportunities offered to rural communities by the development of thermal spring resources. Discussion will be held with any interested parties so as to initiate the implementation of developments as suggested in the WRC Report TT 577/13.

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STANDARD TABLES

Table 1. Present and Planned Production of Electricity

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Gas)		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			37745		2000		1910		2426			
Under construction in December 2014			9564									
Funds committed, but not yet under construction in December 2014												
Estimated total projected use by 2020												

Table 3. Utilization of Geothermal Energy for Direct Heat As of 31 December 2014

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Caledon	B						0.1		3.7	
Worcester. W. Cape	B						0.1		3.7	
Rawsonville. W. Cape	B						0.1		3.7	
Montagu. W. Cape	B						0.1		3.7	
Ladismith. W.Cape	B						0.1		3.7	
Calitzdorp. W. Cape	B						0.1		3.7	
Citrusdal. W.Cape B	B						0.1		3.7	
Aliwal North. E. Cap	B						0.1		3.7	
Cradock. E Cape B	B						0.1		3.7	
Kakamas. N. Cape B	B						0.1		3.7	
Christiana. NW Provinc	B						0.1		3.7	
Bloemfontein. Free Sta B							0.1		3.7	
Vryheid. Kwazulu-Nata	**B**						0.1		3.7	
Kranskop. Kwazulu-Na B							0.1		3.7	
Greytown. Kwazulu-Na B							0.1		3.7	
Pretoria. Gauteng	**B**						0.1		3.7	
Carolina. Mpumalanga B							0.1		3.7	
Thabazimbi. Limpopo	B						0.1		3.7	
Mookgophong. Limpop B							0.1		3.7	
Louis Trichard.Limpopo B							0.1		3.7	
Sagole. Limpopo	**B**						0.1		3.7	
Musina. Limpopo	B						0.1		3.7	
Tzaneen. Limpopo	**B**						0.1		3.7	
TOTAL							2.30		85.10	

B = Bathing and swimming (including balneology)

Table 7. Allocation of Professional Personnel to Geothermal Activities

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010		6	8			
2011		6	9			
2012		6	9			
2013		6	9			
2014			1			
Total		24	36			

(2) Public Utilities, (3) Universities

Table 8. Total Investment 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						
2000-2004						
2005-2009						
2010-2014	0.2					